Histological Changes of the Nerve Cells which take Place under the Influence of Powerful Electric Currents.

By

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It is well known that the nerve cell shows the chromatolysis after the section of the axone, and there is a considerable amount of literature upon the subject. But we have only some few reports conscerning the structural changes of the nerve cells which occurs under the influence of a powerful electric current. *Wendt* (Skand. Archiv f. Phisiol. XI) examined the spinal ganglion of frogs by means of *Nissl's* staining after application of an induced current of 100—500 volts for 2—10 minutes. Besides the ordinary chromatolysis and the excentric situated nucleus he often found a regular network and a vacuole in the nerve cell.

Corrado (referred by *Tousey* "Medical Electricity and Rontgen Rays," Sec. Ed. 1915) applied to dogs a continuous electric current of 720—2175 volts and of 10—30 amperes, one electrode being placed on the head and the other on the lower portion of the spinal cord. The animal died in every instance. The nerve cells of the brain and spinal cord were examined by both the *Nissl* and *Golgi* methods. The cell contents showed the beginning changes of chromatolysis and frequently vacuolisation. Sometimes the chromatic substances were accumlated on one side of the cell. The contour of the nucleus may be either irregular or angular.

I have investigated the subject on the ganglion nodosum of the rabbit. The ganglion was exposed after the incision of the skin on the neck, and moistened with isotonic solutions of the non-electrolyte to prevent drying. As electrolyte Ringer's solution was used and as non-electrolyte 5.5 per cent grape sugar solution or 1.9 per cent urea solution. The non-polarisable

electrodes were placed on the vagus trunk close to the proximal and distal ends of the ganglion, in order to send an electric current through the ganglion. The continuous as well as the alternate current was employed, the former being derived from the storage batteries, the latter from the transformer connected with the street wire. The continuous current had a voltage of 50—150 volts. The ganglion, through which the electric current had been allowed to pass for from one to two hours, was extirpated and thrown into fixing liquids, As to the staining of sections I made use of *Nissl's* method and *Bierschowsky's* dyeing for the neurofibrils. The animal seemed to have suffered severely by the alternate current, so that many of them died sooner or later after the experiments, while the continuous currents gave the animals no serious effect.

With regard to the findings of the nerve cells there is a great difference between the effects of the continuous and alternating currents. In the ganglion which was soaked by Ringer's solution during the passage of the continuous current (6—12 milliamperes), the nerve cell contains no basophile chromatic substances or only a little except in the nucleolus, but its size and contour remain almost unchanged. There is seen an alveolar network in the cell body, the nucleus shows shrinkage and deformation, if strongly affected, nevertheless it keeps the normal position (fig. 1). These findings are characteristic and entirely different from the chromatolysis which follows from the section of the axone.

On the other hand, the chromatic elements remain unchanged in the nerve cell which has been submitted to the influence of the alternating current, although the ganglion was moistened by Ringer's solution as much as in the case of the direct current. However the cell seems to have undergone a shrinkage, the contour being somewhat irregular (fig. 2).

The fact that *Nissl's* granules may disappear by the action of the direct current can be easily explained dy the process of cataphoresis. The chromatic elements must be composed of colloid particles which are in aqueous solution generally negatively charged and therefore move towards the positive

pole in an electric field. As *Corrado* claimed I find not seldom an accumlation of the chromatic substances on one side of the nerve cell (fig. 3). Especially there is such a collection on one side opposite the positive pole. No doubt this is the remainder of the negatively charged chromatic substance which was prevented from migrating to the anode by the cell capsule. The accumlation of the chromatic substances at other places was due to an unknown determining facter. The emigration of the chromatic substance through the cell capsule seems to have been favoured greatly by the movement of ions in the electrolyte with which the ganglion was soaked. Innumerable ions must have traveled through the cell body, so that the superficial layer of protoplasma and the capsule became so porous as to permit the emigration of colloid particles.

With the alternating current it is different. In this case the colloid particles are subjected to an oscillatory movement in the cell body instead of moving in any fixed direction. Therefore the chromatic elements remain unchanged without leaving the cell body, which shrinks however by diminishing the liquid contents perhaps in consequence of the oscillation of the colloid particles.

