"IONIC MEDICATION BY MEANS OF THE ELECTRIC CURRENT."

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Introduction.

AT OUR last month's session the essayist of the evening, Dr. H. H. Schuhmann, of Chicago, presented a very instructive paper in which he set forth his views concerning the relationship between oral infection and systemic diseases. The essayist claimed that we have no scientific proof that there exists a direct relation; and his chief argument was founded upon the fact, that after the infectious foci had been obliterated, the systemic disturbances continued in a majority of cases. As a counter hypothesis to the focal infection theory, Dr. Schuhmann offered as his opinion that these systemic diseases result from lowered vital resistance; which, in turn, may have been directly caused by the infection of the dental organs. This new theory—if we can consider it as such—would do away with the horrors of focal infection, and, in a measure, reduce our responsibility; still, if these focal infections continue to be looked upon as indirect causes of systemic disturbances, then we would fare equally bad under this new hypothesis as we did under the recent focal infection theory. Now, it matters little to which of these two theories we confess ourselves; the focal infection theory has certainly taught us the best lesson of our lives; it has forced us into investigations which demonstrate that we are utterly unable to properly disinfect our root canals, and that our present method of antiseptic treatments are far from being

perfect. In view of this almost lamentable fact may we hopefully look for a renaissance of our methods in the future? You will agree with me that if we could succeed in accomplishing two things, namely, absolute disinfection of our root canals and the cure of pyorrhea alveolaris, we would satisfy the ultimate aims of our profession and place ourselves beyond all repute by our medical brethren. Ladies and Gentlemen, I want to assure you in the presentation of my happy topic this evening, that we have a method whereby this can be accomplished, namely, "Ionic Medication by means of the Electric Current."

On the 15th of last November I submitted for publication a contribution in which I set forth some of my views upon the present standing of Electrolytic Medication. Being in hopes that this contribution would be published in February I had premised in the preparation of this evening's paper, that most of you would have read that article, so that my reading tonight might be looked upon as a supplement to it. In view, now, of this disappointment I shall take the liberty of reading some passages, now and then, from my original contribution in order to present a fairly succinct exposition of my subject.

To treat our subject exhaustively even with the several quotations which I shall make from said contribution would carry us beyond the scope of this paper because the details of Electrolytic Medication comprise basal principles which are

borrowed from three distinct departments of the sciences. First, we should deal with the Physics of Electricity in all its various branches; secondly, we should touch upon a multitude of theories which constitute the foundation of Electro-Chemistry; or more specifically the Physico-Chemistry of ionization and Electrolysis; and thirdly, since Electrolytic Medication is a truly Pharmacological Therapy, we should consider the ionic properties of all these drugs which we would employ in our treatment. You readily see that a compromise must be reached in our selection of material for consideration, which shall be suited to elicit a satisfactory understanding of the entire process in question.

Ionization.

There exists a prevalent misconception among the generality of the profession of confounding Ionization with Electrolysis. The root of this misconception lies in the neglect of carefully distinguishing between an Ionogen and an Electrolyte. In order to avoid this confusion in our minds let us first con-

intelligibility, in the succession of discoveries, is found out last.

Let us begin our study of Ionization with an experiment: Exp. 1. I have here a molecular solution of ammonium hydroxide (NH_4OH) dissolved in ethyl alcohol. To this solution is added a little phenolphthalein ($\text{HC}_{14}\text{H}_9\text{O}_4$) which is an indicator for the detection of alkaline solutions. Note the solution shows no color. But if we now add water to the solution a sudden change takes place and a profuse amount of red color is produced which increases with dilution. The absence of the red in the original solution proved to us that the solution was not alkaline and that it became such only upon addition of water.

Exp. 2. I have here a molecular solution in water of copper bromide (Cu Br_2) which is a dark brown. Note the change in color as I add the water. This (pointed out) is the green stage (Ionization 70 per cent). This (pointed out) is known as the blue stage (Ionization 81 per cent.)

