

mills, and Massachusetts to \$5,500,000 from twenty mills.

Ribbon weaving for many years was the staple work of the Paterson mills. This had been encouraged by the largest silk importing houses, which found an advantage in ordering ribbons of mills right at hand instead of waiting for orders to be filled from Europe. The duty of 50 per cent. or more was always enough to secure a profitable market for the home product. Ribbon weaving required expert men at the looms, and these men received high wages. The minimum of earnings for these men was \$20 a week and more of them received \$40 a week, while the bulk of the help, made up mostly of girls, received so little that the whole average of wages in the silk mills of Paterson in 1880 was only \$1 a day, while \$3 was the average paid in the locomotive works, the other great industry of that city.

The Weavers' Guild was powerful in those days and it was the arbitrary action of this body which finally started the scattering of the silk weaving mills into other parts of the country and particularly into Pennsylvania. The first of the Paterson manufacturers to build elsewhere was the Phoenix Manufacturing Company, which put up the Adelaide Mills at Allentown, Pa., in 1881. A few years later, during a long strike, when the strikers dynamited the home of William Strange, one of the pioneer manufacturers of Paterson, the tendency to go elsewhere to escape such troubles was accentuated, and then began the silk-making boom in Pennsylvania. As the manufacturers looked over that State they found it offered many advantages. Silk and its products are light and freights, therefore, are not of the importance that they are with cotton or wool mills, while throughout Pennsylvania were found scores of towns where the cost of coal was less than \$1 a ton, where the local authorities were glad to remit taxes for many years on the mill properties and where there was an abundant supply of the cheap labor which is a necessity of the silk industry. To-day, of the 861 establishments in the country, New Jersey has 257, New York 228 and Pennsylvania 172, but in the list of looms and spindles required for the equipment of new mills in 1898 Pennsylvania led with 1,255 looms out of a total of 2,340 and 37,000 spindles out of a total of 53,000, and there are silk factories in more than fifty Pennsylvania towns, including Allentown, Alburtis, Altoona, Avoca, Bethlehem, Bath, Bloomsburg, Carlisle, Catasauqua, Columbia, Carbon-dale, Darby, Danville, Easton, Emaus, Ephrata, Eden, East Greenville, Fleetwood, Freeland, Harrisburg, Hawley, Honesdale, Hanover, Hallstead, Lancaster, Leighton, Marietta, Mauch Chunk, New Holland, Newberry, Philadelphia, Plymouth, Pottstown, Pottsville, Reading, Rockledge, Scranton, Sunbury, Stroudsburg, Taylor, Titusville, Williamsport, Weatherly and Wilkes-Barre.

Another field where silk manufacturing may become an important industry is just being exploited by a New York house. Within a month or two a mill has been put in operation in Fayetteville, N. C., by the Ashley & Bailey Manufacturing Company, in which it is their intention to use young negro labor exclusively. The mill has been provided with competent teachers and already from 75 to 100 hands are at work, led by the first pupil, a young negro preacher. The projectors of the enterprise believe that the young people of the negro race are well adapted to acquiring the manual dexterity needed for silk handling, and if this proves true they will go on and build other mills as hands become available. The present mill will employ 350 hands and will do spinning and broad silk weaving.

It is probable that in the future, at least until some great revolution is made in machinery for dealing with silk filaments, the best interests of the silk manufacturers and of the country will be served by scattering the mills about in many places, rather than concentrating the industry. In this way employment will be given to the surplus labor of the community, and especially to lads and lasses, who make the most valuable operators because of their deftness of touch, and even the low wages which silk making pays will be a blessing to the people. These wages, according to a table in a recent report on the industry in Pennsylvania, are an average of \$1.21 a day for males and 70 cents a day for females in a list which shows the earnings of operatives in all occupations in the State—in which the highest wages are for steam pump makers at \$2.44 a day and the lowest are for the female silk workers at 70 cents.

Silk, from the first branch of its production, is essentially prodigal of labor and an article of luxury. It is declared by an expert that it takes more time to build a spool of silk twist than it does to build a modern locomotive, and during much of this time some one's hands must be employed in the operations. It is the amount of time used in raising and tending the silk worms and in reeling off the filaments of the cocoons that has defeated each attempt to introduce silk raising as an industry in this country and will probably continue to defeat its successful introduction.