It is evident that the ganglion soaked with the non-electrolyte (5.5 per cent grape sugar solution or 1.9 per cent urea solution) presents a greater electric resistence than that treated with the electrolyte, the amperage of the continuous current in this case of my experiments being only of 0.7—1.5 milliamperes. Ganglion, so treated, during the passage of continuous current the nerve cell retaines all *Nissl's* granules without showing the least sign of chromatolysis (fig. 4). This is due to the fact that the liquid in which the nerve cells were immersed contained only a small number of ions. The passage of the ions through the cell body must have been too insignificant to permit the emigration of the colloid particles. There are some cells, however, filled with a great vacuole each of which occupies so great a space within the capsule that the cytoplasma and nucleus of the nerve cell are strongly pressed to the side (fig. 4). Let us consider what

is the nature of the vacuole. In microscopic slides treated with osmic acid or with *Bielshowskys* method of dyeing for the neurofibrils they are unstained like bubbles (figs. 5, 6). Therefore they are not composed of myelin or neuroplasma which would flow from the nerve fibres into the nervs cells. Especially in the ganglion through which a current of strong voltage (150 volts) has passed, they are numerous (figs. 4, 7 B) although few of them are seen even in the normal ganglion which has not been subjected to the influence of an electric current. Their appearance seems to be independent of heat, for they do not increase in the least in number, if the ganglion is boiled in the saline or sugar solution (fig. 8). On the contrary they seem to be produced by the metabolic process of the living nerve cells, which may be greatly excited by a passage of a strong electric current. For this suggestion I may point out the following facts: After the application of 2 per cent cocaine solution, the anaesthetized ganglion was submitted to the passage of the continuous current of 150 volts for an hour and a half. This ganglion contains, however, no more vacuoles than the normal one in contradistinction to the ganglion which was treated in the same manner excepting the application of the anaesthetic (fig. 7 A & B).

Perhaps it is due to the suppression of irritability of the nerve cells. The same consideration may be applied to the ganglion which was after extirpation immersed with the sugar solution and submitted to the electrisation. In spite of a long application of the continuous current of 150 volts it shows nothing peculiar except a little shrinkage of the nerve cells.

I can not say definitively what the above mentioned vacuoles consist of, but it is probable that they are formed of carbon dioxide. Having soaked the ganglion with a solution of grape sugar to which was added barium hydroxide, it was subjected to a continuous current of 150 volts for an hour and a half. In the ganglion treated in this manner I found a few needle like crystals resembling barium carbonate, but they were too few to determine that the vacuoles consisted of carbon dioxide only. The ganglion treated with the non-electrolyte and the alternating current shows nothing

peculiar except a little shrinkage of nerve cells. I conclude this article, expressing my sincere thanks to Prof. K. Kōsaka under whose guidance this work was done, and to Dr. M. Seki who gave me an important advice during my experiments.

Fig. 1. A section of the rabbit's ganglion nodosum treated with Ringer's solution and a descending continuous current of 150 volts for an hour. Nissl's method.

a. Nucleus of nerve cell.

Fig. 2. The same treated with Ringer's solution and a alternating current of 100 volts for an hour.

Fig. 3. The same treated with Ringer's solution and a descending continuous current of 100 volts for an hour.

Fig. 4. The same treated with 5.5 per cent grape sugar solution and a descending direct current of 150 volts for an hour and a half.

a, b, c. Vacuoles.

Fig. 5. The same treated with 5.5 per cent grape sugar solution and a descending direct current of 100 volts for an hour and a half. Fixed with one per cent osmium solution.

a. Vacuole.

b. A bundle of medullated nerve-fibres.

c. Blood vessel.

Fig. 6. The same. *Bielschowsky's* dyeing method for the neurofibrils.

a. Vacuole.

Fig. 7. Two sections of the rabbits' ganglia nodosa treated with 5.5 per cent grape sugar solution and a descending direct current of 150 volts for an hour and a half.

Nissl's method.

A. Anaesthetized with cocaine solution beforehand.

B. Without cocaine.

Fig. 8. A section of the ganglion nodosum which was boiled in the sugar solution after extirpation.

Nissl's method.

Fig. 1.

