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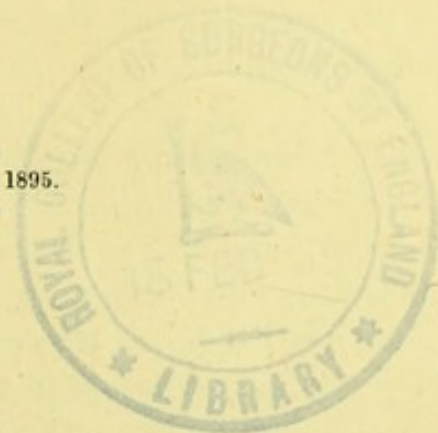
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THE

DISINTEGRATION OF ORGANIC TISSUE, BY
HIGH TENSION DISCHARGES.

BY

J. INGLIS PARSONS, M.D., M.R.C.P.

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THE DISINTEGRATION OF ORGANIC TISSUE BY HIGH TENSION DISCHARGES.

By J. INGLIS PARSONS, M.D., M.R.C.P.

THESE investigations have been undertaken with the object of improving the treatment of malignant disease by interrupted voltaic currents, which I first described in the 'British Medical Journal' for April, 1888. In view of the experience which I have gathered since that time, I should say that at present the rôle of electricity as a method of treatment, except for small ulcers, is to follow after excision when nothing more can be done by the knife, and recurrence has occurred.

A further limitation is imposed on this method. In some cases, on account of the position of the growth, a current sufficiently powerful to injure the tumour cannot be used. The difficulties of the subject are so great that it will probably take another ten years or more before the subject can be worked out, and a final verdict given.

As a result of these investigations I am at last able to demonstrate with the microphotos placed before you, that organic tissue can be disintegrated throughout the path of a current, without appreciable heat or caustic action. Before describing the experiments by which this has been achieved, I will first briefly go over the various steps which have led me to investigate the action of high tension currents.

In a paper published in the 'British Gynæcological Transactions' for 1888, I described some experiments into the effect on fibroid tumours produced by the constant current. It will suffice to say that as a result of these

investigations I came to the conclusion that the destructive action of the constant current is confined to a small area round the poles. There probably is some alteration produced in the tissues between the poles by the transport of elements, but it is not sufficient to injure the vitality of carcinoma, although it will sometimes cause degeneration of a fibroma. For instance, if two needles are inserted into a growth six inches apart, and a constant current of 200 milliampères is turned on for ten minutes, the tissues within a radius of half an inch round the needle points can be seen by the naked eye to be more or less destroyed by caustic action. But the remaining five inches of growth lying between the needles show no alteration even when examined under the microscope. It is obvious, therefore, that the utility of the constant current is limited in scope, because firstly, the area destroyed is small, and secondly, because within that area the destruction is much greater than required to produce devitalisation and atrophy. Instead, therefore, of relying upon electrolysis and the caustic action of the current, I decided to investigate the disruptive action of electricity produced by sudden discharges.

From this I expected two advantages: firstly, that the current would injure the whole of the cells between the needles instead of only those close to the needle points; secondly, that the cells thus injured would gradually succumb, and be followed by fatty degeneration and absorption rather than necrosis.

It appeared to me more than probable that the sudden impact of a powerful discharge from a voltaic battery would produce the desired effect.

This expectation was in part realised, and an arrest in growth and some shrinkage, showing there had been absorption, took place in many cases, while pain was always relieved or abolished. The results, however, varied. In some cases the growth seemed to be easily injured, while others recovered, and their progress was then only retarded by the treatment. As almost all these cases

were beyond further operation by the knife, it is difficult to form an exact opinion of the benefit derived. Many cases were weakened by the continual discharge from large ulcers, before the treatment was commenced. Some were at a late stage, when any result is likely to be vitiated by the presence of metastatic deposits. In other advanced cases the ramifications of the growth rendered it impossible to treat the whole of the disease.

In order to cope with these resistant cases, the strength of the current was raised, but no corresponding advantage was obtained. The increase of quantity caused heating of the needles and increased caustic action at the points, and the destructive action became unequal. That is to say, it was much greater at the poles than in the region between them.

