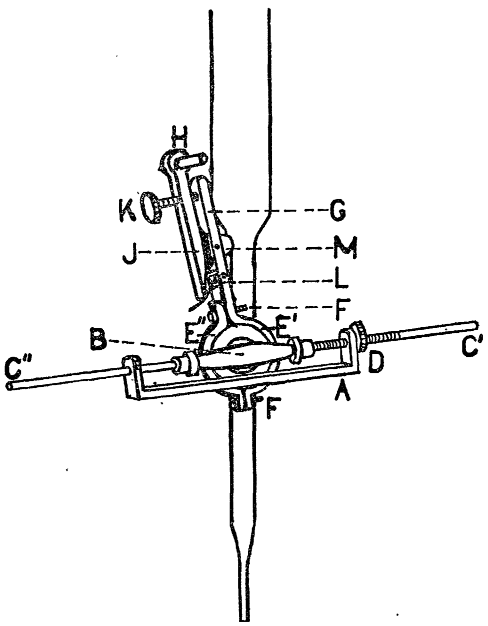


(H), is attached to the sleeve of the stopcock; the movable handle (A), which strikes against the stop, is attached to the glass plug. Both parts are made of brass. To insure rigidity of the handle, the rod (C′) can be screwed tight against the handle of the plug (B) and can be clamped there by means of the nut (D).

The stationary part of the drop-control is clamped to the wider end of the glass sleeve by means of the semi-circular bands (E′ and E″), which are fastened together by two screws (F). One of these bands (E′) is an extension of the body (G); the other band is separate from it. The rod (H) serves as a stop to the rotating rod (C′ or C″) when it is desired to release a drop of reagent. This stop is set perpendicularly into the arm (J) which in turn is supported by (G). Support is effected by means of the projection (M) which passes through a hole in (G) and is held there by a pin, thus permitting a slight rotation of the arm (J) about the pin as fulcrum. The rotation is controlled by the screw (K) which passes through (J) and rests against (G). Movements of the arm, imparted by the screw, are opposed by the spring (L), which is held in a second hole in (G) by means of a pin. The free end of the spring is extended in such a way as to press against the lower end of (J).

The chief precaution to be taken in attaching the movable part to the plug is to have the glass handle fairly well centered with respect to (A). In attaching the stationary part, the body (G) is set at such an angle to the vertical that when the rod (C″) touches the stop (H), drops will flow from the burette tip at a slow but steady rate. Then, by means of the adjusting screw (K), the stop can be set at such a position as to permit the formation of freely falling drops at either a rapid rate or else so slowly as to enable the operator to remove small fractions of a drop at his convenience. On the other hand, it is always possible to get a steady flow of reagent from the burette by reversing the direction of rotation of (A) so that (C′–C″) is vertical. A strip of heavy rubber sheeting interposed between the semi-circular bands and the stopcock will prevent the latter from cracking.

The writer wishes to express his obligations to the departmental machinist, Willy Appledorn, for his assistance in constructing this instrument.

Franklin Hollander
Department of Physiology,
N. Y. Homeopathic Medical College

SPECIAL ARTICLES

THE RELATIONSHIP BETWEEN ELECTRICAL DIFFERENCES OF POTENTIAL IN THE SKIN AND NORMAL BASAL METABOLISM

In 1919 and 1920 Waller published the results of his researches on emotive phenomena and their correlation with variation of conductance of the palm of the hand. In general, Waller's experimental observations substantiated his view that there is "a close association between nutrition and what we may call emotion" and that there is reason for placing the "special class of emotive effects in the general category of trophic phenomena."[1] The experiments of Waller evidenced, therefore, a correlation between the electric resistance (or conductance) of the skin and nutritional changes and indicated that the emotive effect varied considerably in magnitude depending on whether the subject was rested or fatigued. No correlation between electrical conductance and general metabolic activity was attempted.