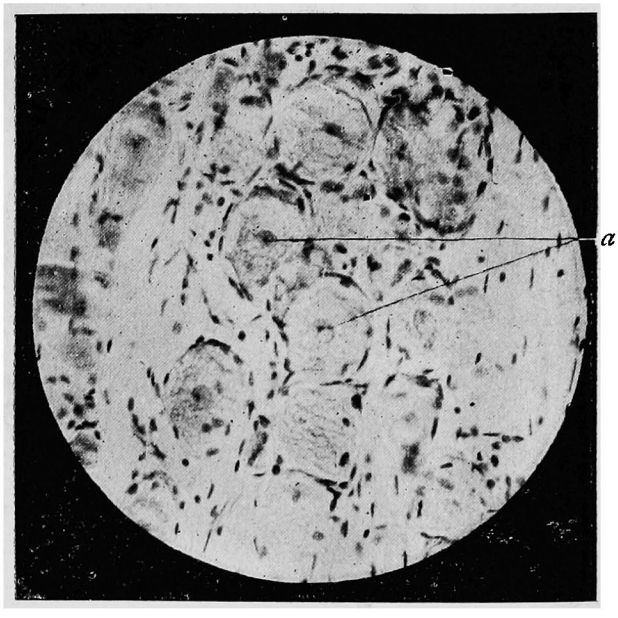

Fig. 2.

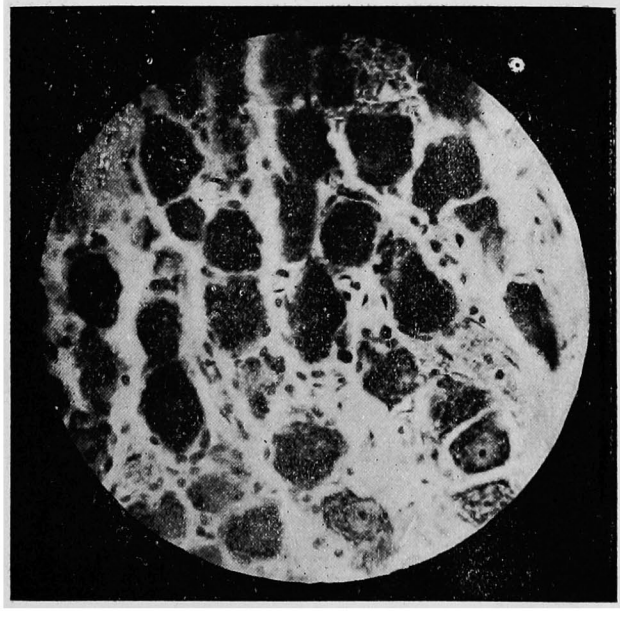

Fig. 3.

Fig. 4.

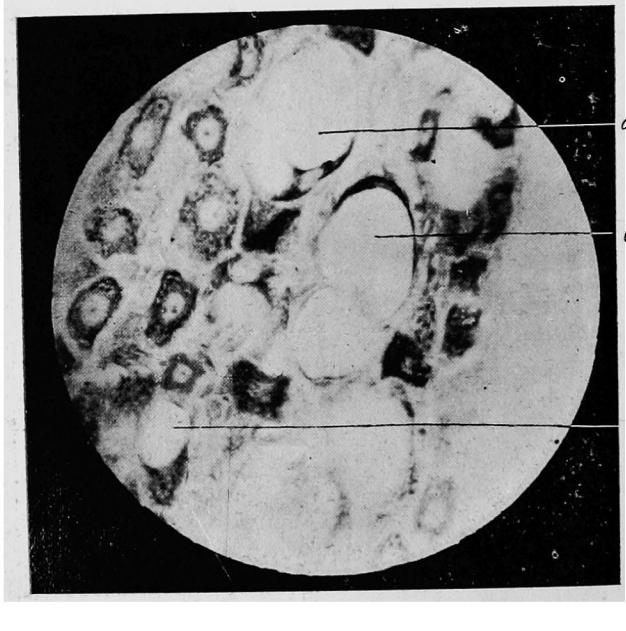

Fig. 5.

