medium, and the cutting is due to constriction in this ring, and the constriction to a change in surface tension, the work invo ved would require a minimum reduction along the inner surface of the ring of at least 383 dynes per centimeter.

The bulk of evidence at hand seems to indicate that the paramecia are divided by the approach of two pseudopods and not by the constriction of a ring. To account for the process on the basis of the surface tension theory, therefore, the surface tension of the amebae would, in all probability, have to be considerably higher than 1118 dynes per centimeter. The surface tension of protoplasm is, however, only approximately 50 dynes per centimeter. It is, therefore, probably at best an insignificant factor in the process of feeding in Ameba.

More detailed descriptions of these observations and calculations will be published elsewhere.

The following references may be listed:

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THE ELECTROMOTIVE FORCE PRODUCED BY THE ACCELERATION OF METALS

By Richard C. Tolman and T. Dale Stewart

DEPARTMENT OF CHEMISTRY, UNIVERSITY OF CALIFORNIA

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Modern theories of electricity have led to the belief that the passage of an electric current through a metal really consists in the progressive motion of 'free' electrons contained in the body of the metal itself. If this be true we may now expect a number of effects arising from the *mass* of these electrons which were not predictable on the basis of older theories which thought of electricity as a sort of intangible massless fluid. As examples of such effects, we should expect the rear end of an *accelerated* rod of metal to become negatively charged owing to the lagging behind of the relatively mobile electrons which the metal contains, and should expect the periphery of a *rotating* disk to become negatively charged owing to the action of centrifugal force on the electrons in the disk. Such effects would presumably be very small, however, owing to the exceedingly small mass probably associated with the electron.

In the case of electrolytes, where the mass associated with the carriers of electricity is much larger than in metals, such effects have already been detected by Colley[1] and Des Coudres[2] using respectively the accelerational and the centrifugal method, and have been subjected to a more elaborate quantitative investigation by Tolman[3] and by Tolman and Osgerby.[4]

In the case of metallic conductors, Maxwell,[5] himself, was the first, not only to discuss the nature of the phenomena which would arise if mass of the ordinary kind should be associated with electricity in metals, but also to try experiments to detect the possible effects. He had, however, no means of predicting the presumable size of such effects if they did exist, since this was before the development of the electron theory, and he merely states the negative results of his experiments without any information as to the dimensions or efficiency of his apparatus. Lodge[6] also reports a negative result for such experiments.

The first attempts to detect such effects in metals of which we have any quantitative information were made by Nichols[7] in 1906. He employed the centrifugal method, using a rotating aluminum disk and making a rubbing contact at the periphery and center with wires, which led to the electrical measuring apparatus. Such rubbing contacts, in particular the one at the rapidly moving periphery, necessarily introduce larger and variable electromotive forces; nevertheless from a series of experiments Nichols was able to conclude that the mass of the carrier in metals is less than that of the hydrogen atom.

Since in the case of metals the centrifugal method of attack almost necessarily involves some disastrous form of rubbing contact, we have been at work during the last four years developing the accelerational method of attack. In 1913[8] we were able to report that the effect in metals, if any, was so small that the mass of the carrier in metals was less than one two-hundredth part of that of the hydrogen atom. With the help of a much more sensitive galvanometer and eliminating one by one a number of accidental effects which appear when greater sensitiveness is reached, we have now apparently obtained a real effect due to the mass of the carrier in metals.

The apparatus consisted essentially of a coil of insulated copper wire, wound on the periphery of a wheel which could be rotated at a speed of about 5000 r.p.m. and brought suddenly to rest. The two ends of the coil were lead to the center of the wheel and there made connection, through wires which were allowed to twist up, with a ballistic galvanometer which measured the pulse of electric current which was produced by the tendency of the electrons to continue in motion after the wheel was stopped. For the purpose of eliminating accidental effects it was found among other things necessary to construct the apparatus of non-magnetic materials, to rotate the coil of wire in a space in which both the horizontal and vertical components of the earth's steady magnetic field has been neutralized, and to compensate for the variable part of the earth's magnetic field by connecting in series with the rotating coil a compensating coil having the same flux area but wound in the opposite direction. For details of the apparatus our complete article which has been submitted to the *Physical Review* for publication must be consulted.

The galvanometer throws were found to be in the direction predicted on the basis of a negative charge for the *mobile* carrier in metals and to agree within the limits of error with the equation

$$Q = M\frac{vl}{RF},$$

of which the derivation will be given in our complete article. Q is the pulse of electricity sent through the galvanometer on stopping, v is the velocity of the periphery of the wheel at the instant of stopping, l the length of the coil, R the total resistance in the circuit, F the value of the faraday, and M is a constant whose value ought to be fairly close to that of the mass associated with one equivalent (*i.e.*, with $F = 96{,}540$ coulombs) of electrons. For copper wire the average value of M from 131 runs was 1/1910 which may be compared with the accepted value for the mass of one equivalent of electrons in free space, namely 1/1845 (*i.e.*, the ratio of the mass of the electron to that of the hydrogen atom).

Our purpose in carrying out these measurements has not been merely to demonstrate an effect which has long been an object of search; we have also had in mind the possibility of obtaining from our experiments information as to the nature of the conducting process in metals and indeed perhaps further information as to the nature of the electron itself. The equation given above which we have tested in this work was derived on the assumption that the conducting process in metals is in the nature of a drift of 'free' electrons when acted on by an electric field, and the fact that the equation seems to fit the experimental facts is to some extent a verification of these assumptions. Such considerations are of particular interest at the present time in view of J. J. Thomson's proposal[9] of a quite different theory of metallic conduction. According to his theory, a metal contains atoms which are in the nature of electrical doublets which will orient themselves parallel to any applied electrical field. These atoms are assumed to have the power of ejecting electrons in the same direction as the axis of the doublet and hence the conducting process on the basis of this theory consists in a tendency for orientation of the doublets under the action of the applied electromotive force and a consequent ejection of electrons from one atom to another in the direction in which the current is known to flow. It seems very doubtful to us whether such a theory can be satisfactorily brought into agreement with our experimental results, since it would seem at first sight to be merely an accidental coincidence if the *mechanical* forces which we apply should produce an orientation in the right direction and of the right amount to give the pulse of electricity whose magnitude we have calculated on the basis of the other theory and actually found experimentally.

[1] Colley, *Ann. Physik., Leipzig*, **17**, 55 (1882).

[2] Des Coudres, *Ibid.*, **49**, 284 (1893); *Ibid.*, **57**, 232 (1896).

[3] Tolman, *Proc. Amer. Acad. Arts Sci.*, **46**, 109 (1910); *J. Amer. Chem. Soc.*, **33**, 121 (1911).

[4] Tolman, Osgerby and Stewart, *J. Amer. Chem. Soc.*, **36**, 466 (1914).

[5] Maxwell, *Treatise on Electricity and Magnetism*, 3rd edition (1892), Vol. 2, pp. 211 et seq.

[6] Lodge, *Modern Views of Electricity*, 3rd edition (1907), p. 39.

[7] Nichols, *Physik. Zs.*, **7**, 640 (1906).

[8] Tolman, Osgerby and Stewart, loc. cit.

[9] Thomson, *Phil. Mag.*, **30**, 192 (1915); Richardson, *Ibid.*, **30**, 295 (1915).

Errata: In Mr. T. W. Vaughan's article, pages 98 and 99, the familiar percentage sign (%) was printed in place of the per-thousandths sign (°/₀₀), following figures for the salinity; the salinities as printed are therefore ten times too large.