The success obtained so far, although not brilliant, was sufficient to stimulate me to further effort.

At this point of my investigations I arrived at three conclusions :

1st. That the alternating voltaic current in sufficient strength did more than the constant current, in that it caused an injurious action on living cells throughout its path.

2nd. That the injury to living cells was not sufficient in all cases to produce the desired result, viz. atrophy.

3rd. That if to surmount this difficulty the strength of the current was further added to, the increased quantity of electricity caused too much heat and caustic action round the needle points, and was followed by sloughing.

Now although heat and caustic action are extremely valuable for ulcers and small nodules involving the skin, the sloughing produced by it is unsuitable for any but small growths, and did not reach the ideal method which I had tried to arrive at, viz. to produce atrophy without sloughing.

I had, therefore, to reconsider the problem, and to find out whether organic tissue could not be injured sufficiently

to produce atrophy without appreciable caustic action and heat.

It then became apparent to me on observing the mechanical destructive effects of high-pressure currents, that I must rely more upon a high E. M. F. than on the quantity or strength of the current. With this object in view, I decided to try the effect of a transformer by which quantity is turned into pressure.

The increase in pressure would cause a greater disruptive action, while the diminution in quantity would reduce in proportion the caustic action at the poles. I hoped by this means to obtain an equal destructive action from the point of entry to the point of exit, without any excess at the points of the needles.

A transformer could be worked in two different ways, either by the alternating current from a dynamo in the primary circuit, or by the use of a current from a battery interrupted as in the ordinary induction apparatus familiar to all of us. The advantage of the current from the dynamo is that the alternations are equal; on the other hand, if taken from the main in the streets they are too rapid for operations. When a powerful current is being used on the body it is necessary in some cases to wait between each interruption of the current, especially if the application is made near the cardiac region.

In addition to this, a special dynamo to give the required pressure—and capable, too, of giving single alternations at a time—would be difficult to construct and very heavy to move about.

The objection to the faradic induction coil is that the alternations are not equal, and they are also liable to variations in strength because the interruptions are made by a rheotome.

Although this variation occurs, I found that when several interruptions were employed the average effect produced was nearly always the same provided the batteries were fully charged.

I therefore decided to investigate the action of a

powerful induction coil. The result of these investigations I place before the Society to-night.

The next point to consider was the rheotome. In the ordinary faradic batteries this works automatically and gives from 40 to 100 interruptions in a second. After looking at all the different rheotomes constructed, I decided to have a handle attached to one of the ordinary form so that it could be worked by hand. A single interruption could thus be given, and any interval of time allowed between it and the next during an operation.

The next question was to decide upon the pressure that the secondary coil should work up to. Electricians have long considered that the secondary coil developed a much higher pressure (E. M. F.) against a high resistance like air than it did against a comparatively low resistance like the human body. In order, therefore, to make sure that the coil should develop sufficient pressure through the low resistance of the body, and achieve the result desired, I decided that it should be able to spark through six inches of air. This means a pressure of 160,000 volts through air, and would probably be more than required.

There was still another defect about all coils which if overlooked would have wrecked the whole of one's anticipations.

This defect is the very high resistance within the ordinary secondary coils. It is produced by the great length of fine wire in the numerous turns required to develop high pressures. The ordinary coil made to spark six inches would have about 25,000 turns of fine wire with a resistance of about 7000 ohms. If this resistance be compared with that of malignant tumours, there is found to be a very great difference. The latter are usually about 100 to 250 ohms. Now the energy of the current in the various portions of a closed circuit would be used up in proportion to the resistance encountered; consequently a tumour with a resistance of say 100 ohms, in circuit with a secondary coil having a resistance of 7000 ohms, would only obtain one seventieth part of the total

energy developed. The other sixty-nine seventieths would be used up in overcoming the high resistance of the numerous turns of fine wire in the secondary coil.

It became necessary, therefore, to have a special coil constructed, which you now see before you. This was made for me by Mr. Apps, who constructed the famous Spottiswoode coil and several others for special purposes.

