that the radius of the electron is related to the Compton wave-length of the proton as 3 to $\sqrt{2}$. This may be interpreted as indicating that in the state of equilibrium of the universe one third of its primordial particles are protons, one third electrons and one third neutrons.

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SPECIAL ARTICLES

IMMUNIZATION AGAINST EQUINE ENCEPHALOMYELITIS WITH CHICK EMBRYO VACCINES[1]

EQUINE encephalomyelitis is a virus disease which, during the past few years, has become increasingly prevalent in many parts of the United States. Fortunately, vaccines capable of producing immunity in susceptible animals can be prepared by formalinizing brain tissue from animals dying of the disease.[2,3] The horse brain now used for large-scale vaccination constitutes a relatively poor and inconstant source of virus. There is much evidence that the immunizing capacity of a vaccine of this sort is proportional to the amount of virus in the tissues before treatment with formalin. We have accordingly sought to produce a better vaccine by utilizing the exceptionally infectious tissues of chick embryos[4] diseased with the virus.

The high virus content of embryos has been emphasized by the fact that it has proved possible to isolate[5] from them, but from no other tissues, a homogeneous substance which seems to be the infectious agent. We have already prepared formalinized extracts of such tissues and have demonstrated that the immunizing principle they contain can be concentrated by ultracentrifugation.[6] In further experiments we have now studied the immunizing capacity of the formalinized embryonic tissues themselves and have compared it with that of the usual vaccines made from horse brain.

The viruses of both the Eastern and Western strains of equine encephalomyelitis grow equally well in chick embryos. The tissues of embryos diseased with the Eastern strain virus regularly attain a titre of 3×10^9 and under proper conditions 3×10^{10} mouse infective units per gram. The titre of the Western strain chick virus routinely lies between 3×10^8 and 3×10^9 m.i.u. per gram. The virus concentration in these tissues is 1,000 to 10,000 times greater than in the most infectious horse brain we have examined and the chick vaccine has proved to be correspondingly more effective as an immunizing agent.

Chick vaccine against the Eastern strain of equine encephalomyelitis has been tested by injecting guinea pigs with two doses at an interval of seven days. Two weeks after the second injection they have received an intracerebral[7] inoculation of 500 minimal lethal doses of virus-diseased horse brain. Of thirty animals vaccinated with eight different batches of vaccine every one was solidly immune and survived the test inoculation of virus with no evidence of disease. All control animals succumbed promptly.

Western strain chick vaccine is equally effective in protecting guinea pigs. One group of experiments utilizing 60 animals has demonstrated its superior immunizing capacity compared with that of a corresponding horse brain vaccine. The chick vaccine protected every tested guinea pig against 1,000 m.l.d. of virus, whereas no animal receiving the horse brain vaccine survived a test injection of 100 m.l.d. In preliminary experiments it has also protected every vaccinated horse against the intracerebral injection of enough virus to kill all the control animals.

In these experiments the vaccine consisted of a 10 per cent. diseased tissue suspension containing 0.4 per cent. formalin. A 1 per cent. chick vaccine has protected about 60 per cent. of the vaccinated animals; more dilute vaccines have proved worthless.

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PROTOPLASMIC STREAMING, ELECTRIC POTENTIALS AND GROWTH IN COLEOPTILES OF TRITICUM AND AVENA

THE effect of electric potentials on protoplasmic streaming in coleoptiles of Triticum and Avena in relation to transport and growth has been studied. Cholodny *et al.*[1] have reported that applied currents mainly decrease growth; Lund *et al.*[2] relate polarity of the plant with observed electric polarity, while on the other hand Clark *et al.*[3] report that the electric

[1] The part of this work carried out at Duke University has been made possible through the interest and aid of Lederle Laboratories, Pearl River, N. Y.

[2] M. S. Shahan and L. T. Giltner, *Jour. Am. Vet. Med. Asn.*, 84: 928, 1934.

[3] P. K. Olitsky and H. R. Cox, *Jour. Exp. Med.*, 63: 745, 1936.

[4] E. Higbee and B. Howitt, *Jour. Bact.*, 29: 399, 1935.

[5] R. W. G. Wyckoff, *Proc. Soc. Exp. Biol. and Med.*, 36: 771, 1937.

[6] J. W. Beard, H. Finkelstein, W. C. Sealy and R. W. G. Wyckoff, SCIENCE, 87: 89, 1938.

[7] Operations on animals were made under full ether anesthesia.

[1] N. Cholodny and E. Sankewitsch, *Plant Physiol.*, 12: 385, 1937.

