EVIDENCE FOR CHARGE DENSITY PULSES ASSOCIATED WITH BIOELECTRIC FIELDS IN LIVING ORGANISMS

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ABSTRACT

Empirical evidence is presented for oscillating, non-ohmic conductivity mechanisms induced in metals by living systems functioning at normal physiological temperatures. When human hands or living plant materials are placed in contact with metallic, charge collector electrodes arranged in a capacitative type monitoring system, oscillatory electrical currents consisting of what are defined here as Charge Density Pulse (CDP) waves with amplitudes in the 0.1 to 10 microamp range, are continuously generated during 30 sec. to one minute test intervals and exhibit well defined polarity orientations. Through the application of perturbation kinetics evidence was obtained to suggest that CDP responses are associated with charge carrier transport across cell membranes. Envelopes of the dissipative CDP traces followed a log-time relationship with a negative slope. The persistence of CDP oscillations suggested metastable systems in which organized electrical pulses propagate as soliton waves. In the case of human hand experiments these solitons may facilitate local electroporation processes in the epidermis. Interposed, dielectric films completely blocked the CDP response, whereas magnetic fields significantly altered its wave form. Aluminum and copper inserts between hand and electrode produced systematic changes in patterns of conductivity with characteristics somewhat analogous to Josephson junction systems. All aspects of this study are compatible with recently published theoretical papers proposing ideas relative to superconducting type mechanisms in living systems.

KEYWORDS: Charge density pulses; bioelectric fields; magnetic fields; non-ohmic conductivity.

INTRODUCTION

In 1939, Burr and Northrup presented a paper in the Proceedings of the National Academy of Sciences, which offered strong evidence that all living organisms possess what was then termed "Electro-Dynamic Fields."[1] This research was based on the detection of local potential differences through surface-contact applications of silver-silver chloride electrodes immersed in a physiological salt solution. Although this type of system was often very tricky to use and the vacuum tube voltmeters were temperamental, it became the laboratory procedure applied in bioelectrochemical studies conducted over the next several decades. Using more recently developed electrode systems, Becker confirmed the earlier work and found complex patterns of electrical potentials which appeared to be related to the total nervous system.[2]

The Charge Density Pulse (CDP) method discussed here provides a simple means for monitoring changes in the bioelectric field associated with a specific tissue region. Furthermore, the CDP system is passive in nature, that is, there is no applied, external signal. Over a three year period of experimentation we have established that the CDP device provides direct information relating to spontaneous changes taking place in the bioelectric field of the test organism. In addition, this CDP system circumvents one of the major problems consistently addressed by investigators dealing with the application of electrodes to living tissue, namely, the formation of extraneous, localized oxidation-reduction mechanisms. In fact, small, capacitor type electrodes have been designed for internally stimulating neural and muscle tissue.[3]

By utilizing an electrical capacitance type of monitoring system in which the bioelectric field is concentrated within metal collector plates it is possible to examine the details of what we define as CDP waves generated between the palms of the hands, or, for that matter, in living plants. The polarized nature of the bioelectric fields, their specific influence on metals interposed in the system and a pronounced magnetic field effect, provide evidence for charge density pulse interactions between metals and living tissue. Liboff has pointed out that "A good case can be made for connecting living things to the electromagnetic field."[4] Here we present empirical evidence for just such a connection.

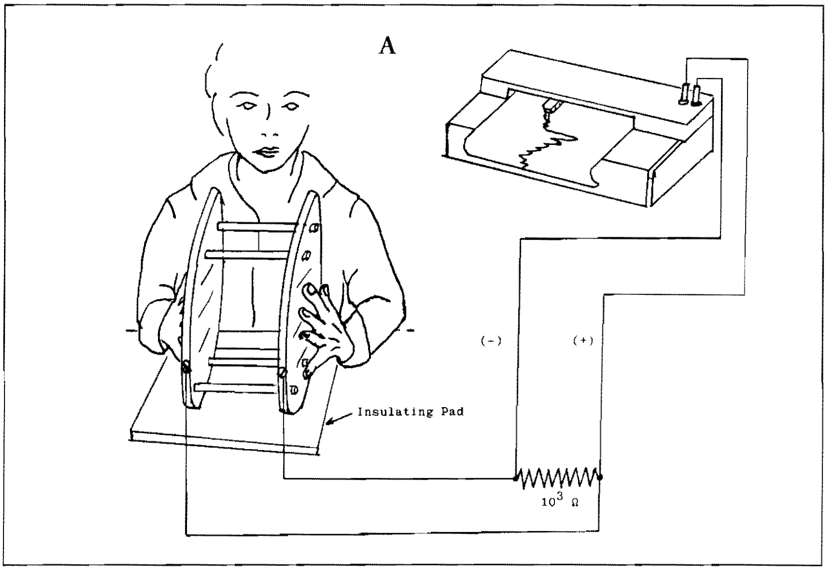

Figure 1A. Illustration of charge density pulse system depicting hand placement on the electrodes, with associated circuitry and laboratory recorder.

MATERIALS AND METHODS

The CDP response traces were generated by placing the palms of the hands on the outside surface of vertically positioned aluminum plates, with (as depicted in Figure 1A) the test subject sitting comfortably in front of the apparatus. These circular, semi-polished, charge collector plates are 31 cm diameter, about 0.6 cm. thick and separated by four nylon spacers which provide an 8 cm air gap. Any voltage fluctuations were detected by placing a 1.0 K ohm resistor across the plates (connectors at edges of plates extended into the metal). As shown in Figure 1A, additional leads on each side of the resistor extend to the input of a mv chart recorder with a maximum full range sensitivity of 1.0 mv (frequency response about 2 Hz). With most test subjects the sensitivity was set at 10 mv full scale. From ohm's law it can be seen that the chart recorder scale gives a direct measure of the current flow I in microamps, that is, a 1.0 mv change across the resistor is equivalent to a 1.0 microamp current flow through the system.