My conditions were: first, that the coil should give a spark six inches in length through air; second, that the resistance of the coil be kept down as low as possible by using thicker wire than usual; third, that the operator should be able to increase or decrease the strength of the current with precision and rapidity whenever required; fourth, that the current breaker could be worked by hand if necessary as well as automatically.

All these conditions have been fulfilled by Mr. Apps in this instrument. [Demonstration of manual interruption, control of strength, &c.]

The resistance of the secondary coil instead of being 7000 ohms is only 1000; consequently when a discharge is sent from this through a tumour having a resistance of 100 ohms, one tenth of the energy in the circuit is developed in the tumour instead of one seventieth.

It must be clearly understood that the secondary coil of this machine acts as a transformer. The large volume of electricity poured out by the accumulators through the primary coil is converted into great pressure or electromotive force with a corresponding decrease in the quantity of electricity in the circuit. The result of this is that very little electrolysis and little or no caustic action takes place when the discharge is sent through a tumour. This fact I can demonstrate to you with Gaiffe's water voltmeter. I now connect this to a Stohrer battery of 40 cells and turn on the current for thirty seconds. You observe that 4 c.c. of oxygen and hydrogen gases have been formed by the divisions on the inner tube. Now compare this with the volume of gas that forms when the

voltmeter is connected up with the induction coil and the current is allowed to pass for the same period of time.

Instead of 4 c.c. being formed, only one fiftieth part of this quantity of gas can be observed.

For the same reason very little heat is developed with the secondary coil, although it can make a spark through six inches of air. [Demonstration.] For instance, I take a platinum wire 18 inches long and connect it to the six accumulators that supply the primary coil, and at once you see that it becomes red-hot. But when I connect it to the secondary coil it shows no change whatever. The same current from the accumulators which made the wire red-hot is raised to a very high pressure but so reduced in quantity that it has practically no heating effect or chemical action.