[2] E. J. Lund, *Jour. Exp. Zool.*, 51: 265, 1928.

[3] W. G. Clark, *Plant Physiol.*, 12: 409, 1937; *ibid.*, 12: 737, 1937.

polarity of plants changes independently of polarity of growth. A study of processes primary to the above reactions, namely the protoplasmic streaming, leads towards the explanation of these phenomena.

The optical system used for the observation of protoplasmic streaming had a high resolving power, and only the smallest visible moving particles were used as a measure.

The coleoptiles were not cut lengthwise and placed in water but were kept intact in air, with a small piece of tissue on the lower side removed in order to yield a better visibility. The objective of the microscope was immersed directly upon the tissue with a special immersion oil. This immersion medium of the correct refractive index had no effect upon the living cells and increased the visibility of the smaller particles through its capacity to diminish scattering of light due to intercellular airspaces, etc.

No decrease of the protoplasmic streaming due to lack of oxygen was observed with this technique (over a period of 10 to 18 hours). Electric currents of 0.01–500 μ amp. were applied to the coleoptile over a distance of 2 cm by means of Ag AgCl electrodes.

Constant strong currents yield an effect after only a few seconds, and ultimately disintegrate the protoplasm. Currents of about 4 μ amp. cause cessation after 5 to 10 minutes, while recovery takes place after several hours. Currents of about 0.1–0.01 μ amp., however, cause a decrease of rate of streaming after 15 to 30 min. The threshold for the different cells varies, due to differences in conductivity, which can be measured in this way. Short exposures to currents cause comparable changes in streaming.

Under the conditions of our experiments no marked difference in the effect on streaming velocity was detected when the current flow opposed the "inherent" electric polarity of the coleoptile, or when it supplemented the "inherent" polarity.

Growth measurements with a horizontal microscope made simultaneously on different plants after application of the same currents show identical decreases in growth. Measurements of transport by means of curvatures in parallel experiments show the relation between protoplasmic streaming, transport of auxins and growth. Together with the data of Bottelier[4] on the parallelism between phototropic and protoplasmic spectral sensitivity, and the other data reported previously, this third parallelism between protoplasmic streaming, transport and growth supports the viewpoint that changes in bio-electric potentials have an effect similar to that of applied potentials. These changes in bio-electric potentials, due to modifications in external and internal conditions, change the protoplasmic streaming, and hence the transport of auxins, and finally the growth. The differences between electric and growth polarity can thus be understood.

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[4] H. P. Bottelier, *Rec. d. Trav. bot. neer.*, 32: 287, 1935.

THE RELIABILITY OF PRINCIPAL COMPONENTS

THE principal components of a set of intercorrelated statistical observed variables can be obtained by applying the Hotelling technique to the matrix of intercorrelations among the observed variables.[1] The principal components thus obtained are independent variates, which as Girshick[2] has shown, may be as many or fewer than the number of observed variables. Moreover, in the same paper, Girshick demonstrates that the component loadings obtained from the Hotelling technique are maximum likelihood statistics, and further that the principal components are obtained in order of their importance. The first principal component, therefore, is shown, under certain general conditions, to be the independent variate which has the least error variance, and the greatest mean-square correlation with the observed variables. The second principal component is the independent variate which has the next least error variance and the next greatest mean-square correlation with the variables, etc.

If a set of observed variables is resolved into principal components, the observed variables can be expressed in terms of the independent variates. In terms of Hotelling's development

$$\gamma = \frac{a_j z_j}{k}$$

where γ is a person's score in the terms of the independent variate, where $\frac{a_j}{k}$ are the weights to be applied to the z_j which are the observed variables expressed in standard score form.

An estimate of the reliability of the principal component scores may be obtained if it were possible to estimate the correlations of the γ scores from one battery of observed variables with the Γ scores from a comparable battery of observed variables. Such an opportunity was given by the testing of a group of 107 individuals made available to the senior author by the Emergency Relief Bureau of New York City and by a partial grant-in-aid by the Columbia University Council for Research in the Social Sciences. The individuals were given all the Thurstone Scales for the "Measurement of Social Attitudes" in print in July, 1934. The Form A of each scale was given first, then after a lapse of two weeks, the comparable Form B of each of the same scales was given.

[1] Harold Hotelling, *Jour. Educ. Psychol.*, 24: 417–441 and 498–520, 1933.

[2] M. A. Girshick, *Jour. Am. Statist. Asn.*, 31: 519–528, 1936.