Every once in a while stories describing the enormous profits to be derived from silk worm raising gain currency. One has recently been going the rounds about a planter near Charleston, S. C., who has an annual income of \$6,000 to \$8,000 from this source and has instructed his neighbors in the art, and now a number of these neighbors are adding \$800 or \$1,000 a year to their incomes by silk raising without interfering in any way with their regular plantation work.

Lest this should start a new silk worm craze, it may be well to call attention to the experiments in this direction that were undertaken by our forefathers, when land and labor were cheaper than they are to-day and the art of silk worm raising was just as it is now. Silk worm culture was begun in Virginia as early as 1619, and the planting of mulberry trees was required under penalty, by an act of the Colonial Legislature of 1623, while a bounty of fifty pounds of tobacco was offered for every pound of reeled silk produced. In 1656 the Virginia Colonial Assembly passed an act imposing a fine of ten pounds of tobacco upon any planter who had not at least ten mulberry trees on his plantation to each one hundred acres of land. In 1657 a reward of 10,000 pounds of tobacco was offered to any one exporting £200 worth of raw silk, but there is no record of any one having claimed it. In Georgia and in the Carolinas similar efforts were made to encourage silk

raising all through the eighteenth century, but with no practical result, although a filature was built at Savannah in 1749 and Italian operatives were brought to the country to teach the art of silk reeling. The greatest amount of raw silk that there is any record of being raised was in 1759, when 10,000 pounds were produced in the cocoon, equal to about 1,000 of reeled silk. Bounties were as high as 3s. 6d. a pound for cocoons, or two or three times their market value, but the industry fell off rapidly until it disappeared.

The greatest silk craze that the country ever had was started in 1831 by a manual of silk culture prepared for the Massachusetts Legislature by Jonathan A. Cobb. Companies were formed all over the country to raise and manufacture silk. Mulberry trees were planted in every region, and there was hardly a household in which some silk worms were not hatched and fed. The price of mulberry slips rose and rose until it is recorded that at an auction sale of rooted slips twelve inches or more long, held at Germantown, Pa., on September 18, 1839, 260,000 slips were sold for \$81,217.75 and a lot of 22,000 mulberry switches from 6 to 8 feet long was calculated to be worth \$45,000 or at the rate of 2½ cents for each bud on them. The bubble burst at the end of 1839, and in 1844 a blight which fell upon the mulberry trees ended the craze entirely, but at this day mulberry trees may be found in every part of the older States, remnants of that time. Efforts have been made to revive the industry since, especially in California and Kansas, and in 1882 a silk dress made from the product of fourteen States was presented to President Garfield's widow by the Woman's Silk Culture Association of the United States, but the work has again fallen into desuetude.

The form in which the raw silk reaches this country is in hanks or twists of the filament as it has been reeled from the cocoons. Each thread of these skeins is composed of five of the original filaments, cemented into one by the hardening of the gummy envelope of the filaments after these leave the basins of warm water in which the cocoons are put to be unwound. The preparation of this silk for the loom is called throwing, and this consists of about a dozen distinct operations. The first of these is putting the twist of raw silk on a reel and winding it off upon spools turn by turn. Then comes the combining and twisting of the filaments into threads of various kinds, known as "singles," "tram," and "organzine." An idea of the intricacy and labor involved in just this part of the operation may be gathered from the fact that a thread of ordinary sewing silk contains about two hundred filaments of the silk as the worm spun it. Every part of these operations must either be done by hand or watched continuously, for the silk thread is built up entirely of continuous filaments.

Although the silk throwing, spinning, and weaving mills form the foundation of the industry in this country, and their products for the year will probably amount to \$100,000,000 or more, this is by no means the whole of the benefit which the country derives from them nor the extent to which they give occupation to workmen or capital. Around this central industry cluster those of the dyer, printer, and finisher, the makers of machinery, the dealers in raw silk, and in the manufactured goods and many cognate businesses. How much these all represent in capital and hands employed it would be difficult to estimate, but in the various direct industries of producing ribbons, broad goods, sewing silks and twist, tie silks, hat bands, knit goods and laces, fringes, braids and trimmings, something like \$120,000,000 is now invested and close to one hundred thousand hands are employed. Roughly speaking, about 50 per cent. in value of the silk product is in broad goods, 25 per cent. in ribbons, and perhaps 10 per cent. in sewing machine silks and twists, leaving 15 per cent. for the varied products of the other factories.

