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STRONG AND PERMANENT INTERACTION BETWEEN PERIPHERAL NERVE AND A CONSTANT INHOMOGENEOUS MAGNETIC FIELD

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A mathematical model of the electric function of the axon-membrane suggested that in addition to its electric also the magnetic characteristics of the nerve structure should be taken into consideration. This prediction obtained a strong experimental support by the present observation about the unexpectedly intensive magnetic interaction between a permanent magnetic field and the sciatic nerve of the frog. No comparable effects were found in other tissues than nerve. The magnetic susceptibility ($\varkappa = 10^{-2}$) of the axon bundle has been measured in order to classify its magnetic characteristics. A proposition is put forward about the possible functional significance of the magnetic properties of the nerve in impulse generation and conduction.

The mechanisms of the potential generating and conducting properties of the axon are usually symbolized with such an electric circuit, in which the resting potential is represented by a battery and the electrical parameters by resistance and capacitance. The impedance of the axon-membrane was usually measured at two characteristic values, at the resting level and at the peak of the action potential (Matsumoto et al. 1970). Although in these measurements the membrane could only be regarded as a "black box", the results are still interpreted as some kind of variation of resistance and capacitance. For the examination of the membrane's complex impedance we have chosen one of the methods of eletronic circuit synthesis (Kuh and Pederson 1959; Mason and Zimmermann 1960; Tucker 1964).* The results of such a mathematical analysis suggested that a wave morphology similar to that of the action potential cannot be reproduced by a linear electronic circuit consisting of merely capacitive and resistive elements. From the physical point of view this suggests that besides the electric one magnetic energy should also take place in the process.

It is obvious that every type of electric current — therefore also the charges passing through the membrane — produces a magnetic field, and in a closed circuit the change of the magnetic field generates an electric current. The effect of the magnetic field mainly depends on the characteristics of the

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* The so-called "transfer impedance" of the membrane is analyzed with equations obtained from axon-spike, generated by electric pulses and responses given to step-pulses, known as the "voltage-clamp" technique. Transforming the impedance-equation into a complex frequency co-ordinate, some of its roots lie outside the abscissa.

solution conducts electrically, it was expected that the alternating magnetic field induced eddy currents in it. Therefore we employed an inhomogeneous permanent magnetic field. For field generation a commercially available permanent magnet measuring 32 ×14 ×10 mm and embedded in synthetic material was used; it produced a maximum field force of 580 Oersted. The 35 mm long axon-bundle was suspended on a hook with a thin silk cord. As a control, a similar silk cord previously soaked in Ringer's solution was suspended on the same hook (Fig. 1). In order to allow parallel mobility, the magnet was cemented to a manipulator and its position was arranged so that one of its poles should fall in line with the axon-bundle and the other with the control cord. During preparation and measurements, care was taken to avoid any contact between the axon-bundle and metallic materials.

Our findings were as follows.

1. When the magnet was first approached to the axon-bundle, a weak but definite force was consistently noticed: the axon-bundle bent in its full length toward the magnetic pole.

2. On repeating the procedure, the pulling force increased gradually and after 7 to 9 trials it had become constant. Approaching the nerve carefully we could establish an equilibrium; namely the pulling force of the magnet and the gravitation were balancing each other (Fig. 2).

3. When the direction of the magnetic field was changed while its intensity remained constant, the axon-bundle turned around its axis, following the direction of the lines of magnetic force. Thus, it behaved as hard magnetic materials do.

4. The olfactory nerve of the pike and peripheral nerves of the rat have shown effects comparable to the above one.

5. The magnetic properties developed during the above procedures persisted after treatment in distilled water, 10% NaCl, 10% formaldehyde solution, or after drying in open air.

6. After soaking the nerve in a 1 : 1 mixture of chloroform and methyl-alcohol for 2 minutes, the magnetic effect disappeared irreversibly.*

7. In control experiments, tissues other than nerves showed no similar magnetic characteristics. Skeletal muscle, heart muscle, liver, intestine, bone, blood vessels could not be magnetized, only a blood vessel section filled with coagulated blood showed a rather weak magnetic response.