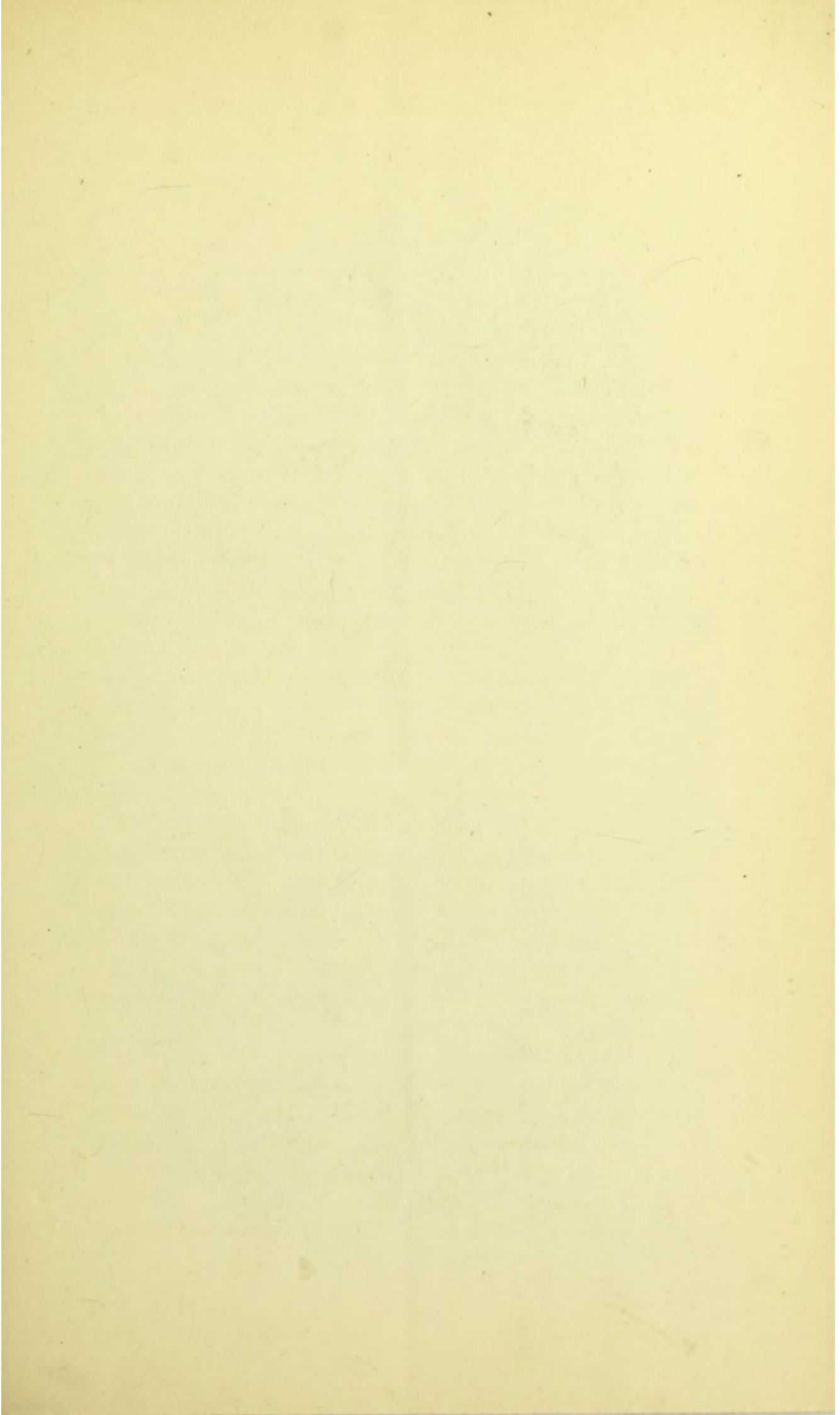
One more difficulty stood in the way—the measurement of the current. This is very simple with a constant current, and several reliable galvanometers are in use. An alternating current from a dynamo can also be accurately measured. With a faradic current the alternate discharges are unequal, it is therefore difficult to measure the quantity of current with any accuracy. This is of secondary importance, because the effects produced by a coil of this kind do not depend on the quantity of electricity, which is always very small, but upon the pressure, which is very high. What we require is to measure the E. M. F. or pressure. Here again there is a difficulty, and in the opinion of electrical experts the pressure developed varies according to the resistance offered. With low resistances it cannot be determined. Lord Kelvin, in answer to my inquiry, was kind enough to write to me that it was impossible to find out the voltage from any data of the dimensions of the coil and resistance in the circuit. The pressure is much greater through the high resistance of air than it is through the low resistance of tumour. According to De la Rue's tables it requires 23,400 volts to spark across one inch of air between a point and a disc. I have found by experiment that this

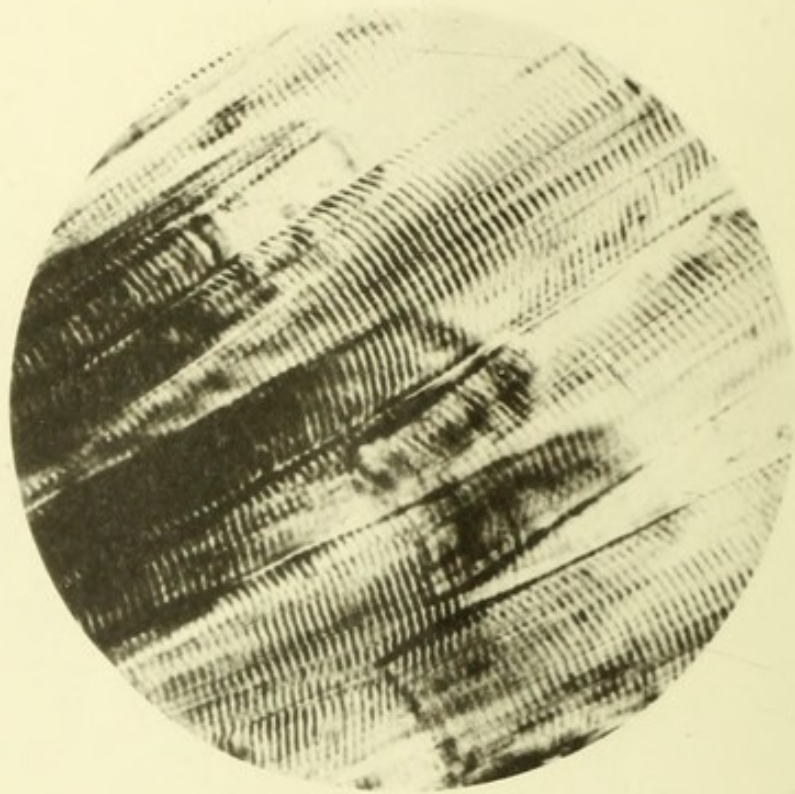
may be taken as a standard upon which to gauge the strength required for any given purpose. The coil is set to spark across a certain length of air. If it is then connected up with a piece of fresh beef it will produce certain results verified by examination which vary hardly at all. The coil can by this means be set with a fair amount of accuracy to produce anything from a mild injury up to entire disintegration.