Many attempts have been made to supersede the product of the silk worm for textile use, but as yet none has succeeded, although artificial silks of several kinds have recently obtained a fair hold as a commercial product. The first attempt in this direction was in cultivating spiders as a rival to the silk worm. Queen Cleopatra is said to have had a robe of spiders' silk that could be drawn through a finger ring, but she was not noted for wearing much clothing. M. Cachot, a Frenchman, has recently succeeded in getting a considerable product of spider silk, by petting the spiders and reeling off their thread slowly, but there is no prospect that his system will become of any importance. The artificial silks are made of wood fiber, reduced to cellulose by the action of acids. This is dissolved to a glue-like consistency, forced through holes in glass and drawn out into threads which dry and harden in the air just as those of the silk worm or spider do. In fact, the material of this thread is identical with that produced by the spider and silkworm, and the fabric produced from it has the same qualities except that it is more harsh and does not wear so well. A cheaper substitute for silk is made of glue or gelatine drawn into threads in a similar manner, but this could never rank as anything but an imitation of silk.

Another imitation of silk is mercerized cotton, which is now finding its way into many uses. The process of giving to cotton a luster like silk and also adding much to its strength and wearing qualities, was invented by John Mercer, an English weaver. The cotton is treated, either in the yarn or piece, with caustic soda, and stretched if a luster is wanted, and the effect of the treatment is to change the fiber into a silk-like substance. Mercerized cotton, however, will never replace silk, although there is, without doubt, a large field for its use.—New York Sun.

THE PHARMACIST'S INK.

A GOOD ink is more of a necessity to the druggist than to any other tradesman. His writings are all "records," and he stakes much upon them. Moreover, his written directions are subjected to all sorts of ill-treatment and abuse, by both animate beings and inanimate things, unavoidably so far as he is concerned, yet he must be responsible. The annoyance which he feels when a prescription bottle is returned to him to be refilled, with the label streaked with internal remedies externally applied, the ink partially washed away or run together, and the writing bleached out, covered with slum gudgeon or otherwise obliterated, is always tinged with anxiety lest he fail to reach exactly the

right conclusion regarding its first condition. It is far easier to decipher illegible prescriptions than to puzzle out smooched or bleached labels. It is also safer.

To secure an ink which exactly meets the conditions is not easy. The demands are rigorous. The ink must of course flow well and give a good initial color. It must dry quickly and not run when afterward it is wet. It must not fade easily, and must resist the action of chemicals to at least a moderate degree. It should keep well under ordinary conditions, and should neither corrode nor foul the pen immoderately.

Any one of these conditions can be secured easily, but the combination is not easy. Yet given a good formula, the preparing of an ink by the pharmacist is no more difficult than the preparing of a tincture or an elixir, and the saving in cost is as proportionate. Furthermore, it is much easier to make one's ink than to analyze or test a commercial ink.

The conditions are best met in an ink consisting of iron sulphate combined with tannic and gallic acids in proper proportions. An excess of either acid or iron will be detrimental. Such a combination does not give a good initial color, but writes pale, and the writing turns a jet black after a few hours' exposure to the air.

A carbon ink would not trouble in this regard and would be more resistant to chemicals, but it is much more likely to smooch and to wash away. The iron sinks into the paper and combines with its fibers better. The proportion of gallic and tannic acids to iron has been well worked out by chemists, and the only difficulty lies in securing a good initial color. Coal-tar dyes will either not dissolve in an iron ink, or if dissolved will precipitate the iron salt. Indigo paste, or indigo carmine, is the color most generally used. This is liable to be very acid as it is obtained in the market, and if used too freely will corrode the pens rapidly and even destroy the paper. A little acid is beneficial to the ink, keeping it in better condition, and an occasional corroded pen is of less consequence than the quality of the ink. Indigotin, a dye substitute for indigo, can be used in place of indigo carmine with satisfactory and more constant results.

Mr. J. A. S. Woodnow, under the writer's direction, has tried some twenty-five different ink formulas, including the Massachusetts standard formula. The inks were prepared from pharmaceutical chemicals and tested at the prescription counter during a period covering nearly two years. The formula which gave the best satisfaction is as follows: Tannic acid, 80 grains; gallic acid, 14 grains; salicylic acid, 1 grain; ferrous sulphate (granulated), 102 grains; indigotin, 90 grains; water, 1 pint. Dissolve the acids in 8 ounces of water, the iron and indigotin each in 4 ounces of water, and mix the solutions.