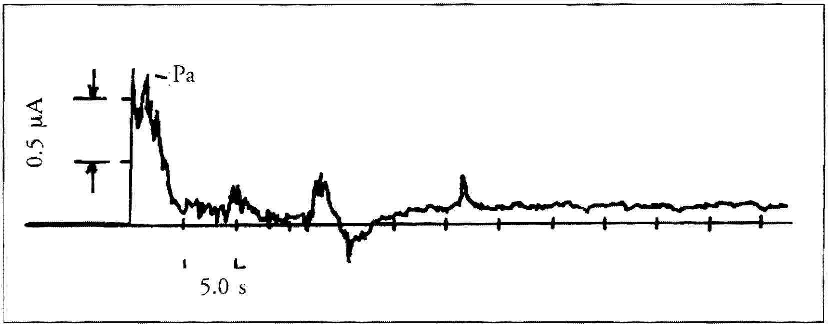

Figure 1B. Typical chart recorder trace with the peak amplitude (P_a) indicated.

A typical CDP hand trace is shown in Figure 1B for a one minute test interval. These chart data were analyzed by recording the peak amplitude at the point on the curve where the current began to drop back to the baseline level. This inflection point (designated as P_a) occurs well after any initial contact potential changes, usually around 5-10 seconds into the trace. The value of P_a as given in this paper is in microamps. The maximum current density, I (microamps/cm^2) in the tissue contact region is given by,

$$I_d = P_a/a_t \tag{1}$$

where a_t is the area of tissue contact. In adult humans the hand contact area is in the range of 90-110 cm^2; in plant stems the contact area is in the range of 0.3 to 0.8 cm^2.

This peak amplitude analysis provided information from one time point on the 60 seconds response curve. The specific form of the oscillating pulses is currently being analyzed both macroscopically and microscopically by using data from an analog-digital converter system.

Testing for Artifacts in the Experimental System

Before discussing specific details of the CDP wave patterns, we summarize results from tests designed to examine the issue of possible "artifacts" in the circuitry or local environment, as being causative agents producing the dissipative pulse patterns. With the system operational the check conditions and resulting responses were as follows:

1. *System Stability* (*no contact with living systems*)—recordings taken continuously for periods exceeding 12 hrs.—no pulses observed (flat trace).

2. *Surface Zeta Potentials* (*no contact with living systems*)—direct short across either the inside or outside surfaces of the large plates. At contact a single, very low amplitude (<0.05 microamp) pulse of about 0.25 sec. duration—no dissipative pulses.

3. *Inductive Effect from Human Body* (*large plates removed from system*)—hand contact with opposite sides of 1.0 K resistor. At contact a single, very low amplitude (<0.05 microamp) pulse—no dissipative effect or current flow seen.

4. *Electrostatic Effects from Clothing*—the removal of all clothing had no significant effect on the CDP hand traces. Clothing material such as wool, cotton, rayon, etc. placed across plates—no pulses observed—flat traces.

5. *Interposed Dielectrics*—polyethylene film (20 micrometers thick) placed between the palms of the hands and the outer surface of the electrode plates. The CDP dissipative responses were completely blocked (flat line trace)—same result obtained by placing latex, surgical gloves on either or both hands.

6. *Reduction in Hand-Electrode Contact*—circular openings in the polyethylene sheets (2.5 cm dia.). CDP traces were identical in form, with P_a, reductions roughly proportional to the reduction in area.

7. *Charge Distribution*—with the *inside* surface of each electrode completely covered with the polyethylene the P_a values were essentially unchanged, indicating that the CDP pulses organize and are distributed within the metal matrix of the charge collector plates.

8. *Repetition of Dissipative Patterns*—within a data base consisting of over 5000 hand contact CDP traces we have never observed the absence of the dissipative oscillations or a trace in which the small amplitude pulses disappear and the trace "flat lines" along the zero base line.

9. *Hand Contact Pressure*—with the hands placed firmly on the aluminum plates minor variations in hand pressure or muscle twitches in the fingers,

if detected, were observed as very minor spikes (<0.06 microamp) in the dissipative curve.

RESULTS

One important aspect related to the biophysics of the hand traces, is the presence of large fluctuations or pulses of charge transfer through the plates (a situation not explained by artifacts). The temporally decreasing amplitudes of these pulses suggests a dissipative system, with fine structure oscillations persisting throughout the one minute test intervals. The initial circuitry was arbitrarily organized so that the left palm contacted the designated cathode plate and the right palm the anode plate. This generally produced CDP curves which after 10 to 15 seconds diminished to much lower amplitudes and approached the zero or base level (as in Figure 1B). If however the palm positions or lead wires were reversed, the CDP curve had essentially the same shape, but it peaked in the opposite direction relative to the base level, in other words the chart trace formed an approximate "mirror image." This gave us our first solid clue that we were detecting biofield polarity differences between the palms of the hands. In the majority of cases the distribution of charges on the surface of the hand is primarily cathodic on the left and anodic on the right. Under certain conditions to be discussed later the polarity may change. This hand polarity effect has been consistently observed in all test subjects examined at the Pinelandia Laboratory (40-50 individuals, both adults and children); however the amplitudes of the pulses and their fine structure varied considerably between test subjects.