The present findings suggest that

a) the natural orientation of the structure responsible for the magnetic effect develops gradually due to the applied outside force;

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* The author whishes to express his gratitude to Professor A. M. MONNIER for suggesting this procedure while he was visiting the laboratory.

The results of a series of susceptibility measurements fell between $\varkappa = (9300 \text{ to } 13\,050)\, 10^{-6}$. For the sake of simplicity we took $\varkappa = 10^{-2}$ as the mean. Accordingly, the macroscopically determined effect corresponds to a magnetic permeability of $\mu = 1.125$.

Susceptibility is determined according to Gouy's method by the force which affects the cross-section of the axon-bundle by the identified magnetic field. Since the lipids or rather phospholipids fill only a small fraction of the whole cross-section, the actual susceptibility (permeability) is considerably higher than the value measured.

Since the macroscopically determined magnetic parameters are not always the exact measure of the microscopic characteristics, our results only reflect the order of magnitude of the phenomenon.

If we suppose that the magnetic properties of the axon play a role in its function, then first of all we should examine the axon's microstructure. In further experiments we should identify the basic structural element responsible for the observed behaviour and to establish whether it had an oriented texture. In other words we have to determine that structure which can be considered the basic magnetic domain. It also remains to be decided whether there exist one or several directions of the magnetic field, which may be the outcome of a particularly intensive interaction. If any of these possibilities could be answered positively, our results would only reflect fragments of the real magnetic effect, since it is unlikely that the outside field and the functional field of the axon should have the same direction and intensity. In short, our magnetizing effects were not applied in the so-called "magnetic easy direction".

The measured value for permeability suggests that from the point of view of action potential genesis the magnetic effect cannot be an epiphenomenon. In the study of the membrane potential it would be erroneous to identify the force acting on the electrically charged particles with the $F = qE$ formula, instead of Maxwell's equation $F = q(E + vxB)$, describing the full phenomenon. This would mean that the second part of the whole equation (q/vxB) does not alter the course of the electrically charged particles, as Lorenz's force, but produce an induced current (Lenz's rule) by regaining part of the magnetically stored energy, invested in the material texture as a magnetomotive force. This induced current flows in a direction opposite to that of the depolarizing membrane current, therefore it results in such an ion movement which corresponds to the mechanism of the active metabolic pump. If further experiments would indicate that the magnetic property of the axon, similarly to a number of materials, has the feature of square-loop hysteresis, then the membrane responses induced by hyper- and depolarizing electric stimuli would have a plausible explanation.

b) since the magnetic effect is abolished on dissolving the lipids, and since other tissues showed no comparable magnetic effects, one may suppose that the effect is connected with phospholipids.

As a further step we have determined the susceptibility of the axon-bundle as its macroscopic feature. In order to produce an intensive magnetic interaction, the sciatic nerve was placed in the measuring device before the measurement. To minimize elastic deformation, the axon-bundle was exsiccated. As a measuring method we took advantage of Gouy's scale method, well-known in physics. To avoid the nerve being caught by either of the poles we used a magnet of sharp angled poles and with a small slit, generating an inhomogeneous field, and placed it 3 mm below the nerve. Before the measurement the magnetic field was tested.