This writes a greenish-black at first, changing to jet black on standing. It dries readily, does not rub or run, and is almost fadeless. During the time in which it was kept, it appeared to be permanent and satisfactory.

The addition of a little sugar (one to two ounces) will make it of service as a copying ink. An equal amount of acacia will add to its permanence and render it more glossy, but it will not flow quite as well and will foul the pens. It should be remarked that a good quality of water should be used in making an ink, since the iron is easily oxidized by dissolved air or precipitated by other matter. The writer would be pleased to receive reports from pharmacists who may choose to try the formula given.—Portions of an article read before the Massachusetts Pharmaceutical Association by Professor Wilbur L. Scoville, and reprinted in *The Spatula*.

THE ELECTRO-CHEMICAL AND ELECTRO-METALLURGICAL INDUSTRIES IN 1899.

By JOHN B. C. KERSHAW, F.I.C.

THE year 1899 has been marked by steady advancement in several of the industries with which this annual review of progress deals; and in one industry the growth has again been phenomenal.

The aluminium industry, the industries based upon the electrolytic decomposition of salt and the copper refining industry, all exhibit signs of healthy expansion; while in the calcium carbide industry the rate of growth has been extraordinary, and in the writer's opinion, has been too rapid to be sound.

No new electro-chemical or electro-metallurgical process of any industrial importance has been introduced to the public during 1899; but two processes since the preceding have been developed, and works for their operation on a large scale are now in course of erection. One electro-chemical works has closed during 1899, and one other has, for the second time, met with difficulties which have necessitated the temporary cessation of manufacturing operations. As a set-off to these failures, a large number of new factories for the operation of processes already at work on an industrial scale have been planned, and some of these have already commenced production.

The only litigation during 1899 has been that carried on between the Castner-Kellner Company and the Commercial Development Corporation with reference to the validity of the patents for the Rhodin cell. The judgment of 1898 has been reversed, on appeal, in favor of the latter company, but it is expected that the case will now be carried before the House of Lords.

The details for the separate industries are given below:

ALKALIES AND BLEACH.

No new electrolytic alkali processes have come under the writer's notice in 1899, beyond those which form the subject of patent applications only. As space is limited and inventors are prolific, no attempt is made to deal with these in this review. The Greenwood process, to which reference was made a year ago, has not fulfilled expectations, and the trials at Winsford have been stopped.

The Rhodin process has made its reappearance in America, and the American Alkali Company, with a capital of £120,000, has been formed to work this process at Sault Ste. Marie. Electrical energy at this spot is estimated to cost only 42s. per E.H.P. year. The Commercial Development Corporation receives £108,000 for the American patent rights of the Rhodin process and cell. For a patent which has not received, as far as the writer is aware, industrial trial, and may

still have to face extended litigation, this price is undoubtedly satisfactory from the vendor's point of view. Whether the purchasers have reason to be equally satisfied with the bargain, is a question to which a decisive answer may be given two years hence.

The Hargreaves-Bird process has during 1899 entered upon the third and final stage of its development, a company with a capital of £500,000 having been floated for purchase of the English patents, and erection of a works at Middlewich, in Cheshire. The new company—the Electrolytic Alkali Company—is to pay £100,000 to the Parent Company for the patent rights in the United Kingdom. The projected works at Middlewich will require about 3,500 H. P. (steam or gas power will be used) and are estimated to cost £140,000. This process is now being operated industrially in France; the St. Gobain Chemical Company, after lengthy trials, having bought the French patent rights.

The Castner-Kellner process is developing rapidly, and there are now three works which use this process in operation—at Weston Point, Niagara, and Ostermberg—while two are building, the one at Jenappe, in Belgium, and the other near Moscow. The works at Weston Point have been completed during 1899, and 4,000 H. P. is now available for the production of alkalis and chlorine at this place. The total expenditure upon plant and machinery has been £292,000 and the capital of the company is being increased to £450,000. The operation of this works for the year 1898-99 was financially successful, and an 8 per cent. dividend has been declared. The Mathieson works at Niagara are also a success, and extensions are now in progress.

The Richardson & Holland process at St. Helens, as noted above, has met with further difficulties during 1899, and the works have been stopped for alterations and repairs during a portion of the year.*

The processes worked by the "Elektron" Company at Griesheim, and by the Bitterfeld Company at Bitterfeld (both diaphragm processes), are extending even more rapidly than the Castner-Kellner process, as the following list of places, where works, using one or other of these processes, are in operation, will show:—Griesheim, Bitterfeld (2), Rheinfelden, Ludwigshafen, Westeregeln, Montiers, La Motte, Zombkowitz, Slawiansk, and Flix, in Spain.