CHARACTERISTICS OF DISSIPATIVE CURVES

After reaching the peak amplitude P_a, the envelope of a CDP curve decreases non-linearly toward the base line of the trace. From analysis of this dissipative phase of the hand traces, we observed a log-time relationship, a typical example of which is shown in the Figure 2 regression curve (r = 0.98). The general form of which is given by,

$$I = -a_1 \, [\ln(t)] + a_2 \qquad (2)$$

where I is the current level at t seconds into the trace, a_1 and a_2 are constants. This relationship is suggestive of an unstable system in which the current density exhibits a systematic decrease with time. Here, we will let the rate of charge carrier dissipation at the electrodes be a function of P_a, t and u, as follows,

$$-dI/dt = f(P_a, t, u) \tag{3}$$

where P_a is the maximum charge carrier concentration at the inflection point in the CDP trace, and u their ionic mobility. As a first approximation the current will be taken as inversely proportional to time, since the level of charge carriers decrease after the initial P_a level. From this we set up the rate function,

$$dI/dt = -(P_a\ u)\ (1/t) \tag{4}$$

and

$$\int dI = -(P_a\ u) \int (1/t)\ dt \tag{5}$$

which after integrating gives,

$$I = -(P_a\ u)\ (\ln t) + k \tag{6}$$

Since P_a and u are taken as constants for any given trace, this rate function is identical in form with equation (2), obtained from empirical data such as shown in Figure 2.

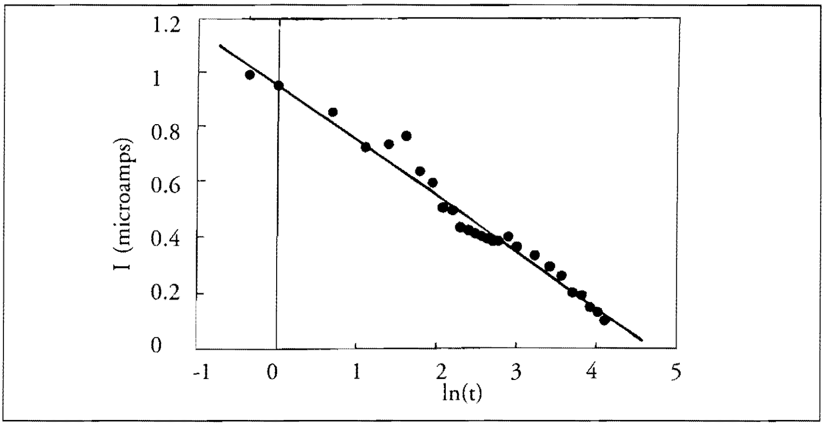

Figure 2. *Relationship between current level I, and ln-time (seconds); data taken from a typical CDP trace, r = 0.98 for linear regression curve.*

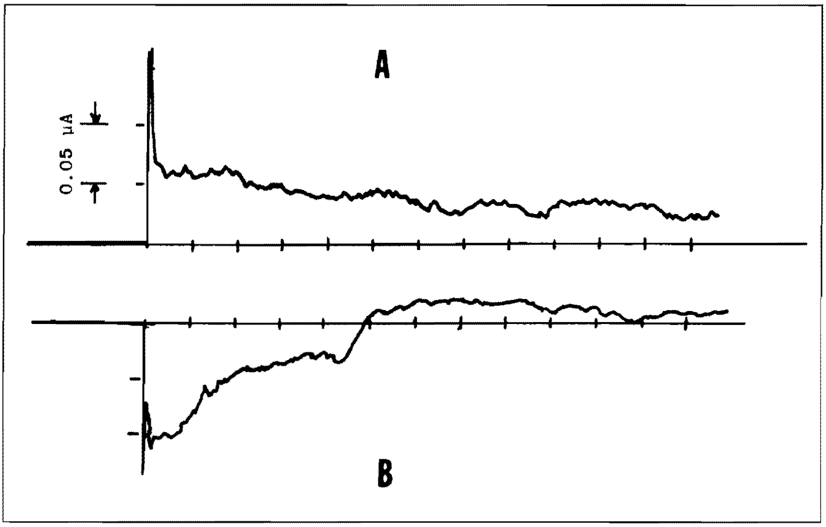

Figure 3. Polarity effect in CDP responses from a living plant (Impatiens spp.) stem about 30 cm long and 2 cm diameter. A) basipetal (bottom) end of stem on outer surfce of cathode plate, acropetal (top) on anode. B) basipetal anode, acropetal cathode.

This same type of dissipative function is characteristic of traces taken from living plant material. The CDP traces in Figure 3 were obtained from a freshly excised, red flowered, *Impatiens* spp. stem about 30 cm long and <1 cm diameter, placed across the outside surfaces of the large aluminum collector plates. In the A trace the basipetal (bottom)end of the stem was positioned on the cathode and in the B trace on the anode. As in the hand traces, a distinct polarity effect was consistently observed in living stem sections as well as in intact, living plants. At the present time the plant tissue studies include *Pelargonium maculatum, Impatiens spp., Begonia spp., Glycine max* and *Zea mays.*

ORIGIN OF CDP PULSES

With the discovery of the apparently ubiquitous nature of these CDP patterns, we are faced with the question of how and where the pulses originate within the living system. Conceptually, the location within the tissue at which these pulses form may be examined through the utilization of perturbation kinetics, which is most easily carried out in plant material. We examined the influence of known quantities of microwave energy on the CDP pulses originating in 5 cm long stem sections from living *Impatiens* plants. In these tests the large collector plates were replaced with aluminum probe electrodes (12 cm long and 0.64 cm diameter) with flat, semi-polished, tissue contacting ends. These probes were horizontally mounted on a lab bench covered with a polyethylene film (see Item 5 in Materials and Methods). The ends of the freshly excised sections were placed with the basipetal (bottom) end contacting the cathode and the acropetal (top) end the anode. With this orientation the mean, base line P_a level was determined from non-exposed sections (N = 8) to be 0.40 ± 0.08 microamps. During exposure the stem sections were placed horizontally in a microwave oven which was determined calorimetrically to have an energy output of 0.107 J cm^2 S^{-1}. After exposure each sample was allowed to reach room temperature before taking the CDP pattern.