Waller was of the opinion that emotive effect is to be regarded as due to diminished resistance (increased conductance) rather than to increased electromotive force. However, Lund[2] and his colleagues

[1] A. D. Waller, "Concerning Emotive Phenomena. Part II. Periodic Variations of Conductance of the Palm of the Human Hand," *Proc. Roy. Soc. London*, Series B, 91: 17–31, 1920.

[2] E. J. Lund and W. A. Kenyon, "Relation between Continuous Bioelectric Currents and Cell Respiration. I.

very pertinently pointed out in the first of their series of articles on bioelectric currents and cell respiration that "methods which determine only the electromotive force and the changes in electromotive force are to be preferred when clearness of thought and interpretation and a greater nicety of distinction are to be attempted."

Lund concluded from his investigations on bioelectric currents and cell respiration that "the experiments definitely prove that the electric polarity of the cell is quantitatively correlated to the respiratory exchange of the cell and that electric currents accompany cell oxidation."[3] Lund[4] also advanced the theory that bioelectric currents produced by cells and tissues are the result of oxidation-reduction potentials developed by the respiratory mechanism of the cell, and that stimulation changes the electrical potential and therefore the electric polarity of the cell because it temporarily accelerates the reaction reductant $\rightarrow$ oxidant, thereby changing the ratio of oxidant to reductant. Data indicate the applicability of the familiar equation for oxidation-reduction potential

$$E = E_0 - \frac{RT}{nF} \log \frac{[ox]}{[red]}$$

to the various phenomena studied.

Child[5] has written recently an excellent résumé of investigations on physiological gradients. Electrical potential differences are present along physiological axes (at least in many of the simpler organisms). In his consideration of differential susceptibility he pointed out that, in spite of criticisms, the data at hand show or indicate that differences in susceptibility to certain reagents are paralleled generally by quantitative metabolic differences. In general, "the protoplasmic factors immediately concerned in originating potential differences may be various, but that potential differences must be associated with the graded quantitative metabolic and other differences characteristic of the axial gradients appears to be beyond question."[6]

Electric Correlation Potentials in Growing Root Tips," *Jour. Expt. Zool.*, 48: 333–357, 1927.

[3] E. J. Lund, "Relation between Continuous Bioelectric Currents and Cell Respiration. V. The Quantitative Relation between E_p and Cell Oxidation as Shown by the Effects of Cyanide and Oxygen," *Jour. Expt. Zool.*, 51: 327–337, 1928.

[4] E. J. Lund, "Relation between Continuous Bioelectric Currents and Cell Respiration. II. A Theory of Continuous Bioelectric Currents and Electric Polarity of Cells," *Jour. Expt. Zool.*, 51: 265–290, 1928.

[5] C. M. Child, "The Physiological Gradients," *Protoplasma*, 5: 447–476, 1929.

[6] C. M. Child and L. H. Hyman, "Studies on the Axial Gradient in *Corymorpho palma*. I. Respiratory, Electric and Reconstitutional Gradients," *Biologia Generalis*, 2: 355–374, 1926.

Sheard and Johnson[7] have shown that, in response to various qualities and quantities of radiant energy, there is a definite correlation between the electrical potential differences developed across areas situated near the base and tip ends respectively of leaves intact with plants.

These experimental results and theoretical considerations as well as others not cited led us to investigations concerning the possibility of a relationship between differences of electrical potential in the skin and the basal metabolisms of persons who were said to be normal clinically.

We have used, with slight modifications, the nonpolarizable type of electrodes developed by Alvarez, Freelander and Clark.[8] Potential differences were measured by standard potentiometric methods or by a portable combination of apparatus consisting of a millivolter and a galvanometer. One of the nonpolarizable electrodes was placed on the skin of the forearm just above the articulation of the ulna and radius at the wrist; the second electrode was placed at an arbitrarily chosen but fixed distance of 12 cm. The distance of separation of the electrodes need not be very exact since a change of 1 cm in the position of one of the electrodes gives a negligible change in the potential difference between them. Furthermore, the difference of potential, due essentially to electromotive forces developed between two given areas on the skin at a given distance apart, is the same after any difference of potential between the electrodes *per se* have been taken into consideration. Such observations militate against the view that we are dealing with contact differences of potential.