This progress has been independent of the amalgamation, to which reference was made in the last report, of the two Parent Companies. During 1899 further changes in the financial organization have been made, and the Allgemeine Elektrizitäts Gesellschaft, of Berlin, is putting an additional £180,000 into the Parent Companies.

The Hulin process, at Clavause, in France, is reported to be working satisfactorily, but manufacture by this process has not yet been commenced in other countries.

The Kellner process at Hallein, in Austria, is still operated on a comparatively limited scale; arrangements have, however, been made during the past year for the provision of the capital required to complete the works as originally designed. The Le Sueur process, which has been operated since 1893 at Runford Falls, U. S. A., has succumbed during 1899 to the fall in prices of heavy chemicals in New York, and the plant at this works has been stopped.

In addition to the processes named above, others of which no details are available are already being utilized, or are about to be utilized, at the following places: St. Michel, Chevres, Monthey, Thusis, Cumberland Mills, Michigan, and at two unnamed places in Italy and North America.

The electrolytic alkali and bleach works in operation in Europe and America will, therefore, shortly number 29. When one recalls the fact that ten years ago there was not a single electrolytic alkali works in existence, the progress is seen to have been remarkable.

ALUMINIUM.

Although the number of works producing aluminium is now only six, the output of the metal is increasing; this increase being due to the concentration of the manufacture at the larger works.

The projected aluminium works at Sarpsfos, in Norway, is still unbuilt, the capitalists responsible for the developments at this place having decided that calcium carbide is the more profitable product.

Owing to the refusal of the European Aluminium Companies to supply figures of their output for publication, the writer is unable to give any detailed production figures; but the totals for the three years 1896-97-98 are believed to have been as follows: 1896, 1,789 tons; 1897, 3,394 tons; 1898, 3,958 tons.

The price of aluminium has remained fairly stationary during 1899, and it is hardly probable that any material reduction in price can occur with the present methods of extraction. The price at which aluminium is being sold for conducting purposes, 14½ d. to 15 d. per pound, will leave little or no profit to the producers.

There have been considerable additions to the capital accounts of the leading aluminium companies during the past year—the Pittsburg Company, the Foyers Company, the Neuhausen Company, and the Le Praz Company having all raised fresh capital for extensions during 1899.

As three of these companies have taken up the manufacture of calcium carbide, it is impossible to say what effect these increases will have on the aluminium industry.

No new process for the production of the metal has received industrial trial during the past year. The Peniakoff process, to which reference was made in the last review, has apparently failed to answer the expectations of those interested in it, for direct inquiry has failed to elicit any information concerning its progress. The only two processes for aluminium production in actual operation are, therefore, still the Hall and Herault processes.

The chief feature of 1899 with regard to the utilization of aluminium has been the extension of its use for conducting purposes. Owing to the high price of copper during the past year, electrical engineers have been disposed to try the new metal, and in America especially a large number of aluminium transmission lines have been installed.

The behavior of these eight aluminium power transmission lines, carrying, in the aggregate, 9,000-12,000 H. P., at pressures ranging from 10,000-29,000 volts, will be studied with interest by all electricians. The use of aluminium for telephone and electric light work is also being experimented with in this country, but the proverbial caution of our race hinders rapid progress in this direction.

With regard to other uses of aluminium, the most striking progress during the past year has been in connection with the application of aluminium to printing work.

As a substitute for stone it is rapidly gaining favor, and in both Germany and America "aluminography" is becoming a special branch of the printing industry.

There is little progress to report in other directions during 1899. The contributions of Ditté to the French Académie des Sciences have somewhat shaken the confidence in the durability of aluminium when exposed to atmospheric or other influences; and despite Moissan's defense of the new metal, it is felt that further practical trials are necessary.—English Electrical Review.

ANIMAL ELECTRICITY.

By W. S. HEDLEY, M.D.

