Diversity in Biomedical Engineering

- Acupuncture Issues
- Medical Expert Systems
- ECG Enhancement Algorithms
The Science of Acupuncture—
Theory and Practice

1. Introduction

Acupuncture is a therapeutic modality used in China as early as the late Stone Age. Throughout Chinese history, both acupuncture theory and practice have steadily evolved into an increasingly rich and complex system, eventually offering treatments for virtually every form of medical condition. Much of the history of the development of acupuncture therapies can be seen in the evolution of the needles themselves (Figs. 1 and 2), but the meridian system is of primary importance, and the conceptionalization of the system has changed very little in the last 2000 years. (Figs. 3 and 4)

Acupuncture has long been considered more important than herbal pharmacology. The earliest classical book on traditional Chinese medicine discusses acupuncture more than herbal pharmacology. These references include Huangdi’s Internal Classic (ca. 100 B.C.E.) and two other works that are pre-date it: the Moxibustion Classic with Eleven Poui-Hand Channels and the Moxibustion Classic with Eleven Ying-yang Channels, both of which were discovered during the Mawangdi tomb excavations in 1973. (1) There is even a traditional saying: “first you use the needle (acupuncture), then fire (moxibustion), and then herbs.”

Acupuncture did not enter modern Western consciousness until the 1970s, when China ended a period of isolation and resumed foreign political and cultural contacts. In 1972, the respective New York Times columnist James Reston underwent an emergency appendectomy while in China. He later wrote about acupuncture treatment for post-operative pain, which was very successful. This report attracted attention and many American physicians and researchers went to China to observe and learn acupuncture techniques.

It appeared as though acupuncture was used to treat everything in China, but the number of accepted acupuncture applications has grown very slowly in the West. The first use of pain acceptance was in analgesia, which is still where its effectiveness is best documented. (2) Acupuncture research has since become a very broad active area both in Asia and the West. Research at the Shanghai Institute has demonstrated acupuncture’s effect on various biological systems, including the digestive tract, cardiovascular system (helpful in hypertensive status), immune system (phagocytosis), and the waducine system (the secretion of ACTH, oxytocin, vasopressin, neuropeptides, and endorphins) (3). A recent issue of the bilingual, Chinese journal Acupuncture Research includes successful studies of acupuncture treatment for hemiparesis, facial paralysis, cervical spondylosis, human epicondylitis, herpes zoster, and lumbago (4). Current research in North America and Europe includes urine contractions (5), pulmonary disease (6), addiction, mental disorders, and as an adjunct to AIDS treatment (7).

The primary reason for the slow acceptance of acupuncture is the lingering suspicion that it is a pseudoscientific and magical therapy that cannot be explained. This has not been true since 1975 when it became obvious that acupuncture could have a physiological and neurological basis, possibly involving ‘long’ reflexes to distant parts of the body.

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1. Diagram dating from 1081 AD of the standard needle type used in acupuncture for approximately the preceding 2000 years. From left to right, they are an arrowhead needle for prickling the skin to drain heat, a round needle for superficial massage, a pressure needle for pressing against a meridian, a sharp needle for blood letting, a sword needle for draining pus, a round sharp needle for eliminating acute obstructions, a filiform needle for strengthening normal qi, a long needle for deep-seated obstructions, and a large needle for arthritis with effusion (18).
which implicates a distribution by specific spinal segments or nerves; and are partially via unknown connections" [8]. This hypothesis could explain remyelination, but as the generation suggests, it is a very incomplete explanation. Neurochemical theories center on the release of neurotransmitters triggered by the pain and microvascular damage caused by needle insertion. This hypothesis has been used primarily to explain acupuncture-induced general analgesia, but it can explain little else.

Both of the above explanations are acceptable to the mainlined medical community to explain acupuncture. But in 2. Modern, stainless steel acupuncture needles.

grafting acupuncture is Western medical theory, aspects foreign to orthodox medicine are simply jettisoned. Because of the emphasis on genetics, anatomy, physiology, and biochemistry in modern medicine, and a near complete denial of energetic processes in the body, chi (body energy) and meridians (paths of body energy flow) are either ignored or considered fallacies with some metaphorical or pneumatic value. Emphasis is placed by most researchers on the "needle and the physical effect" of its insertion into the skin, but this side of acupuncture is not essential. According to our research, acupuncture is essentially manipulation of bodily energy as it flows through the meridian system. The acupuncture needle is only one of many possible tools used to accomplish this activity. In the remainder of this article, "meridian theory" will be understood to include acupuncture theory and practice. "Meridians" is used to stand for both the meridian itself and the acupuncture points along the meridian.