We will now explain the reactions by means of the symbols on the card board:

sider what is strictly understood by Ionization; and then, let us define Electrolysis. Now, in the order of dependence one upon the other, Ionization is a condition pre-requisite to Electrolysis; but in the order of time the phenomenon of Electrolysis was known long before the true conception of Ionization was developed. This is an occurrence which is quite common in the sciences: what ought to be known first in the order of

The Ammonium hydroxide molecule is split up into two radicals, viz., $(\text{NH}_4)^+$ and $(\text{OH})^-$. The phenolphthalein is also dissociated into two dis-

crete particles ($\text{C}_{14}\text{H}_9\text{O}_4$), and hydrogen H^+ . Now, part of the hydroxidion $(\text{OH})^-$ from the ammonium hydroxide united with the hydrion of the phenolphthalein forming natural water. In propor-

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tion as the hydrion (H^+) was neutralized by the hydroxidion, the other phenolphthalein radical ($C_{14}H_9O_4$) grew into prominence. This radical is the beautiful red which you observed. The copper bromide is a black solid. Upon adding just sufficient water to dissolve it we obtain a molecular solution, which upon addition of more water begins to break up into its component particles, copper-ions and bromin-ions. The copper-ion has a color of its own which gives the color effects which you noticed. These solutions, now, of ammonium hydroxide and copper bromide would conduct the electric current which could be demonstrated upon trial. Before the water was added no electricity could have been passed thru the solution. The conduction of electricity in these cases is explained by the presence of the discrete particles on the one hand of ammonion (NH_4^+) and hydroxidion (OH^-)

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and on the other hand of cuprion (Cu)

and bromidion ($2Br^-$) which are respectively charged with positive and negative electricity. These charges exist prior to any passage of the current and have come into existence, in the very act of the molecules dissociating into its particles. It is at this point where the common misconception is engendered of considering these charges as being produced by the current.

With these remarks we are in a position to define Ionization as the phenomenon of a substance dissociating in such a manner that the dissolved particles become carriers of electricity. The etymological derivation of the term "Ionization" is this: Faraday in 1835 introduced the term Ion from the Greek *ἰόν* ("going") to designate the dissolved particles which were the parts which moved with the electric current. Now, the formation of such Ions naturally is Ionization. The term Ionization, however, is only a substitute for another

expression which was originally introduced by Arrhenius 1887, the first propounder of the Ionic hypothesis; namely, **Electrolytic Dissociation**. This latter expression is more in accord with the essence of the phenomenon which is a dissociation of an electrolytic nature in virtue of its capability of electric conduction. Both expressions, however, are equally well adapted. What significance attaches to this theory of Ionization? In physical chemistry it forms the keystone to its entire structure. To convince oneself of this statement one would only have to examine into the works of Van't Hoff, the discoverer of the dilute solution law; of Pfeffer, the first successful investigator of osmotic pressure; of Hirtoff, the propounder of ionic migration; and of Kohlrausch, the prime authority of electrical conduction; save the mention of all the other investigators, like Faraday, Ostwald, Nernst, etc. In chemistry whether static or dynamic, we find the Ionization theory indispensable as an explanation to most, if not to all, reactive phenomena. In analytical chemistry it constitutes its very foundation as all its relations are those of the Ions. By means of this Ionic conception; for instance, we are enabled today to understand the action of the acids, bases and salts. All acids are capable of dissolving the metals. Some do this rapidly, others require considerable time. Of course, in comparing reactions of this kind it is assumed that equivalent quantities of the acids are taken i. e., the gram equivalent dissolved in the same unit volume of the solvent. In comparing hydrochloric acid, sulphuric acid and acetic acid we find that the ratios of their activity stand respectively as 80, 51 and .4 for deci-normal solutions. Now, since all these acids contain the same amount of hydrogen and since the hydrogen alone is held accountable for the acid reaction (the other radicals of the acid not entering into consideration) why is it that one acid is so much more pow-

erful than the other. It has been scientifically demonstrated that all the acids are variously ionized, i. e., the degree of dissociation is different in the different acids. Thus in the cases above considered hydrochloric acid is ionized 80%, sulphuric acid 51% and acetic acid .4% in a deci-normal solution. Hence, the strength of an acid is directly proportional to its degree of Ionization. Now, the electric conductivity is also directly proportional to this degree of dissociation. Therefore, you readily see that the electric conduction is a measure of the degree of Ionization and consequently also of the chemical value of the substance ionized. We say at infinite dilution all acids would have the same strength because at this dilution all acids would be completely ionized. The process of Ionization may be represented as shown in the following scheme:

- (1) $\text{HCl} [\text{gas}] \rightarrow \text{HCl} [\text{diss'd}] \rightleftharpoons \text{H}^+ + \text{Cl}^-$
- (2) $\text{HNO}_3 [\text{liquid}] \rightarrow \text{HNO}_3 [\text{diss'd}] \rightleftharpoons \text{H}^+ + \text{No}^+$
- (3) $\text{Zn Cl}_2 [\text{solid}] \rightarrow \text{Zn Cl}_2 [\text{diss'd}] \rightleftharpoons \text{Zn}^{++} + \text{Cl}^-$
- (4) $\text{Na C}_7\text{H}_5\text{O}_2 [\text{diss'd}] \rightarrow \text{Na C}_7\text{H}_5\text{O}_2 [\text{diss'd}] \rightleftharpoons \text{Na}^+ + \text{C}_7\text{H}_5\text{O}_2^-$
- (5) $\text{Na Cl} [\text{solid}] \rightarrow \text{Na Cl} [\text{diss'd}] \rightleftharpoons \text{Na}^+ + \text{Cl}^-$

Let us consider a few cases of Ionization in Pharmacology. The antiseptic value of Zn Cl_2 (3) depends upon the zinc ion. If this be the case, then any zinc salt could be employed for the same purpose. So it can, providing the negative radical exhibits no objectionable features. In sodium salicylate (4) the salicylate radical is regarded as the antiseptic or anti-rheumatic ion. In sodium chloride (5) neither the sodium-ion nor the chlorine-ion would be looked upon as a characteristic antiseptic ion. Sodium chloride is therefore tabulated as a weak antiseptic. These three antiseptics mentioned are such only in the ionized condition, i. e., when they are dissolved in water. In their crystallized or solid state they have no antiseptic properties,—they may even be sterile. In my articles "The Higher Valency of Arsenic"

and in "Hydrogen Peroxide" (Dental Cosmos, Nov., 1914, and June, 1915,) I have so arranged my material as to present a concise exposition of the leading principles involved in Ionic Chemistry. To these I would refer for additional information.

At this point I wish to criticise the peculiar usages to which the term "Ionization" is often applied. I read the following from my original article: "When we try to ascertain the general understanding among the profession of ionization, we find that it is most commonly confounded with what we properly term, Electrolysis. Where this misconception does not obtain from personal impression, it is casually gleaned from extant literature upon the subject, as is evidenced by the following quotations:

"An example of the movements of ions

is furnished when the current is passed thru a solution of zinc chlorid between two poles and Zn Cl_2 is split or dissociated into the cation Zn which becomes positively charged and moves towards the negative pole, and the anion Cl_2 which becomes negatively charged and moves towards the positive pole." (Prinz-Sturridge¹.)

"The Ion itself may be an invisible product of electrolysis." (Sturridge².)

"* * * the passing of a galvanic current thru the body is regarded as productive of ions * * * " (Ibid.)

"This is what is known now as ions of the metals which are dissolved by the action of the current." (Ibid.)

¹Herman Prinz, Dental Materia Medics and Therapeutics.—C. V. Mosby Co., St. Louis, Mo., 1916.

²Ernest Sturridge, Dental Electro-Therapeutics.—Les & Febiger, New York, 1914." * * * *

"* * * * good results were invariably obtained with simple salts from which ions of an antiseptic nature were readily formed by a low current strength." (Ibid)

"All substances are not dissociated by the effect of the current." (Ibid.) * * * *

"Aside from the misconception of Ionization by the current, there is another misuse of the term "Ionization" (or to ionize) to express the action or effect of ions upon the various tissues which we wish to treat. This misuse is apparent from the following quotations:

"The therapeutic effect of the ions * * * * must be determined in the selection of the drug for ionization." Ionization with Anions". (Prinz-Sturridge.)

"Needles of zinc and copper are also used sometimes to pierce the part to be ionized." "Caré has described the following method for preparing sounds for the ionization of fistula, urethrites, etc., (L. Jones).

"Zinc Ionization for Epithelioma." "Salicylic Ionization in acute Rheumatism." "Lithium Ionization in Gout." (Tousey).