My next step was to test the efficacy of this coil in a practical manner. So many difficulties and so much prejudice stand in the way of vivisection that I decided to use freshly-killed beef as the most suitable organic tissue upon which to demonstrate the disintegrating effect of high pressures. The structure of the voluntary muscles with its delicate striation is easily seen under the microscope, and this enables the observer to readily discern any change which takes place. Dead muscle according to Hermann (Erb, 'Electro-therapeutics,' p. 45) conducts twice as well as living muscle; consequently any change that takes place in dead muscle after the passage of the discharge would be still greater in the case of living muscle because the latter offers a higher resistance.

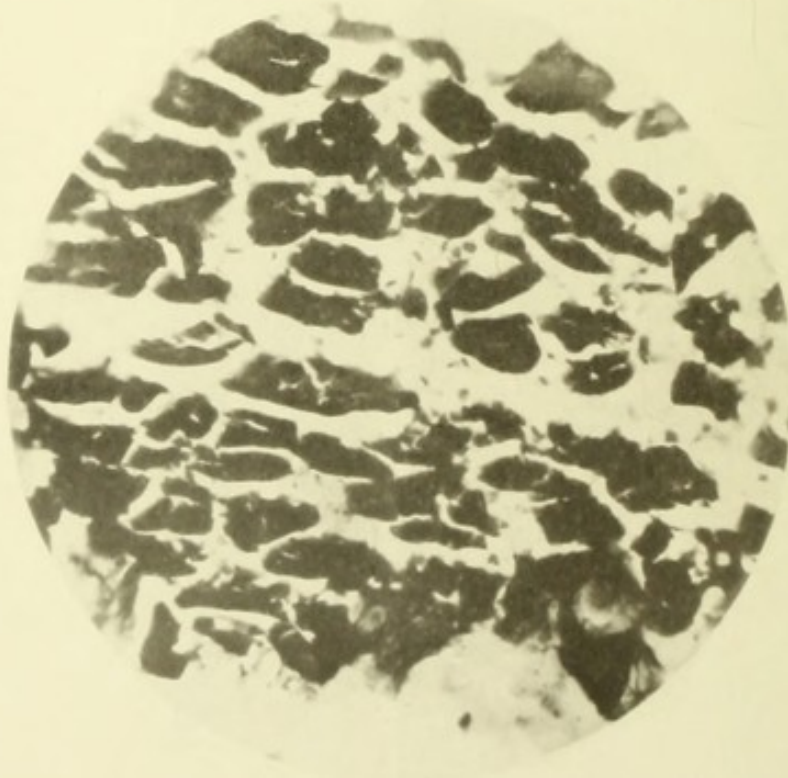
The pieces of beef used were obtained from the buttock in a solid mass six inches thick, so as to allow diffusion of the current. In each experiment the electricity was applied within twenty-four hours of the animal being killed. At every one of the experiments a small piece of the beef was cut off before the discharge was sent through and sections were made from them for comparison. Two platinum-pointed needles were used, introduced into the beef.

On the first occasion one third the full power of the battery was employed with the needles 4 inches apart. A small piece was cut midway between the needle points. Dr. E. J. Maclean had great difficulty in cutting the section from the beef through which the current had passed on account of friability of the tissue. On examination under the microscope I was delighted to find that





No. 1.