We agree with the conclusions of Alvarez, Freelander and Clark that cleansing of the skin (as with water or alcohol) has little if any effect on the values of the potential differences obtained. It has been suggested that the presence or absence of perspiration would have an effect on the values of the potentials. In order to minimize such an effect, if present, we have applied the electrodes to the outer side of the forearm where the skin contains relatively few sweat glands. Waller believed that the emotive phenomena which he observed must be explained on a more comprehensive basis than that of sudomotor variation. It appears, therefore, that the condition of the surface of the skin where contacts are made with the electrodes is not of importance if the areas of contact are relatively small.

Readings on the difference of potential were made

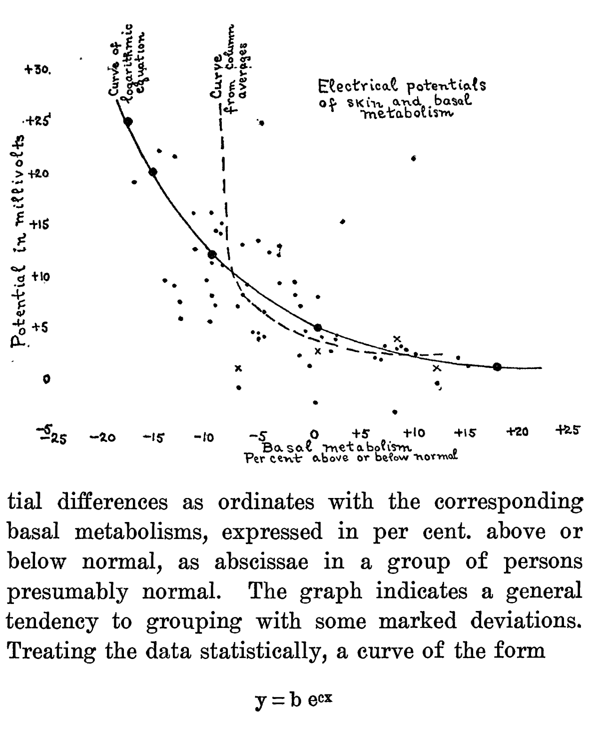
[7] Charles Sheard and A. Frances Johnson, "Potentiometric and Spectrophotometric Changes in Plants Produced by Infra-red and Ultra-violet Irradiation," *Proc. Soc. Expt. Biol. and Med.*, 26: 618–621, 1929.

[8] W. C. Alvarez, B. L. Freelander and L. B. Clark, "An Electrode for the Measurements of Skin Potentials," *Jour. Lab. and Clin. Med.*, 11: 83–85, 1925–26.

at various times during the period of rest of twenty minutes preceding the tests for the basal metabolism or again, in one group of subjects, during the metabolic tests. Basal metabolic rates were determined in certain groups with the Benedict-Roth closed circuit recording type of apparatus (measuring oxygen consumption) and in other groups by the open circuit gasometer followed by analyses of the expired air by the Haldane method. The Du Bois standards were used in our calculations.

The difference of potential between the electrodes applied to the skin ordinarily reached a fairly constant value after about ten minutes; if it did not, an average or a modal value was used. The true difference of potential then was obtained by subtracting the potential difference of the electrodes *per se* from the constant, average or modal value of the potential.