With increasing microwave exposure the P_a levels increased significantly. Although microwave radiation is non-ionizing the thermal energy disrupts tissue and decreases cell membrane integrity; however, the damage takes place in very localized regions within the tissues.

Thus, we can examine the possibility that the observed increase in P_a levels with exposure time, is the result of cell membrane damage. If this damage is represented by a random target model then in a population of microwave exposed cells the P_a alterations can be examined with the Gompertz Function utilized in Radiation Biophysics to describe the relationship between cell damage and exposure time.[5] As applied here this function is given as

$$\ln(P_a) = k(t) + b \tag{7}$$

where t is the exposure time (seconds), k the rate constant and b the intercept constant.

The P_a levels obtained from microwave exposed stem sections are plotted in Figure 4 according to equation (7). The high degree of correlation (r = 0.96) clearly suggests that the damage is occurring at the cellular level. Thus with

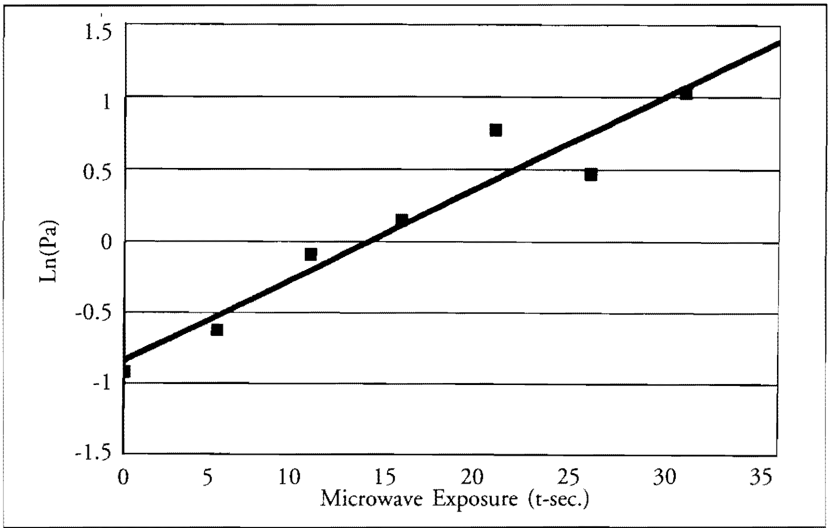

Figure 4. Relationship between P_a levels and microwave exposure in Impatiens plant stem (data plotted according to Gompertz Function—see text).

increasing microwave exposure a cell membrane porosity increase allows higher amplitude, oscillatory CDP structures to be transmitted through the tissue. Here we see clear evidence that cell membrane porosity is an important factor controlling the dissipative phase of the CDP traces.

Indicated Electroporation in the Epidermal Layers

A vital constituent of any process in which oscillations occur is that of feedback. Some intermediate products of the reaction must be able to influence the rate of earlier steps. This may be a positive, catalytic mechanism where the feedback species enhances the oscillation process, or an inhibition through which the oscillations are reduced. In our human studies the driving force generating the CDP oscillations is the potential developed between the palms of the hands and the electrode surfaces. Considering the dielectric, semi-insulating properties of the outer skin layers, we found it surprising that the CDP oscillations in the hand traces were in the same range of amplitudes and frequencies as obtained in the living plant systems where by comparison, internal, hydrated tissue was in direct contact with the electrodes.

Although the stratum corneum presents a barrier for charge carrier transport through the skin, it has been shown that very rapid increases in charge transport can be created in human skin (excised from cadavers) through application of "high voltage" pulses (around 200 V across skin samples about 50 micrometers thick).[6] These results were interpreted as being due to the electrical creation of ionophoretic pathways through the tissue by means of electroporation. Furthermore, this work presents a model which lends support to a hypothesis that in living tissue the spontaneous formation of voltage pulses such as those observed in the CDP oscillations could generate ionophoretic pathways for charge transport across the stratum corneum.

From the fine structure in the CDP traces it becomes clear that the low amplitude pulses form and disappear on a time scale of fractions of a second, whereas the peak amplitude (P_a in Figure 1B) forms within 2-10 sec. after the initial hand contact, that is, the concentration of CDP pathways reach a maximum at P_a, then decline in a dissipative manner according to the equation (2) function.

If these pathways form through electroporation mechanisms then one might obtain some idea of the transport properties by examining the effect of reaction product formation at the pore sites. That is, with rapidly repeated hand traces can one detect a change in the P_a level due to feedback inhibition resulting from the buildup of reaction products in CDP generated pores in the epidermal tissue? The results in Figure 5 are from a 60-minute test during which the CDP traces were repeated at 2 minute intervals. At the onset of this test (0 to 15 minute interval) the rapidly changing P_a levels are characteristic of spatial-temporal, self-organized reactions far from equilibrium and taking place at solid surfaces.[7] At around 16 minutes into the test the P_a values become negative and continue with this polarity reversal until the end of the test period; a clear indication of the buildup of reaction products forming a local reservoir of charge carriers with opposite sign to those originally present. This reaction product buildup seems to have a short refractory period. If the between test interval is increased from 2 to 5 minutes or more the rapid decline in P_a (as in Figure 5) does not take place.