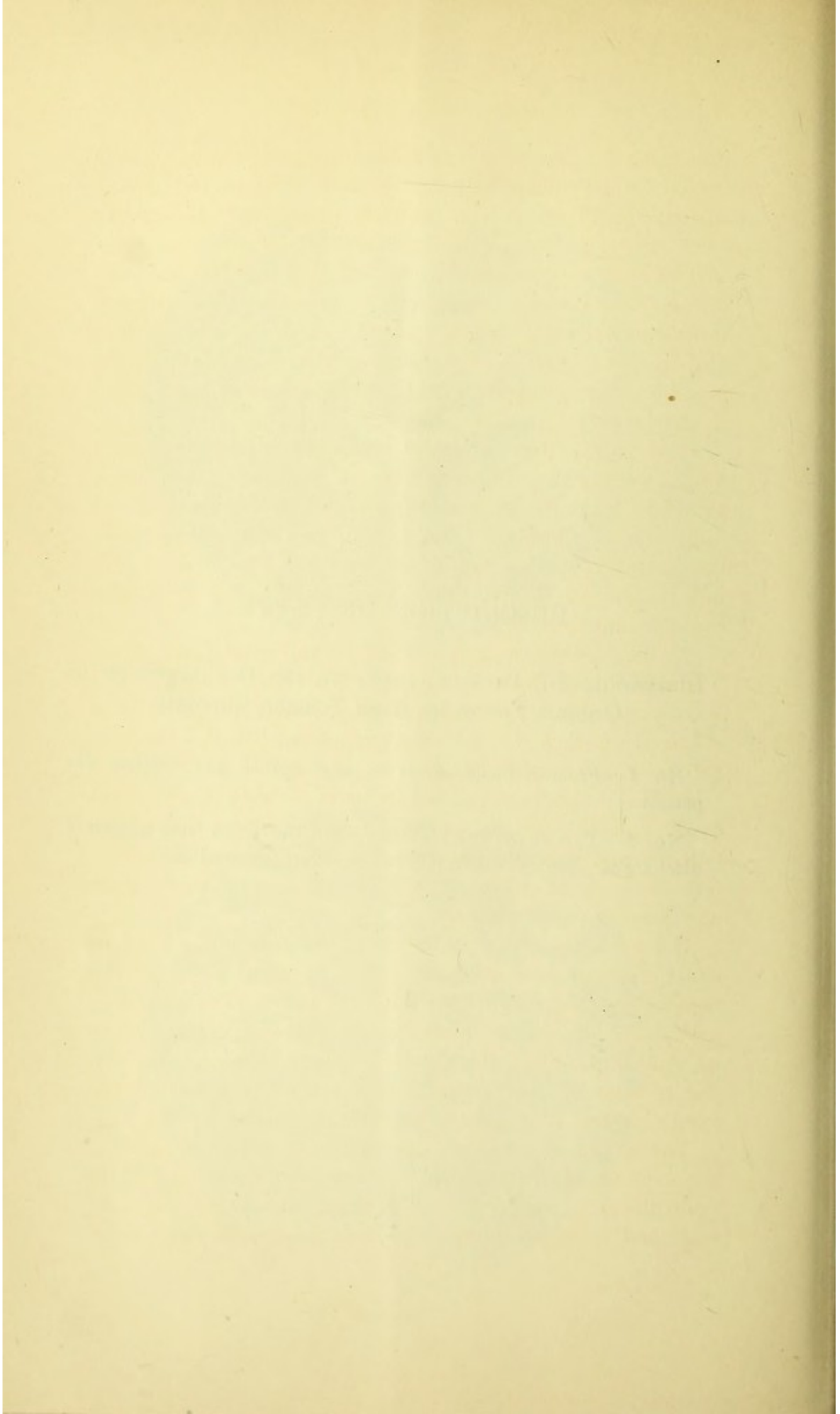
No. 2.

DESCRIPTION OF PLATE I,

Illustrating Dr. Parsons' paper on the Disintegration of
Organic Tissue by High Tension Currents.

No. 1.—From a piece of fresh beef before any current was
passed.

No. 2.—This shows the breaking up of the fibres from a series of
discharges. Section taken midway between the needles.



the muscular fibres were broken across in places and frayed out; whereas a piece of beef removed for examination, and of which a section was easily made before the current was passed, showed no such alteration.