"Copper electrodes are often used by the author for the ionization of fistulous tracts* * * * "The effect is, in case of ionization with an antiseptic ion * * * * " (Sturridge).

Now, we all understand that neither the purpose nor the intention exists to ionize (or convert into ions) the tissues in question, since, all that concerns us, is simply the therapeutic effect of the ions of our drugs."

In Electrolytic Medication we often employ ions which come directly from the "soluble" anode. These ions according to Sturridge are an immediate production by the current and according to Lewis Jones they are the result of secondary reactions. In my original article I pointed out that neither view is correct. After describing the respective demonstrations of these two authorities I continue: "What, then, is the real cause of the appearance of these ions? We may now give as our

positive answer, that the ions in question are due to the electrolytic solution pressure of the metals and, in the case of the experiments above, to that of the iron and copper. For this solution of the problem, we are indebted to Prof. Nernst (W. Nernst-Ztschr. Phys. Chem. 4, 129) (1889), who did not primarily introduce the electrolytic solution pressure to account for the presence of ions, but rather for the establishment of the source of electromotive force. With the ratio of the electrolytic solution pressure (P) to the osmotic pressure (p) of the solution (the moist medium of the above experiment), Nernst was enabled to develop his famous mathematical formula to express the value of electromotive force (E):

$$E = 0.029 \log \frac{P}{p} \text{ volts in the case of a bivalent metal or } E = \frac{0.058}{n} \log \frac{P}{p} \text{ volts,}$$

in which n stands for n valence of the metal."

Electrolysis.

With a clear understanding now of Ionization we are in a fair position to develop our conception of Electrolysis, [since Ionization is a condition without which no electrolysis can take place.] The solution in which Ionization is assumed to have taken place constitutes an Electrolyte. This Electrolyte possesses the property of conducting the electric current as we saw. Now, if any Electrolyte be placed in circuit with a source of an electromotive force a current will flow as can be attested by an ammeter. After a sufficient lapse of time the current will cease to flow and the Electrolyte upon examination will reveal the fact that the original dissolved substance has disappeared and that it was decomposed by the passage of the current. Hence, you observe that electric conduction is possible only at the sacrifice or loss of the ions in the

Electrolyte. This is precisely what is meant by Electrolysis, namely, a chemical decomposition by the electric current. Note particularly at this point where there is no conduction there is no Electrolysis, and conversely; these two facts go together. Let us examine into the mechanism of these two facts by means of the following illustration:

In our illustration we represent eight positive charges for four copper ions and eight negative charges for eight bromin ions. As the picture stands the phenomenon of ionization is done and completed, no current having been employed. Now, turn on the current. What happens? The anode becomes positively charged by the source

(A) represents the Electrolytic cell containing the Electrolyte copper bromide, such as we obtained in our experiment No. 2 which is ionized into its
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cuprion (Cu) and bromidion, (Br). We might state in passing, these ions are an allotropic modification of the atoms for which the symbols stand. Thus the symbol Cu stands for the atom, copper, in the compound; or for the elementary copper when we indicate this by placing the degree sign (°) to the right of the symbol (Cu°) or for the ions when we employ the plus or minus signs for such
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designation as (Cu).

(B) of our illustration represents the source of electromotive force. In connection with the illustration we will place our copper bromide solution of Exp. 2 in circuit with four dry cells. The deposition of copper upon a nickel which I will employ as the cathode may be examined after our meeting. We might here remind ourselves once more that the ionogen Cu Br₂ produces equal numbers of positive and negative ionic charges in the Electrolyte.

of the current and meets with the ionic particles of the copper ions holding positive charges, and bromin ions holding negative charges. As we know from Physics, like signs repel and unlike signs attract each other. Consequently, the copper-ions will be repelled and the bromin-ions will be attracted. But opposite electricities neutralize one another so that the bromin-ions, losing their negative electricity are set free. Simultaneously the copper-ions being repelled from the anode travel towards the cathode; here they are attracted, but their positive charges are at once neutralized by the negative charges of the cathode, so that they are also set free and deposit themselves on the electrode. One copper-ion and two bromin-ions being set free means the decomposition of one molecule of copper bromide. This process continues with another set of ions and then with another until the whole Electrolyte is exhausted. As the decomposition takes place strictly at the electrode surfaces by neutralization of the charges of the ions with those of the electrodes, the ions must of necessity move towards them. We therefore ob-