In Fig. 1 there are plotted the values of the poten-



tial differences as ordinates with the corresponding basal metabolisms, expressed in per cent. above or below normal, as abscissae in a group of persons presumably normal. The graph indicates a general tendency to grouping with some marked deviations. Treating the data statistically, a curve of the form

$$y = b\,e^{cx}$$

fits the data very well. With the insertion of the proper constants this equation becomes

$$x = \frac{\log\ y - \log\ 0.005}{-0.0396}$$

where x is the basal metabolism and y is the difference of electrical potential of the skin. The data of Fig. 1 show that higher basal metabolic rates are accompanied by lower differences of potential and *vice versa.*

Recently we have used the formula given in the preceding paragraph in an attempt to predict the basal metabolism. In a group of clinical subjects (some of whom had thyrogenous dysfunction) the predicted and observed values agreed within a range of ± 4 points in the metabolic rate expressed in percentage above or below normal in 62 per cent. of the individuals examined. The predicted basal metabolic rate agreed with the rate determined by test in nearly all cases (six exceptions) falling within the range of + 13 per cent. to − 10 per cent. Practically all the observed values which were not in agreement with predicted values fell either above + 13 per cent. or below − 10 per cent. The data as a whole, therefore, are divisible into three portions: (1) those showing a correlation between electrical differences of potential in the skin and basal metabolic rates such as are exhibited by normal individuals; (2) those above the normals, and (3) those below the normals.

It is known that individuals who have hypofunctioning thyroid glands manifest retardation in the rates of basal metabolism and circulation of the blood, whereas those who have excessive functioning of these glands show an increase in basal metabolic rates and in the circulation of the blood. We have carried out some experiments in which the circulation of the blood in the lower portion of the arm has been retarded or cut off by pressure and have observed marked increases of the differences of potential as compared to the values obtained under conditions of circulation of the blood ordinarily existing. Such observations indicate that there may not be a correlation of normal basal metabolic rates and differences of electrical potential of the skin if there are marked impairments of physiological functions, such as retarded (or accelerated) circulation, in the region in which the readings are made on the differences of potential. Since high and low basal metabolic rates (that is, outside the range of normal basal metabolism, + 10 per cent. to − 10 per cent.) are associated, respectively, in general, with a retarded or increased rate of circulation of the blood, it is entirely possible that the correlation lies between differences of electrical potential of the regions of the skin under test and circulatory conditions of the blood rather than between such potential differences and the basal metabolic rates *per se*. In normal, healthy individuals, however, with normal circulation of blood and normal physiological functioning of the skin there is a definite correlation between basal metabolism and differences of electrical potential.

The results of investigations now in progress regarding the electrical gradients in the skin and basal metabolism in various pathologic conditions as well as data concerning the general relationships existing between metabolic rates, skin temperatures, blood pressures, differences of electrical potential and so forth, under controlled environmental conditions, will be published elsewhere in medical literature.

CHARLOTTE PURDY
A. FRANCES JOHNSON
CHARLES SHEARD
DIVISION OF PHYSICS AND BIOPHYSICAL RESEARCH,
THE MAYO FOUNDATION

STUDIES IN CERTAIN FACTORS AFFECTING THE RESISTANCE OF PLANTS TO INSECT PESTS

As far as the writer is aware, only two scientific papers have been written on the general subject of resistance of plants to insect pests. The first of these was published by McColloch[1] in Kansas in 1924, and the second by Lees[2] in England in November, 1926. An interesting but popular account of the problem was given by Treherne in 1917.[3] It has also been ably discussed in Wardle and Buckle's "Principles of Insect Control"[4] and in certain other text-books. Lists of references to observations on the resistance of plants to insect pests[5] are to be found in the published work of Mumford, Wardle and Buckle, McColloch, and Lees.

Resistance to insect pests may be due either (1) to some external protective agency, such as thickened epidermis or cuticle, the development of hairs, etc.; (2) to some condition of the cell-sap which repels the insects, such as the presence of certain oils, alkalis, organic acids, etc., or (3) though not actually unattractive or repellent, the sap may be unsuited to the insects' food requirements. The word "resistance" is also used in another sense—to denote the plant's ability to survive or "pull through" severe insect attack. In this case, though the insects still attack the plant, the damage is not apparent. Vigorous, healthy plants are said to "outgrow" the checking influence of attacks more readily than weaker, ill-nourished plants.