The next experiment was to try the full force of the current that could be developed. A series of discharges were sent through a piece of beef 5 inches thick. When Dr. Maclean tried to cut some sections he found it impossible; the specimen simply crumbled away even when it was frozen.

However, after a great number of experiments and after wasting many pounds of beef, I at last found the right strength of current, and succeeded with great difficulty in obtaining some sections that showed the breaking-up of the muscular fibres. For these I am indebted to Dr. T. W. Eden, who cut them for me at the College Laboratories.

I have had these photographed and now place them before you as Nos. 1 and 2. No. 1 shows the beef before any discharge was passed. No. 2 shows the loss of striation and partial breaking across of the fibres at one point after a discharge.

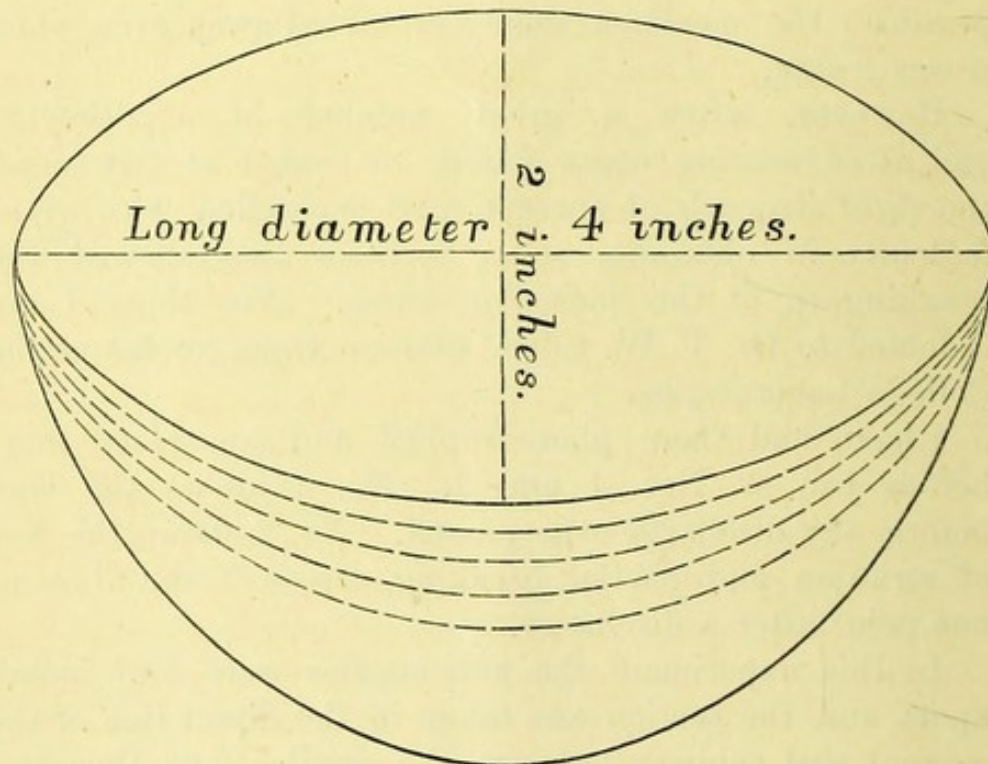
In this experiment the two needles were four inches apart, and the section was taken in the direct line of the current and midway between the needles, and therefore out of the area which would be affected if there were any heat or caustic action.

However, in order to demonstrate how little heat or caustic action is developed, I took a small piece of the beef as near as possible to the point of one of the needles, and it exhibited no charring or chemical action such as one finds when the voltaic current is used. In fact the change in tissue is almost exactly the same at the needle points as it is at a distance two inches off.

The next point was to determine as nearly as possible the area throughout which this breaking-up of the fibres took place. I made several experiments in this direction, and had a large number of sections made from small

pieces of beef that were cut out at different places in the path of the current.

I used as large a mass of beef as I could obtain, so as to allow the current to diffuse well, and I found that the area affected took more or less the shape of an elliptic spindle, the diameter of the short axis being about one half that of the long axis.