tain another phenomenon which is known as **Ionic Migration** in which the positive ions move in opposite direction to those of the negative ones. But these opposite ions move with different velocities which seems to be somewhat in contradiction with the statement that equal numbers of ions are simultaneously liberated at the two electrodes. But we cannot discuss this question now. The ions carry a definite amount of electricity so that the quantity of the material liberated becomes a measure of the current passed, and *visa versa*. This is embodied in Faraday's law of "Electro-Chemical Change" which we must also pass by at this time.

Application of the Theory of Ionization and Electrolysis to Electrolytic Medication.

I have now expatiated somewhat on Ionization and Electrolysis, because with a clear conception of these two phenomena we will the better be able to develop our theory of Electrolytic Medication. Electrolytic Medication may be defined as the process of conveying medicinal ions by means of the galvanic current into the deeper structure of the tissues which we wish to treat or medicate. You observe that I here employ the term "Electrolytic Medication" where you would have expected the use of "Ionic Medication."

Allow me to read the following passage from my original article in which I suggest the term "Electrolyte" for "Ionic": "What can be said about the name of that branch of Medication which we effect by means of the galvanic current? At present, it is called "Ionic Medication." Is the name appropriate? By convention, perhaps, it has come to assume the meaning, but, in strictness, it does not express the essence of the process. The writer would suggest that the term "Electrolytic" be substituted for that of "Ionic", for reasons which are too apparent to be passed by. We have Ionic Medication in the absence of all electric current when, for instance, we

seal zinc chlorid in the root of a tooth for antiseptic purpose. We know that the dissociated zinc (i. e., the zinc ion) of the compound possesses the antiseptic property primarily, and not the dissociated chlorin, for, otherwise, any indefinite chlorid could be employed. If, then, the zinc ion sterilizes the root canal specifically, in as far as it is in the ionic condition, we certainly have ionic medication, altho we never applied the current. Consequently, we include in the term "Ionic Medication" more than we really express. Dr. Tousey (Sinclair Tousey—Medical Electricity, W. B. Saunders Co., 1915,) avoids this difficulty by using the expression, "Ionic Medication by Electrolysis". In selecting the term, "Electrolytic", we introduce nothing new, but simply employ the nomenclature of Faraday (1835), the discoverer of the laws of **electro-chemical change**, who called the process of conduction of electricity by an electrolyte by the name, **Electrolysis**. (LeBlanc—Text-book of Electro-Chemistry, The McMillan Co.) Now, since the Medication under discussion depends primarily on the movements of particles (the Ions) of ponderable matter, and this movement is essentially the conduction of electricity it is apparent that no better name could possibly be employed than the term "Electrolytic."

In order to picture to our minds how the ions are transported, let us compare the human body to the electrolytic cell which we showed in our illustration. As far as the conduction of the current is concerned, it is immaterial of what the electrolytic fluids of the body are composed, they may even be of an indeterminable mixture. The sponge-electrode—technically called the indifferent electrode—may be moistened with any electrolyte you choose. Remember well, Electrolysis takes place only at the electrode surfaces, and between the electrodes we have simply migration of ions. Now, let us assume we employ zinc

chloride solution—which you recollect is already ionized; the current having had nothing to do with the Ionization—we wrap a platinum broach—or some other metal would do—saturate it with zinc chloride and insert it into the root of a tooth in such a manner that the solution on the cotton forms a continuity with the body fluid at the apex. The broach itself need not, necessarily, reach as far as this. We make the broach the anode, or the positive pole. The indifferent electrode which may be strapped say to the wrist, constitutes the cathode, or negative pole. Now if we turn on the current and remember that the zinc-ion migrates to the negative pole, we readily understand, the only passage of the zinc-ions in the effort to reach the negative pole is from the apex of the tooth into the structure immediately surrounding the tip of the tooth. The depth of migration or penetration into the tissues depends on the time during which the current is allowed to pass; in practice, we say, from ten to fifteen minutes is sufficient. The chlorin ions, on the other hand, travel in the opposite direction, namely, away from the apex, and is liberated as free chlorin on the surface of the broach; whence it may escape as a gas being thus removed from the site of medication. As the chlorin is liberated on the broach surface, zinc should also be simultaneously deposited on the negative electrode at the wrist. But the zinc ions cannot instantly reach that pole so that in its place the metal ion of the Electrolyte in the sponge is deposited and the zinc ions of the medicament continue to migrate deeper into the tissues. It is customary to employ salt water with the sponge. The metal of this solution is sodium, an extremely powerful caustic and would destroy the tissues at the indifferent electrode. But remember sodium is liberated on the electrode surface and not on the flesh; the sponge intervening, preventing actual contact. That the sodium enters into a secondary reaction does not concern us here. Sec-