The problem of resistance is so complicated that the use of a special nomenclature seems advisable. The writer has proposed[6] the term *epiphylaxis* for external protective agencies, and *endophylaxis* for the internal protection afforded by biochemical qualities that render the plant unattractive or repellent or unsuited to the food requirements of insects. The importance of the water-balance as a factor in the resistance of plants to insect pests has recently been discussed by Mumford and Hey (1930).[7]

Examples of epiphylaxis.—An example of epiphylaxis is to be found in the protection afforded by the thick skin in certain varieties of *Citrus*. In Florida, it is the thin-skinned varieties of *Citrus* that suffer most from the attacks of such plant-bugs as *Nezara viridula* Linn. The thin-skinned tangerines, *Citrus nobilis* var. *deliciosa* and Satsumas, *C. nobilis* var. *unshiu* are the first choice of these bugs; oranges, *C. sinensis,* come second; grape-fruit, *C. grandis,* is but rarely attacked.

Further examples of epiphylaxis are found in the leaves, stems and bracts of the American Upland cotton, *Gossypium hirsutum* L., which are covered with short hairs that protect the growing plant. Sea Island cotton, *G. barbadense* L., and Egyptian cotton, *G. peruvianum,* possess no such protective covering. In South Africa, American Upland cotton has been found capable of resisting the ravages of the Jassid, *Empoasca facialis* Jacobi, whereas Sea Island and Egyptian cottons were the first to be attacked. Lloyd Worrall[8] also found a great difference in the protective character of the various Upland varieties, some having only a few scattered hairs whilst others were hirsute. Even within a given variety, certain strains possessed more protective characters than the average plant typical of that variety. When individual plants were seen to remain resistant when neighboring plants were badly attacked, in every instance these individuals were found to be covered with dense hairs on leaf, stem and bracts. Hairy types of cotton are not totally immune from injury due to Jassid attack, but in large measure they resist the insect to such a degree that the plant is enabled to mature its bolls before it is seriously injured.

Other plants possess similar agencies capable of

1 J. W. McColloch, "The Resistance of Plants to Insect Injury," *Biennial Report of Kansas State Hortic. Soc.*, Vol. 37: pp. 196–208, Topeka, Kansas, 1924.

2 A. H. Lees, "Insect Attack and the Internal Condition of the Plant," *Ann. App. Biol.*, Vol. 13, No. 4, pp. 506–515, Cambridge Univ. Press, 1926.

3 R. C. Treherne, "The Natural Immunity or Resistance of Plants to Insect Attack," *Agric. Gaz., Canada,* Vol. 4, No. 10, pp. 855–859, Ottawa, 1917.

4 R. A. Wardle and P. Buckle, "The Principles of Insect Control," Chapter 1, "Host Resistance," pp. 1–16, Manchester, 1923.

5 The breeding of plants to resist either disease or insect attack has not been discussed in this paper, but is of the utmost importance. See McColloch, Wardle and Buckle, *loc. cit.*, and Babcock and Clausen, "Genetics in Relation to Agriculture," pp. 444–463, New York, 1927.

6 "Cotton Stainers and Certain Other Sap-feeding Insect Pests of the Cotton Plant. A Preliminary Inquiry into the Effect of Climatic and Soil Conditions upon the Incidence of these Pests." 8vo, 79 pp., 14 pp. refs., London, Empire Cotton Growing Corporation, January, 1926, *Rev. App. Entom.*, Vol. 14, Ser. A., pp. 461–462, London, 1926.

7 E. P. Mumford and D. H. Hey, "The Water-Balance of Plants as a Factor in their Resistance to Insect Pests," *Nature*, Vol. 125, No. 3150, pp. 411–412, March, 1930.

8 L. Worrall, "Jassid-resistant Cottons," *Jl. Union S. Africa Dept. Agric.*, Pretoria, Vol. 7, No. 3, pp. 225–228, September, 1923; Vol. 10, No. 6, pp., 487–491, June, 1925.