A bio-physical or bio-chemical approach to acupuncture robs it of its actual foundation, and because of this, acupuncture research to date has been only partially successful. Fortunately, advances in physics, electromagnetism, quantum mechanics, and bioenergetic research have enabled researchers to develop a paradigm that, for the first time, successfully explains a majority of acupuncture related phenomena [9]. We have enhanced this bioenergetic paradigm, not simply because it can explain more of acupuncture phenomena, but because it is a true description of acupuncture's mechanism of action as well as an important facet of all life processes. The only way to address acupuncture successfully and scientifically is through the meridian system.

This four-article series will attempt to give a fairly complete representation of meridian theory research based on the bioenergetic paradigm. This, the first article, covers traditional acupuncture, early research into the the electrical properties of acupuncture points, and basic electrodermal screening test (EDST) methodologies. The theoretical foundation for the bioenergetic paradigm is discussed in two articles by physicist Kuo-Da Chen. The fourth article is a review of research into an application of bioenergetic properties called the electrodermal screening system (EDSS). In that article, Dr. F.M.K. Lam, Prof. Peixu Chou, and I hope to demonstrate the effectiveness of the EDSS as a screening/diagnostic method and offer evidence of the causal connection between points, meridians, and internal organs.

Traditional Acupuncture

According to traditional Chinese medicine, a form of body energy, called chi, is generated in internal organs and systems. This energy combines with the blood and circulates throughout the body, forming paths called meridians. The meridians form a complex multilevel network that consists of the various areas of the body, including the surface with the internal. All of the various meridian systems work together to assure the flow and distribution of chi throughout the body, thus controlling all bodily functions. The interwoven meridian systems and the possibilities for diagnosis and treatment they offer, are called meridian theory. When an organ or system is not balanced, related acupuncture points may become tender or red, providing a mechanism for diagnosis. For treatment, a point on the skin is stimulated through pressure, suction, heat, or needle insertion, affecting the circulation of chi, which, in turn, affects related internal organs and systems.

"Meridians" is the most common translation of the Chinese ching-lo (jinglu), but is a very imperfect translation. Ching means to pass through, and lo means a net or to connect. "Meridian" was originally used by French researchers to describe all meridians, and is used in this article in that sense. The term "channel" is used increasingly for all meridians. Some prefer to maintain the original distinction between ching and lo and to use the terms channels and collaterals respectively. With that distinction
Chi combines with the breath and circulates, forming meridians.

4. A modern "acupuncture drill."

life engineering in medicine and biology.
Meridians are classified into six groups, according to location and function.

In electroacupuncture treatments, direct electric current is administered through the acupuncture points. This electrical energy follows the electromagnetic tracks to the system, effecting treatment. Electroacupuncture therapy is a separate area of research and will not be discussed in detail here. On the other hand, anything that alters or interferes with a system's function or structure changes the performance of the related meridian and acupuncture points. The electrodermal screening device (EDSD), described below, determines the balance of a system by measuring resistance and polarization at these points. By other words, acupuncture and standard electroacupuncture are therapeutic, while the electrodermal screening test (EDST) can be integrated into diagnostic procedures.

The Device (EDSD) and Method (EDST)

In the 1970s and 1980s, two distinct electrodermal screening methodologies were developed, one by Nakashii in Japan (Ryodoraku) [10] and one by Voll in Germany (EAV, electroacupuncture according to Voll) [11]. The most obvious difference between the two systems were the types of points they measured. In Ryodoraku, meridian passage points on the wrists and ankles are measured. The points used in EAV are located all over the body, though the distal points on the hands and feet are used most often. EAV is the more versatile and precise of the two methods, and for this reason we were attracted to it. EAV is the basis of the EDST, and the standard device used in EAV, the DermaEvent (Pittering Electronics, Munich), is the prototype of modern EDSSs.