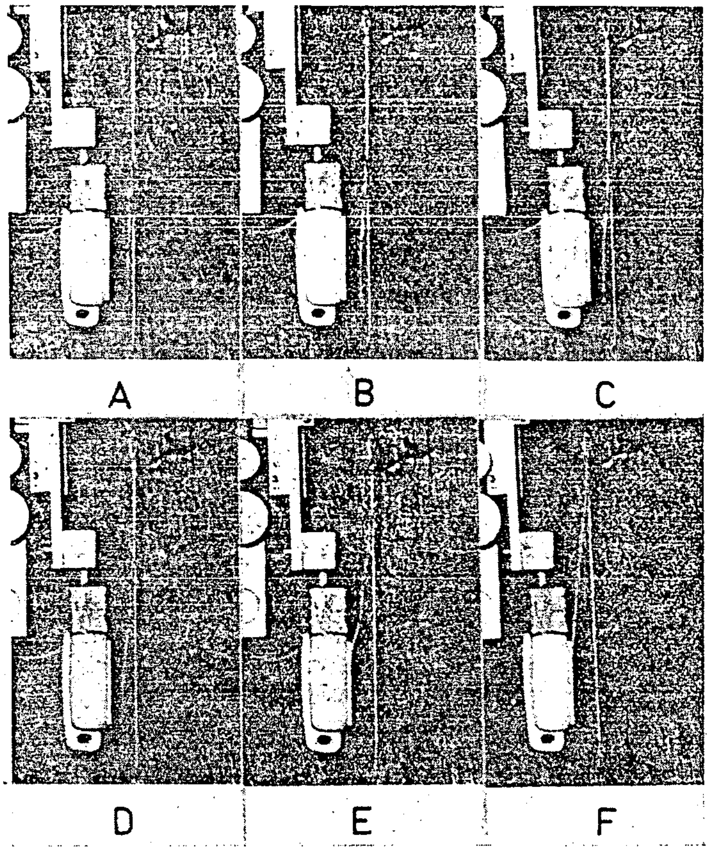

Fig. 2. The magnetic interaction overcomes the gravitation. The permanent magnet pulls the axon-bundle to itself. The position of the control cord is unchanged

given material, namely on its susceptibility ($\varkappa$) or rather on its permeability which is related to the former, $\mu = 1 + 4\pi\varkappa$. While the value for susceptibility in the CGS system hardly differs from 10^{-6}, in other words, as long as the material is diamagnetic ($\varkappa < 10^{-6}$) or paramagnetic ($\varkappa > 10^{-6}$), the effect of the magnetic field can be disregarded in the electric and geometric relations of the membrane.

In order to verify the results obtained with network synthesis, it became necessary to measure the susceptibility and/or the magnetic permeability of the axon. For this purpose a well myelinated fibre bundle, the frog's sciatic nerve has been chosen in view of the surprising observation that the direction of the rotating movement of the Schwann-cells — producing the myelin sheath — coincided with the expected direction of the magnetic field generated by the current in the excited fibres of the axoplasm.

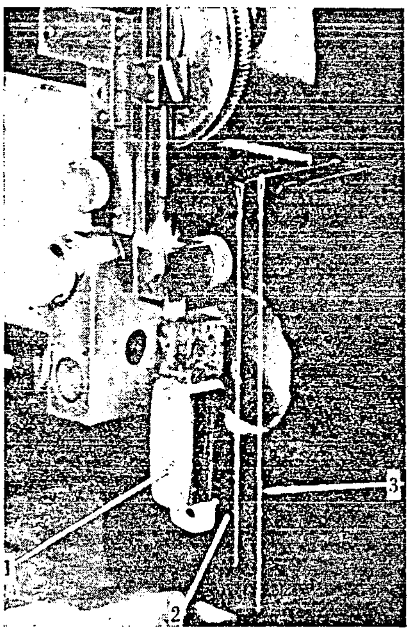

Fig. 1. Experimental arrangement 1: permanent magnet; 2: sciatic nerve; 3: control cord

CHALAZONITIS et al. (1971), measuring magnetic effects on the outer segment of the frog's photoreceptors, calculated a 10^{-6} degree of susceptibility and demonstrated a correlation with the structural order of the examined material, which manifested itself as magnetic anisotropy. To our great surprise, in our own experiments a ten thousand-times higher susceptibility was measured.

We have demonstrated the interaction of the axon-bundle and the magnetic field in a simple way. Since the isolated axon-bundle kept in Ringer's

LITERATURE

Chalazonitis, N., Chagneux, R., Arvanitaki, A.: Rotation in a constant magnetic field of photoreceptor outer segments. First European Biophysics Congress, Baden near Vienna **1971.**

Kuh, E. S., Pederson, D. O.: Principles of Circuit Synthesis. McGraw-Hill, New York, Toronto, London **1959.**

Matsumoto, N., Inoue, I., Kishimoto, U.: The electric impedance of the Squid axon membrane measured between internal and external electrodes. Jap. J. Physiol. **1970**, 20: 516–526.

Mason, S. J., Zimmermann, H. J.: Electronic Circuits, Signals and Systems. John Wiley, New York. London **1960.**

Tucker, D. G.: Circuits with periodically varying parameters. The Radio and Electronic Engineer, March **1963**, pp. 263–277.

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