ondary reactions of this kind are quite numerous and require special study. If we had a medicament in which the ion—say, iodine-ion—constituted the antiseptic agent, then we reverse the polarity of our electric source. We always select that polarity which will cause the ion desired to flow into the tissue.

The Therapeutic Effect of Electrolytic Medication.

I hope my exposition up to this point has been sufficiently clear to give you a fair understanding of Electrolytic Medication in its coarse outlines. As we have avoided a review of the numerous theories involved in the process so we will also omit the details of the technic therewith connected; as all these can be brought out in our discussions. What I wish to touch upon especially is the Therapeutic Effect of this mode of Medication. We are not amazed at present when the radiograph reveals to us that a root which we treated and filled many years ago shows a shadow at the apex of the tooth. How often have we modified and remodified our methods of antiseptic treatment to overcome this common occurrence? In order to cover over or explain all these infections which we thus find, a common theory is held that the condition was aseptic at one time; but has become septic subsequently by the carriage of infectious bacteria by the circulation or otherwise. It is not my purpose to dispute this latter theory but I would like to emphasize the following: What scientific proof have we that the condition about the apices of our devitalized teeth was aseptic at one time? No doubt, here lies the cause of our trouble: We have never been assured of absolute disinfection. With our usual treatments we simply place an Ionic Medicament in the root canal; seal up, and then depend upon the diffusion of our drug. We may reasonably assume that we medicate up to the very surface of the limiting walls; but we have no assurance that our antiseptics exercise

any potency subcutaneously or as suggested by Dr. H. T. Smith periapically. Many surfaces, as we know in general medicine, once infectious, may heal over with a formation of a new tissue, burying the infectious bacteria underneath. No antiseptic topically applied would reach those bacteria, which at any provocation may suddenly reappear at any time. If we consider the complexity of structure in the neighborhood of the apices of our teeth, a subcutaneous habitat by the bacteria may be readily assumed possible. Here antiseptic treatment would be of no more avail than has been possible with other parts of the body where the structural tissues are simpler and better adapted for absorability; as in the mucous membrane. Personally, I have always held that the root canal with its almost innumerable dental tubuli presents a physical condition which directly counteracts the diffusion of the drugs. We know that the smaller the diameter of the tube is, the larger is its capillary attraction. The capillary attractions of all the tubuli are additive so that a considerable suction force would be necessary to overcome the total surface attraction of all the tubuli. It seems to me that this capillary attraction should greatly overbalance the diffusive power of our drugs. With regard to the disinfection of the entire length of the tubuli themselves, we may accept the condition that the bacteria at the entrance of the tubes are destroyed; but that further back they are never reached. Again we know that the diffusion itself is a phenomenon depending directly upon the osmotic pressure. It would be an intricate problem indeed to figure out how this osmotic pressure is modified within the encasement of a sealed root canal. The few circumstances thus mentioned are arguments against absolute disinfection (it being understood that temporary sterilization which is probably always accomplished, merits no consideration in this connection). If then, our modes of treatment are really

so ineffectual, a positive method should be quite welcome. Personally, I am convinced that Electrolytic Medication supplies us with such a method; first, because its principles rest upon scientific facts and secondly, on account of the clinical evidences. The Therapy of Electrolytic Medication is a Pharmacological one; and hence, its reactions are those of Ionic Chemistry. If simple double decomposition with the formation of albuminates from the albuminous material of the germ-body does not satisfy, more energetic means, namely, oxydation or reduction processes, may be introduced, so that the therapeutic effect can be depended upon, providing the bacteria are reached wherever they are. But the antiseptic ions under the influence of the galvanic current will absolutely go where the electrolytic fluids of the body forms the electrical path; and this path is an extremely divergent one, so that every part to be disinfected can be reached.