GALVANI'S experiment was this: Laying the nerve muscle preparation on a glass plate, the nerve was raised with a glass rod, and then being allowed to touch the muscle, a contraction ensued. This was the demonstration of animal electricity, the existence of which Volta had denied. But Volta proved his assertion (which Galvani had denied) that metals in contact with a fluid produce an electric current. The demonstration of this latter fact was the discovery of the Voltaic cell.*

Animal and metal currents were first clearly differentiated by Du Bois-Reymond. He considered, and it is difficult to prove the contrary, that a natural electric current exists in normal resting muscle, "current of rest." During the action of the muscle he proved the existence of a current in the opposite direction to the "rest current." This was called "the negative variation," now known as the "current of action." Hermann combats the opinion that a resting uninjured muscle shows any current, and holds that the so-called "current of rest" is the result of chemical or other inequalities due to the injury. The views of English physiologists are as follows:

1. Normal muscle or nerve gives no current.
2. Local injury produces a current through the muscle from the injured to the living part.
3. Local action produces a current through the muscle from the active to the resting part.

Thus an injured or an active muscle produces electromotive force, and as in the Daniell cell the current goes from the active plate (the zinc) to the copper, so does current travel in the injured muscle from the injured part to the sound part. When the circuit is completed through a galvanometer, of course the direction is reversed, and it is usual to describe the direction of a current in its relation to the galvanometer. The manifestation of the sudden difference of potential which is the result of stimulation is sometimes spoken of as the "excitatory variation" when the muscle is referred to, and as the "action current" when the galvanometer is referred to.

The Negative Variation.—If a muscle giving the muscle current ("injury current") be tetanized, an action current will proceed from the uninjured to the injured part, i. e., from the part more capable of action to the part less capable of action. This current being in a direction opposite to the muscle current (injury current) constitutes a counter electromotive force which tends to cut down or diminish the muscle current, and this diminution is the "negative variation" of Du Bois-Reymond—"action current of Hermann."

The Diphasic Variation.—A contraction wave propagated along the fiber of an uninjured muscle is accompanied by an electrical disturbance traveling from the active to the resting part, and this variation (as revealed by a galvanometer uniting two electrodes placed at an interval on the surface of a muscle) is double or diphasic for the obvious reason that the action is not simultaneous throughout the muscle, but requires time for its transmission.

By far the most striking manifestations of animal electricity are, of course, to be found in electric fishes; here the nerve surfaces represent the active element of the battery, viz., the zinc in the Daniell cell.

The electromotive action accompanying voluntary muscular contraction in the human subject has been demonstrated by Du Bois-Reymond, and that accompanying tetanic contraction from electrical stimulation by Hermann. Physiologists consider that the variation of electrical potential from the beat of the human heart has been demonstrated. It is by some regarded as proved that the white columns of the spinal cord give electrical signs of nerve action, and even that action currents are manifested by the gray matter of nerve centers. The skin of all animals is traversed by an electrical current from without inward. This is considered to be caused chiefly by cutaneous glands, but partly by the skin itself, as is proved in the case of the eel, whose skin has no glands. The action of light upon the retina causes an electrical change, i. e., a current accompanies retinal activity, as it does muscle activity. Indeed, it is probable that electrical phenomena always accompany vital action.

Certain of the above points have been carefully studied by Sir J. Burdon-Sanderson, and his latest contribution to the subject comes in the form of the Croonian Lecture delivered before the Royal Society, for an abstract of which we are indebted to the pages of Nature. As might be expected from the direction of his previous investigations, it was the electrical rather than the chemical or mechanical concomitants of the function of muscular action that chiefly engaged his attention. But it was necessary to begin by explaining some points in connection with the mechanical effects. These could be investigated in two ways: (1) By observing and recording the changes of form a muscle undergoes when, in response to a stimulus of short duration, it acts isotonically, as in lifting a weight; or (2) by observing the increase of tension

which occurs in overcoming a resistance, i. e., when it acts isometrically. The latter method is the best when dealing with an entire muscle, but isotonic conditions are preferable when estimating the time occupied by a single element of muscular structure in developing its maximum tension under stimulation.