I quite expected to find that the tissue in the direct line from one needle point to the other would be more broken up than that lying in the outer part of the spindle, but this was not the case. If anything, the breaking-up appears to be greater in the outer part of the spindle than in the centre. In the zone near to, but outside the spindle some injury was found to have taken place. This is shown on the diagram by a few lines; but sections taken outside that showed no change, although we know that if all the diffusion could be demonstrated it would be found to be globular as shown in the outer dotted line on the diagram.

The importance of arriving at this conclusion cannot be over-estimated, because if these powerful currents should come into practical use for malignant disease, it is imperative to know the area as nearly as possible that will be disintegrated.

I have found in using a voltaic current that some patients are very susceptible to electricity, and cannot stand a very powerful shock. Having found that thirty interruptions at a given pressure would produce disintegration with the needles 3 inches apart, I next tried the effect of reducing the pressure by one-half and doubling the number of interruptions to try if it would make up for the reduction in pressure. On comparison the results were found to be the same. This was most satisfactory if it would also apply to living cells, because with patients unable to stand strong currents, the defect could within certain limits be made up by using a greater number of discharges. It soon became apparent in carrying out these experiments that one must know how much tissue was included between the needle points when these were placed at different distances from each other. For instance, if the needles are 4 inches apart at one experiment and at another are 3 inches apart, it will be obvious that more tissue will be affected in one case than in the other, and that in order to make up for this the pressure must either be increased or more interruptions must be given. The question, then, is this—What is the proportion between the solid contents of an elliptic spindle 4 inches long compared with another 3 inches long?

The calculation is rather difficult, and one of my friends, a mathematician, kindly confirmed my results. The contents of a solid elliptic spindle four inches long contains more than double the tissue of another which is three inches long.

If we take the tissue included in an elliptic spindle two inches long as 1, then at three inches the contents will be 3.3 greater; at four inches 8 times greater; at five inches

15.6; and at six inches 27.0. We thus see that with the needles six inches apart the current has twenty-seven times more tissue to disintegrate than when they are two inches apart. In order to make up for this the pressure and the number of interruptions must be increased in a similar proportion.

When describing the drawbacks of a transformer, I pointed out that in the opinion of leading electricians a transformer does not develop against a low resistance like beef anything like the pressure which is developed against air. Now the resistance of the beef used was only 220 ohms. I therefore tried the effect of interposing an air gap $1\frac{1}{4}$ inches in the circuit. By this means a pressure of at least 30,000 volts must be developed to spark across the air gap. A similar experiment was tried with a vacuum tube in the circuit instead of an air gap. On examining sections of beef from the former, I found very little change. The enormous resistance of the air gap probably exhausted nearly all the energy of the current.

With the vacuum tube in the circuit, a greater change could be seen. There was some loss of striation and fraying of the muscular fibres. The resistance of a vacuum tube is very much less than air, consequently more energy in this instance was expended on the beef.

My next experiment was to try the effect of a Leyden jar as a condenser in conjunction with the transformer. The two poles from the transformer [Demonstration], as I now show you, are connected one with the outside, and one with the inside of the jar. The electricity first charges the jar, and is then discharged. You will also observe that a considerable change has taken place in the character of the discharge. The spark is much thicker, and shorter. In other words, the quantity is increased at the expense of the pressure. The spark will not extend much more than three quarters of an inch. The pressure, therefore, is approximately about 18,000 volts. There is also another change. The discharge takes place more

quickly than from the transformer. Some have estimated it at one 10,000th of a second.

At first sight it appeared as if electricity in this form would suit one's purpose better than any other, and that no tumour would ever be able to withstand its shattering effects. On trying it on a piece of beef it did utterly smash up the fibres. This is well shown in micro-photo No. 5, the section for which I am indebted to Dr. Ewen Maclean. But on further sections being taken from different parts of the beef, I found that the destroyed area was very small. There was hardly any diffusion in spite of the increase in quantity. A narrow lane from one needle point to the other covered the area of disintegration. This concludes my investigations as far as they have gone.

Allow me to thank you for the patience with which you have listened to me, and to hope that in your criticisms you will make some allowance for the difficulty of the subject with which I have grappled.