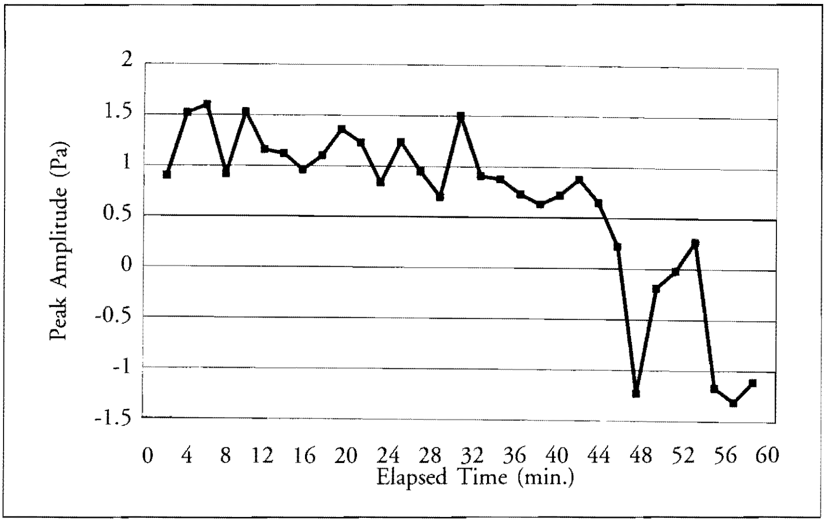

Figure 5. *Variations in peak amplitude (P_a) in CDP traces taken at two minute intervals during a one hour test period.*

MECHANICALLY ABRADED EPIDERMIS

Since the palms of the hands are in direct contact with the electrode plates the influence of minor cuts, abrasions and surface roughness comes into question. To examine this aspect the palms of the hands were mechanically abraded by applying a hand held grinding tool equipped with a rotating, carborundurn sphere 1.3 cm diameter (Norton 38A90 OV). This tool was applied until the electrode contacting palm area was abraded to the point of creating frictional heating and redness of the skin.

In Figure 6 are CDP traces taken before and at different times after the abrasive treatment. The apparent increase in the P_a levels in the (b) and (c) curves can be attributed to a transient thermal expansion of the pores in the stratum corneum, which resulted from frictional heating during the abrasion. This expansion effect is not seen in curve (d) taken 5 minutes after the treatment. Aside from this temporary heating effect there are no significant alterations in the polarity or form of the CDP traces which can be attributed to the skin abrasions.

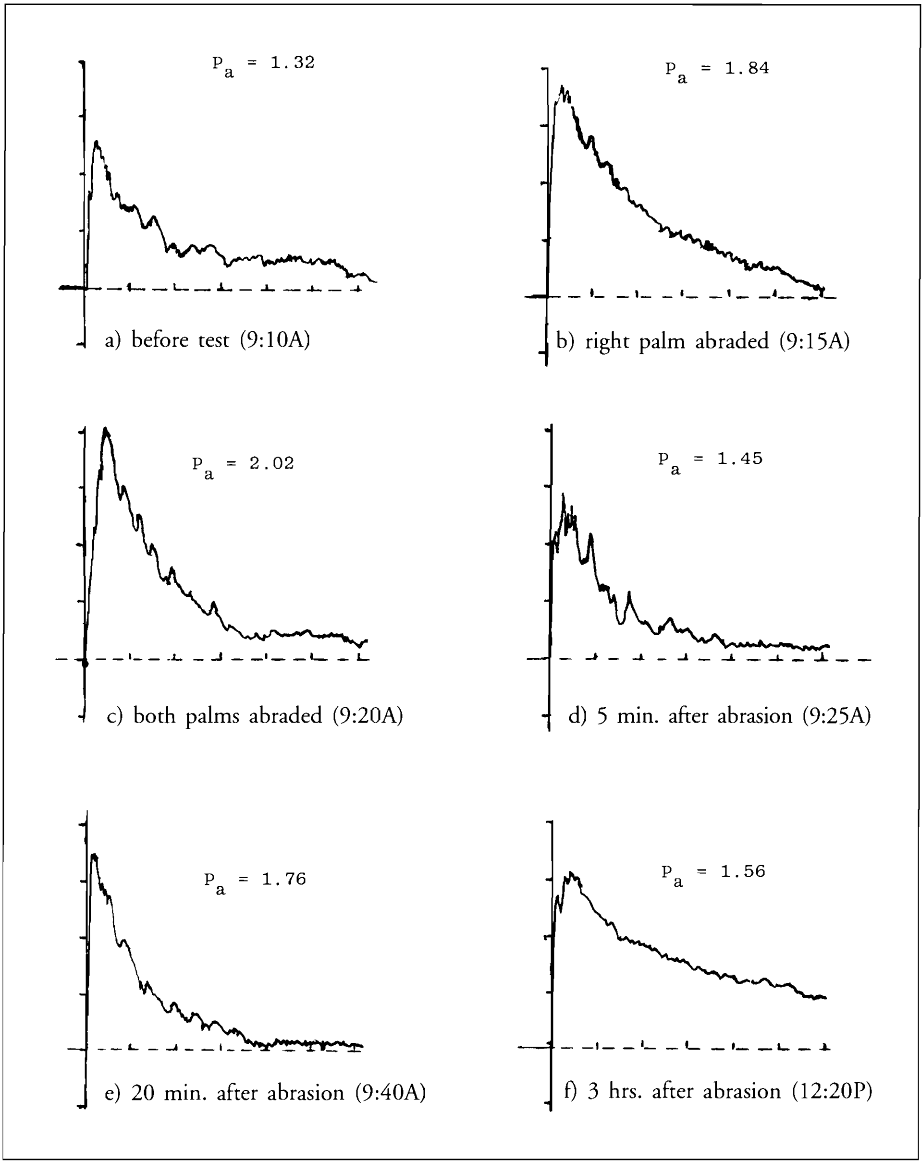

Figure 6. *Effect of skin abrasions on CDP traces taken in the palm of the hand. a) before test; b) and c) show slight increases in* P_a *due to thermal expansion from frictional heating; d), e) and f) curves at various times after abrasion—no significant alterations in the form of the dissipative curves.*