The method employed consists in observing the change of surface form that occurs in a muscle when a single break induction current is led through it in such a way that the observed surface is at the cathode. A sensitized plate moves behind a slit, upon which a magnified image of the cathode (moving freely with the muscle) is thrown. An observation thus made shows that the process of contraction at the point immediately excited, i. e., at the point immediately underneath the cathode, attains its greatest activity before the end of the first hundredth of a second. It is known, as already stated, that an electrical change, an action-current, accompanies the mechanical change, i. e., the change of form which a contracting muscle undergoes. Are the change of form and the electrical variation synchronous, or does one precede the other? On connecting two parts of the surface of a muscle through a capillary electrometer or other galvanoscope, it is found (1) that similar parts in a similar physiological state are equi-potential; (2) that in similar parts, but in a different state, there is a difference of potential the less capable of function, i. e., the less living being negative to the more living; (3) that transitory differences of potential arise between two parts of the living surface when the one is active and the other resting, the condition of rest or fitness for function being denoted by relative "positivity," discharge of function by relative "negativity." The "first fundamental experiment" was then described. A parallel-fibered muscle (curarized) is submitted to an instantaneous stimulus at τ .

$$\frac{p}{\tau} \quad \frac{d}{\tau}$$

The result is that a wave of excitation passes along each fiber, its progress being marked by electrical and mechanical change. The latter consists of an alteration of shape or contour in the contracting muscle. If we have two contacts, p and d , applied to different parts of the contracting muscle and connected through a galvanometer, the electrical effect of the stimulation appears; it consists in the sudden manifestation of a difference of potential between the two parts of the contracting muscle.

Now, reverting to the mechanical effects (alteration of contour) produced by the stimulation, the photographed curve represents the wave of excitation as it starts from the point of stimulation, τ , affecting first the near contact, p , and then the distant one, d . But if, by tying a tight ligature across the path of propagation, we limit the observation to what happens at one contact only, "we find that the curve has assumed an entirely different form." It is natural to conjecture, and capable of proof, that the difference of contour in the two experiments represents the arrival of the wave of excitation at the distal electrode, d . A curve representing the change which occurs in the difference of potential between the surface of contact, p , and the rest of the surface of the muscle during excitation can be obtained by calculation from measurements of the polar ordinates of the curve resulting from the first experiment. Assuming an identical curve at d , but relating to a period 15,000ths of a second later, we may obtain the curve which expresses "what must be the successive differences of potential between p and d , when the effect of the change at d is not canceled." If the curve be deduced from the second experiment, i. e., where the change at d is canceled, it coincides with that obtained by summation, where the change at d is not canceled. Therefore, from p , we can obtain the curve which expresses the successive differences of potential required, and the determination of the monophasic variation ought to be the aim of such experiments.

The curves that represent the change of contour also represent the electrical response to excitation. The electrical state of the muscle when at rest depends upon the way in which the effect of the wave of excitation at the distal electrode is canceled. If this be done by applying a ligature between p and d , the contacts remain equi-potential; if the part of the nerve to which d is applied be de-vitalized, e.g., by heat, the unexcitable dead surface is found to be strongly "negative" to the other.

It thus becomes evident that the phenomena observed depend "exclusively upon the state of the surfaces of contact, and consequently, when the distal contact is canceled, on that of the proximal contact only."

Having considered the electrical results of a single instantaneous excitation, further experiments were detailed, showing the electrical concomitants of continuous contraction. It has been contended that the continuity of voluntary muscular action is apparent only, and an identity in sound emitted by muscle contracting normally, and one contracting under a series of instantaneous stimuli, has been adduced in favor of this view. "It is argued because we can produce continuous contraction (artificial tetanus) by discontinuous stimuli, that all continuous contraction is so produced." Putting such questions aside, and limiting attention to the electrical concomitants of continuous action, it was shown that under certain conditions a continuous contraction can be produced by a single uninterrupted stimulus, and that in reflex spasms there is no evidence of discontinuity, "at least, in the sense in which this term is ordinarily understood." There is rhythm, but it is central, not muscular. If spasm be artificially produced by exciting the motor apparatus through a sensory nerve, the cells of the cord having been rendered hyper-excitable by a dose of strychnia, a prolonged contraction occurs, the graphic tracing of which is often distinguishable from that of complete tetanus. But by analyzing the electrical concomitants as recorded photographically, it is seen that the curve resembles rather that of complete tetanus interrupted at regular intervals than that of a series of responses to single instantaneous stimuli following each other at $\frac{1}{10}$ of a second or more. Thus a single stimulus to the motor cells of the cord has produced a series of responses in the muscle, but, as already stated, the rhythm is central, i. e., the motor

* Since writing the above the writer has learned that great improvements have been effected in this process during 1899; and the electrolytic plant at St. Helens is again in operation.

* For this and a portion of the following, see "Therapeutic Electricity," by W. S. Hedley, M.D. (Churchill, London.)