Report Cases.

I. I desire to enumerate just a few cases from my own practice which gave highly satisfactory results:

A. C. Male, aged 50 variously treated at different health resorts for Sciatic Rheumatism. He was practically cured at the time of his first visit. I advised him to have radiographs made of his teeth. The pictures showed all the teeth normal, except for a slight pyorrhetic condition at the lower central incisors. After scaling these teeth, I gave the electrolytic treatment for 15 minutes with zinc-ions employing a current of 3 ma. Eight days later another treatment was given with zinc-ion for 15 minutes with a current of 3-4 ma. Still eight days later I treated the gums with iodine for 10 minutes; employing a current of 4 ma. I show the case in illustrations completely cured in 14 days.

II. Dr. F. H. aged 45. Pyorrhea alveolaris, upper and lower arches involving 20 teeth with pus discharge and exces-

sive recession of the gums. A radiograph was made for future reference. After careful scaling, copper-ion was employed for 5 minutes per tooth with a current of 4 ma. After this I treated the mouth in sections, taking five teeth at a time, and treating the patient twice a week. At these sittings I employed zinc and iodine-ions giving 10 minutes to each tooth with a current from 4 to 6 ma. After three weeks I tried to grow a culture which failed after 48 hours of incubation. This patient now calls monthly.

III. November 17, 1916. B. J., male, aged 35, with a fistula from the apex of the upper right lateral. The nerve probably died from the irritation of a large gold filling inserted seven years ago. Treatment with zinc-ion was applied for 35 minutes with a current of .6 ma. The root was filled at the same sitting and a synthetic filling inserted. Saw the case a month later in excellent condition. In this case report you note I employed only .6 ma. Why such a small current? It was the largest amperage I could obtain in his patient. Ordinarily the question would be answered by stating: on account of the high resistance of the patient. But it would be more correct to say: on account of the low conductivity of the patient. Upon this point I said the following in my original article:

"While, upon the question of the resistance of the body, the writer would briefly criticize the manner in which this subject is treated in our usual text-books. We should not speak of resistance at all. The proper designation is conductance (or conductivity), which is the reciprocal of the resistance. Resistance is used in speaking of conductors of the first class, such as the metals, while conductance is applied to conductors of the second class, namely, the electrolytes, of which the human body is a representative. The measurement of the

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conductance, in reciprocal ohms (—),
ohm
of electrolytes is essentially different

from that of the ohms in the conductors of the first class, for which discovery, as also for the method of measurement, we are greatly indebted to Kohlrausch. Kohlrausch (1880) introduced the alternating current in connection with the Whetstone Bridge, for measuring the conductance of electrolytes in order to avoid polarization, which is always produced with the direct current, and which gives inaccurate information. This being true, the information as given in our text-books on the resistance of the body and the calculations derived from it must necessarily be misleading."

IV. (November 17, 1916). Miss I. H., aged 30, revealed a joint rheumatism of the left arm which she could not move in any position without the aid of the other hand. Her history is this: Ten years ago she fractured a corner of the right upper central incisor, which was subsequently restored with a gold filling; no attention being given to the condition of the pulp. Recently a slight fistulous had developed over this tooth. At the recommendation of her sister, who was still under treatment, she came to me for consultation. I gave her the electrolytic treatment at her first visit with zinc-ion 15 minutes with a current of 3 ma. At her second visit, one week later, the abscess had completely healed. I treated the tooth once more with zinc-ions for 10 minutes and with iodine-ion, 5 minutes, and at once filled the root. Two weeks later she reported that her arm was rapidly improving. Believing that the electricity produced the desired results she intended to take further electrical treatment for her arm from some specialist. Knowing that the good effects were achieved from the cured condition of her tooth, I advised her to the contrary. Today she has almost the full use of her arm.