Evidence of Non-ohmic Charge Carrier Transport

If charge carrier transport involved in the CDP traces takes place through simple electronic conduction one would expect the current I to follow the well known ohmic principles of electrical conductivity. To obtain a clear understanding of the hand-electrode conductivity mechanisms the following simple experiment was performed. Small samples of aluminum metal with quite diverse cross-sectional areas and shapes, were interposed between the palm of the hand and the electrode plate. CDP traces were taken with each interposed metal sample placed between the L-palm and the cathode and the R-palm and the anode. The rather astounding results from these metal "insert" tests are shown in Figure 7 where the P_a values are charted (non-linear abscissa) as a function of the cross sectional area of the interposed test metal.

From the classical view of electronic conduction in metals the level of the P_a current should be directly related to the area-length ratio (A/L) for each inserted

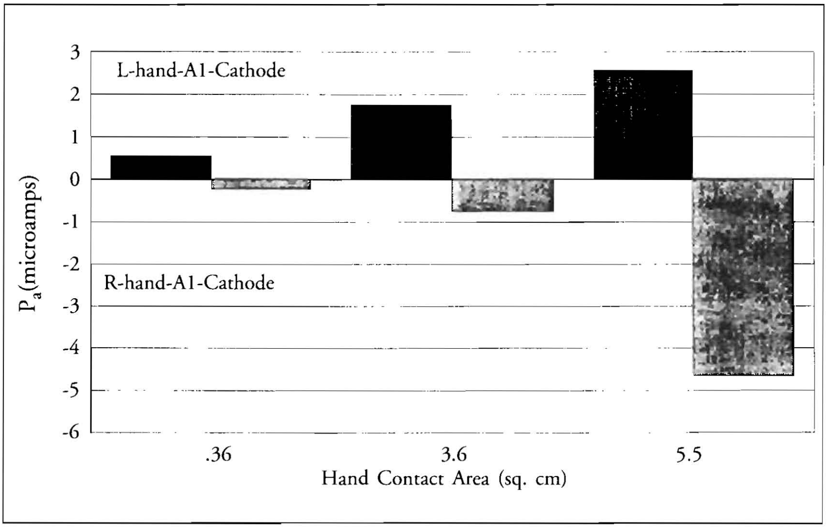

Figure 7. Effect of placing an aluminum metal insert between one hand and the electrode (as indicated on the bar chart). The P_a levels indicate the response in three inserts with widely different hand contact areas (abscissa nonlinear scale). Impedance variations caused by the area/length ratio of the insert metal, cannot account for the left/right differences shown here (see text).

test object, that is, major impedance differences would depend on the contact area between the hand and metal insert and the length of the insert element. Obviously the data in Figure 7 deviate considerably from simple ohmic conductivity principles, that is, the P_a values from the L-palm—cathode contact are, when examined with regression analysis, directly related to the cross sectional areas (A) of the interposed metal and appear to be independent of conductivity path length (L). This path length independence is highly suggestive of charge carrier transport taking place within a metal lattice in which soliton wave formation occurs with only slight loss of energy.

Furthermore, from classical ohmic conductivity one would assume that the interposed metal objects are acting as simple conductivity elements between the palm of the hand and the electrode plate. Therefore, switching the metal test objects to R-palm-anode contacts should have little influence on the area-P_a relationship. This, however, as shown in the lower bar chart in Figure 7, is far from being the case. Here we observe three additional aspects of the CDP waveforms; 1) a complete reversal in polarity, 2) a complex nonlinear relationship with hand contact area, and 3) charge carrier amplification.

In $Al_2 0_3$ the energy gap for electron conduction is given as 8.3 eV, whereas in$CU_2 0$ it is 2.2 eV.[8] From this one would predict that charge density amplification in copper, applied as an insert metal, would greatly exceed the levels found in the aluminum interlayer. For the purpose of comparison, two copper elements were individually inserted in the hand trace system and in the same manner as the aluminum insertions. Both copper inserts were prepared from commercial material; one a copper tube 2.5 cm diameter and 2.5 cm. length and a solid cylinder of about the same length and diameter. Listed in Table I are comparisons between the P_a levels in the two copper inserts and those expected from aluminum inserts with the same hand contact areas (values extrapolated from Figure 7 data).

With the copper inserts the P_a currents are increased from 3 to over 30 times the P_a levels found with the aluminum inserts. These data suggest that the biofield potentials are inducing unusual, electrical conduction mechanisms in the metals, with the current levels being related to the energy band structure of the metal and accompanying oxide layers. Fundamentally this experimental arrangement may be thought of as a crude type of Josephson junction, where the conducting elements (hand-metal-electrode) are placed in proximity and

Table I
Comparison of P_a values from CDP-hand traces produced with metal inserts between the palm and electrode plate. The P_a values for aluminum are linear extrapolations from Figure 7 data, at hand contact areas corresponding with the same contact areas as used in the copper tube and copper cylinder inserts.

Electrode Conditions	Metal-Contact Area cm^2	Metal Insert (P_a microamp) Copper	Al (from Fig. 7)
L-palm Metal Cathode	0.95	-5.0 (tube)	+0.8
	2.84	-4.5 (cyl.)	+1.5
R-palm Metal Anode	0.95	+6.2 (tube)	-0.2
	2.84	+7.0 (cyl.)	-0.5

each separated by a thin, non-conducting film (oxide layer).[9] The conduction of charge carriers across interfaces between the metal-oxide layers in a Josephson junction deviates significantly from simple ohmic conductivity.