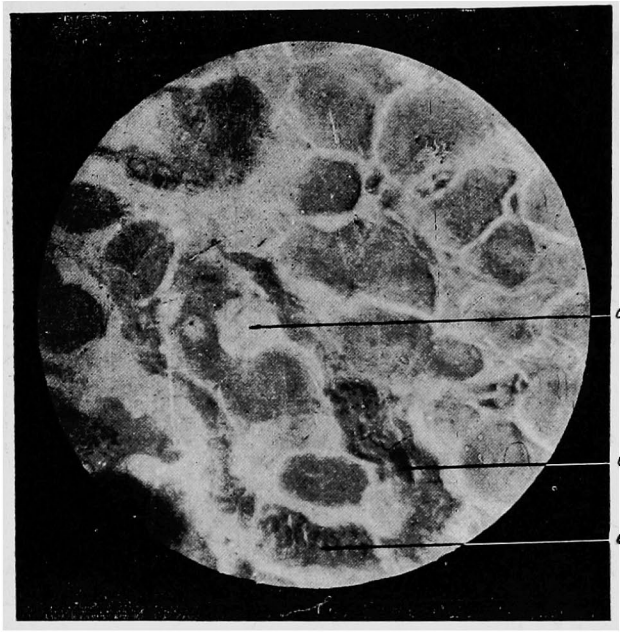

Fig. 6.

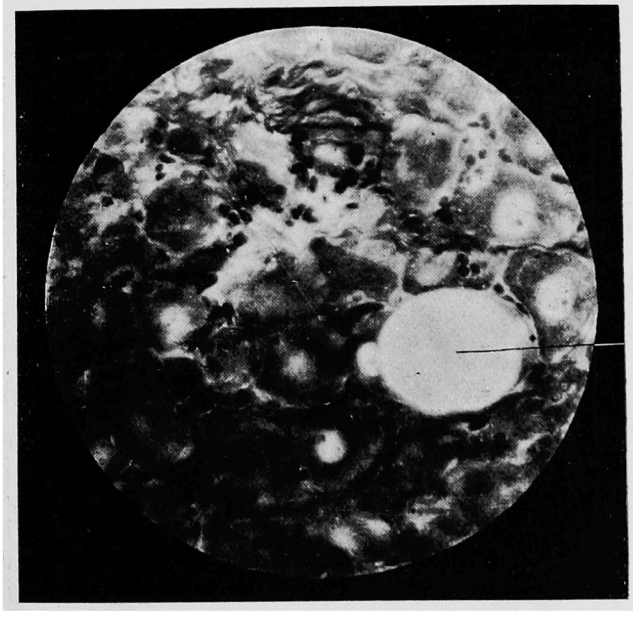

Fig. 7.

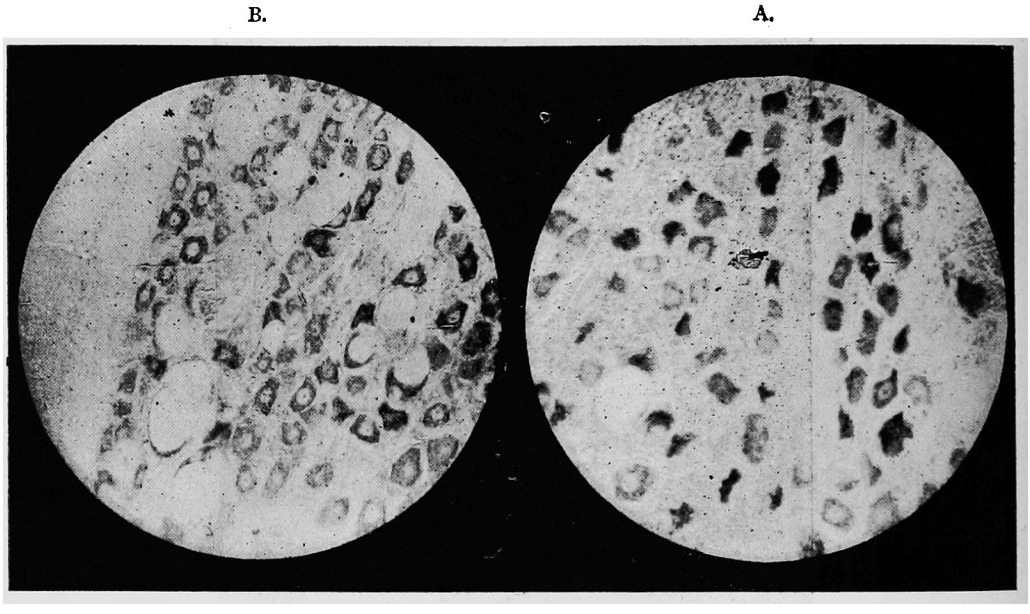

Fig. 8.