V. (December 2, 1916). Miss C. H., aged 25, displayed an acute pericementitis of the upper central incisor. I had to remove a Logan to get at the condition. A week or so later, I successively

tried the following treatments without the current: Formo-cresol, sodium dioxide, zinc chloride, phenol, Black's 1, 2 and 3, with powerful sprays of benzoic acid in between; but I could not stop the profuse flow of pus in spite of the fistulous opening. These treatments covered a period of six weeks. Finally, I gave her one electrolytic treatment for 10 minutes with a current of 3 ma., and requested if she has no pain to call a week later. No pus could be found at this sitting. I tried to grow a culture by infecting a culture medium with some extracts from the apex, but no growth took place after 36 hours of incubation. I had the patient call a week later. Then I applied the electrolytic treatment once more for 10 minutes with zinc-ion and replaced the Logan. The condition is excellent today.

VI. (December 7, 1916). Mr. Wm. R., with an acute abscess of the left upper cuspid in which the pulp had died. The cheek was largely swollen and the eye was closed. I applied a sponge electrode to the face saturated with magnesium sulphate (Dr. Martin Fischer's salt solution) with a current of 3 ma. Relief was felt, cheek softened, and swelling considerably reduced after fifteen minutes. The next morning the swelling had disappeared. This case gave me extreme satisfaction on account of the suggestion which I made in my original contribution and which I will read to you: "In conclusion, the writer would exhort those members of the profession now practicing electrolytic-medication to turn their attention to, or try out, the application by means of the galvanic current of Dr. Martin H. Fischer's (Martin H. Fischer—Oedema and Nephritis, John Wiley, Inc., 1915), salt solution in oedematous conditions about the mouth. It is not known to the writer whether or not Fischer's salt solutions have been introduced in this way. Certainly, these solutions, being specifically employed as electrolytes, could be easily introduced into the tissues by the current, espe-

cially, since neither cataphoretic, nor anaphoretic transport is intended, but, primarily, only that of either the positive or negative ions of the solution. The one successful and rapid means of relieving those troublesome swellings about the gums which are so vexing to the dentist, and so painful to the patient, would amply justify the practitioner in familiarizing himself with the principles and technic of electrolytic medication."

In citing the above cases I mentioned various currents ranging from .6 to 6 ma. What might be said on this point is well stated in my original article: "It being understood that electrolytic medication consists essentially in the application of drugs which in the ionic form are carried into the tissues by a continuous electric current, the question may now be asked, what particular phase of the physics of electricity should chiefly occupy the practitioner's attention. This particular phase is the exceedingly important question of **electrical energy**, without a real conception of which, electrolytic medication can never stand out as a true science. We must conceive electricity as an **energy**, like we do heat, light, work, etc., if we would understand the essence of electrical phenomena. The failure in our current literature to consider electricity as an **energy**, is probably the chief cause of the discrepancy among our authorities on the point of voltage or amperage to be employed. While each of the authorities recommend a certain suitable current, or amperage, they all seem to show some uncertainty as to the electromotive force to be employed, as tho this were a matter of choice, to be worked out by practice. Naturally, as we know, a certain current passed thru the body will, in a measure, determine the voltage, because the patient will just tolerate a certain dosage, or "pain limit," as it is called by some writers. Now, neither current, nor electromotive force, separately, constitutes electrical energy, but if we take the product of these two factors, current and electromotive force,

we arrive at the definition of electrical energy." * * * * *

"We know from Faraday's law that the greater the quantity of current (in coulombs) is, the greater will also be the quantity of ions which will migrate into the tissues. Consequently, by reducing the voltage, we can correspondingly increase the current with the resultant greater movement of ions, without altering the electrical energy numerically, i. e., without hurting the patient by overcharging. We may adopt the voltage as small as we choose, providing we observe the limits of the decomposition voltage of the substances around the electrodes." * * * * *

"In conformity with what has just been

said, an "electrolytical posology"—if the writer may thus introduce the term—could be elaborated with a complete neglect of the resistance (?) of the various parts of the body. By employing a certain voltage—say of ten volts—and enclosing a standard milliampere meter in circuit with any part of the body, we could read off the current directly. We would thus have both the intensity factor (V) and

C ma
the capacity factor(——) of the electri-
1000

cal energy impressed upon the part of the body in question. The calculation would be simple, viz:

$$V \times \frac{C \text{ in milliamperes}}{1000} = E."$$