Effect of Magnetic Fields

A notable characteristic of complex charge carrier processes in metal-oxide systems is a pronounced sensitivity to magnetic fields. Under conditions of relatively low level magnetic fields the electron tunneling currents are spatially modified by the H-field. If there are charge carrier mechanisms in the metal insert tests which have characteristics somewhat analogous to those in superconducting type materials, then a low level magnetic field would be expected to modify the CDP response patterns.

In experiments designed to determine the influence of magnetic fields on the CDP wave patterns the H-field was "directed" between the parallel plate electrodes by means of a magnetic probe coil.[10] A core rod composed of metal with low remnant magnetization was positioned as shown in Figure 8 with its pole face located at the midpoint between the electrodes and extending 15 cm

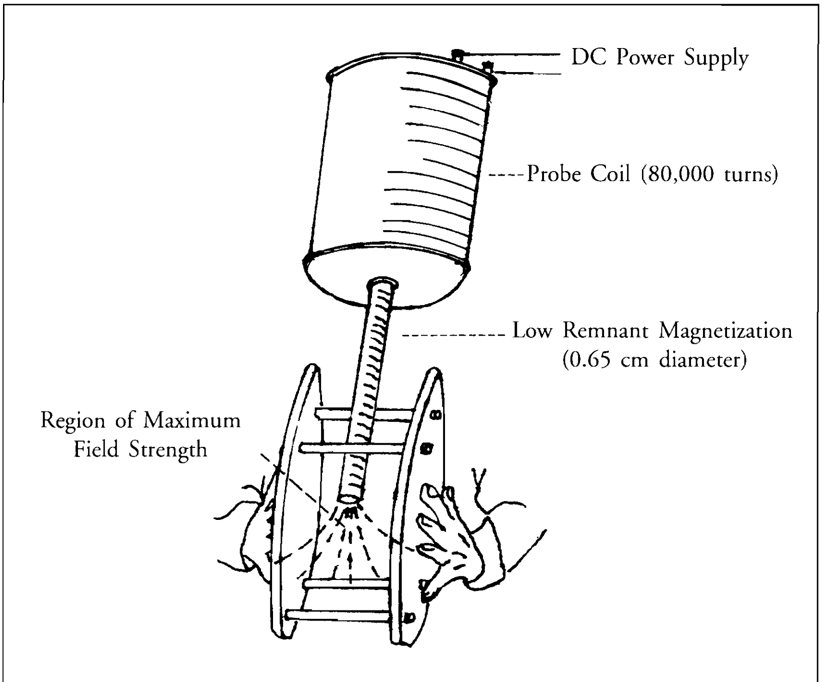

Figure 8. Location of magnetic probe coil relative to charge carrier plates (1.0 mA increase in probe coil equivalent to about 12 gauss increase at probe face).

radially into the electrode gap region. The generated magnetic field is expressed here as the DC current directed through the probe coil with each mA increase in current being roughly equivalent to a 12 Gauss increase in field strength at the pole face.

Hand traces were recorded at 5 minute intervals, starting with zero probe coil current and continuing to 15 mA (or around 180 Gauss) in 0.5 mA steps. Each series of P_a data were obtained over the same diurnal interval (9:00 a.m. to 11: 30 a.m. local time); two series with the applied H-field and two control sets (no H-field). The control designated as Pa(C1) was the second of three tests conducted over a 72 hour period during which the P_a(H)-S pole and the P_a(H)-N pole were examined. Control P_a(C2) was obtained seven days after this initial three day test period.

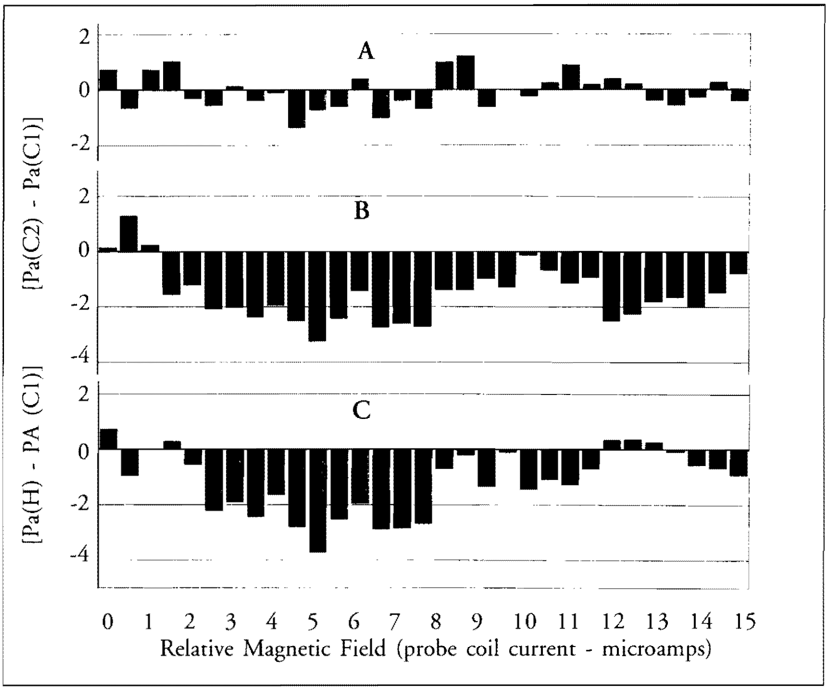

Figure 9. Influence of a magnetic field inserted between the electrode plates. Hand traces taken at 5 minute intervals in steps of 0. 5 mA probe coil current (approximately 6 Gauss steps). Each test series was conducted over the same diurnal interval. The data are presented as current amplitude (P_a) differences between each test and a control $P_a(C1)$ taken at the same time of day. A) differences between two control tests taken a week apart (no magnetic field). B) differences between $P_a(H)$-N pole and $P_a(C1)$ control. C) differences between $P_a(H)$ - S pole and the $P_a(C\ 1)$ control. The pair-wise comparison of each control with the H-field tests gave $P < 0.000\ 1$ (2-tail) in all four combinations.

The data in Figure 9 are presented as current amplitude or P_a differences between test series and the initial $P_a(C1)$ control. Bar chart A presents differences between the two controls, chart B the difference between $P_a(H)$ - N pole and Pa(C1), and chart C differences between $P_a(H)$ - S pole and the P (C1) control. In the B and C charts there is a clear indication of a magnetic field effect on the CDP waves, notably, in the 1-10 mA (12-120 Gauss) region where the envelopes of the bar charts are clearly suggestive of a periodic wave function. A statistical analysis of the possible pair-wise comparisons of these four data sets was made by using the Wilcoxon matched-pairs signed ranks test.[11] Comparison of the two controls $P_a(C1)$ and $P_a(C2)$ showed that they did not differ significantly from each other. The pair-wise comparison of each of these controls with the $P_a(H)$ N-pole and Pa(H) S-pole gave highly significant differences with $P < 0.0001$ (2-tail) in all four paired combinations. A comparison of the N-pole with the S-pole data gave a significant difference at the $P < 0.05$ level (2-tail) and this lower level of significance may reflect what appears to be another wave period in the 10-15 mA region of chart B (N-pole) but is absent in chart C (S-pole).

DISCUSSION OF RESULTS

From the specific interactions of the CDP waveforms and from considerations of their organized, sustained oscillatory behavior it becomes apparent that the transport of the charge carriers from intracellular sites to the tissue extremity regions takes place with minimum loss of energy. The log-time dissipative function, equation (2) suggests a highly organized transport structure of the type observed in soliton wave formation within metastable systems in which organized electrical pulses are known to occur. It has been shown theoretically that at the cell membrane surface a mechanical signal can be transduced into an electromagnetic wave in a self-consistent manner.[12]

For charge transport to occur at the site of pulse formation, free charges must be inherently present and/or energy injected into the system from the local environment. Gutmann points out that with a potential difference of about 5 mv across a cell wall membrane of 5 mm thickness, the generated 10^4v/cm^{-1} field strength does not present a "serious problem for space charge limitation of current flow through biological systems."[13] Furthermore, in the presence of a transmembrane electric field the formation of solitons may take place on a cell membrane as an energy transductive step.

Under conditions of steady-state dissipative structures it has been demonstrated by Nicolis and Prigogine that cellular metabolism can generate sustained oscillations which as pointed by these authors "are far from exceptional in living cells."[14] Although the membrane sites at which the oscillatory electrochemical pulses originate are located deep within the biological tissue, they directly influence the external bioelectric field patterns. At the hand-metal contact region on the CDP electrodes only the form or collective composition of the charge transfer groups will change. Essentially no electrochemical reaction takes place in this capacitance type of situation. If this were not the case a current flow would have been observed under check condition-3 in Materials and Methods.

Thus we conclude that the charge density pulses formed when the hands are applied directly to the electrode plates may be of a quite different makeup than the CDP waves formed in the presence of the interposed metal inserts. In Figure 7, both the polarity change and the amplification effect may be due to quite different electron pairing states during the formation of the CDP waves. It has been suggested that charge transfer may result from the capture of electrons by moving solitons.[15] In the metal insert system the charge carriers may consist of one or an array of electron (e) interactions such as, [e-e], [e-phonon], [e-spin state] (spin density waves), coulombic interactions or positive hole migration. In these metal insert systems it is not possible at present to predict the type of charge density waves involved; however, the continuous current pulsing in the direct CDP hand traces appears to be a unique feature of non-ohmic metal-oxide systems. As pointed out by Gruner and Monceau, "Perhaps the most spectacular observation in the field is the detection of current oscillations in the nonlinear conductivity region."[16]

At first glance the concept of Josephson junction behavior in living tissue seemed rather far-fetched; however, a number of recent studies point out that it is possible to compare a Josephson junction with a living system. For example, the theoretical aspects of Josephson junction behavior in living cells has been discussed by Costato, Milani and Spinoglio, where they point out the high probability that charge carrier behavior can be transferred from one living cell to another, and in the process may carry information through the cell membrane along the backbone of the helical proteins.[17,18] In this same regard, Cope has discussed experimental evidence pointing to the fact that electron tunneling currents can develop between micro-regions of superconductivity in living cells at physiological temperatures.[19] The pronounced effect of magnetic fields on the form of the CDP traces suggests a direct interaction between the dissipation currents and the external magnetic field. The point we wish to emphasize here is the fact that the evidence suggests that these electron tunneling currents and other charge carrier mechanisms can be amplified and undergo polarity changes through contact with living tissue.

The main findings of the research reported in this paper can be more precisely expressed by saying that the objectively measurable phenomena associated with biofield-metal interactions of the kind described above can be usefully modeled with techniques and arguments drawn from the physics of non-ohmic conductivity mechanisms involving charge density waves, or—as we prefer to describe them in the present context—Charge Density Pulses. It was the consequential challenge of accounting for the objectively measurable phenomena that were in fact observed, that led step-by-step to a consideration of non-ohmic conductivity type mechanisms as being involved in the CDP, dissipative structures.

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