There are some variations in the construction and performance of EDSSs, but all share the same basic design (Fig. 5). The core of the EDSD is an ohmmeter designed to deliver approximately 10-12 μA DC at 1-1.25 v, a comfortably safe amount. The ionization potential of hydrogen atoms is 1.56 volts: only at this level and above could any physical damage occur. On the majority of the devices, the meter is calibrated to read from 0 to 100, such that the standard skin resistance of 100 μΩ reads 50. The minimum value of zero represents infinite resistance (to electrical conductivity), and the maximum value of 100 indicates zero resistance at the given voltage and current. Some of the devices use a range of 0 to 200, with 100 being normal skin resistance [12].

The EDSD testing probe consists of an insulated body with a tip of brass or silver, connected to the positive side of the circuit. The examiner holds the probe by the insulated body and presses the tip against the measurement point of the patient (Fig. 6). The negative side of the circuit is connected to a hand electrode made of brass tubing, which is held by the patient in one hand. If medicine testing (described below) is to be done, a metal plate or holding device, usually made of aluminum, is placed in the circuit between the device and the hand electrode. The pressure of the probe tip on the skin might create a temporary dimple and be slightly uncomfortable, but it should not be painful. To assure adequate electrical contact, it is usually necessary to slightly dampen the probe tip and the hand electrode with water.

A reading taken with the EDSD is usually described using two values, the initial reading (generally the highest value) and the indicator drop (ID). Many practitioners also note the length of time of the ID. An initial reading of approximately 50 followed by little or no indicator drop is considered to be balanced. Initial readings above 80 may indicate inflammation in the system being measured, and initial readings below 45 may indicate changes caused by degenerative processes. As ID indicates a probable imbalance, within an ID is present, it is considered the most important part of the reading. Through a process called medicine testing, the ID can be used to determine the nature and cause of an imbalance.

Organ structure, function, EM pathways, and emotional interaction are crucial to the meridian

are measurements of whole-body energy levels (Fig. 7). These readings are taken using a pair of brass-tube hand electrodes and a pair of brass-steel foot electrodes. Using the probe, the Chen's measurement points (CMP, some of which are also referred to as summation measurement points) are then measured to determine the general condition of an entire meridian. The beren points along the same meridian are checked if there is a positive reading at the CMP or if symptoms suggest that a complete check of a meridian is warranted, regardless of the CMP reading. When a point exhibiting an ID is located, various reagents can be tested against that point in a process referred to as medicine testing. It is the goal of the physician to find one or a combination of reagents that will balance the point. In case the point tested has a reading near 50 and not leave an ID. Reagent samples in sealed glass containers are put into the measurement circuit by placing them on a metal plate designed for this purpose. The physician tests various reagents, basing the selection on medical knowledge and experience, until an appropriate reagent or combination of reagents is found. A reagent that balances the reading may have a positive effect on the system being measured and therefore be an appropriate medication or dietary supplement. No response implies that the reagent would have no effect on the system, and a worsening response implies a negative effect. For example, pancreas CMP readings of a person with diabetes will become balanced when the proper dose of insulin is placed within the circuit and will show a larger ID if refined sugar is put there.

Medicine testing is perhaps the most controversial aspect of the EDSS, though many also consider it the most promising (13). It was discovered and used by Voll in connection with homopathy, and the effectiveness of the EDSS in testing homopathic remedies has been demonstrated in clinical studies (14). Homeopathic remedies serve as particularly useful reagents for medicine testing because they are prepared at various dilutions, which increases the likelihood of finding an appropriate "resonance," a phenomenon which will be discussed in Kuo-Gee Cea's second article. Medicine testing has also been shown effective in the testing of herbal and allopathic medicines (15) and has been used very successfully to test for allergies (16) and for the presence of environmental pathogens such as insecticides. (17) Virtually any sort of biological reagent can be tested in this fashion.

Conclusion

Acupuncture has been used for thousands of years and is effective in a wide range of situations. It has not been integrated into modern health care primarily because of lingering suspicions that it is not scientific. A bio-energetic model has been developed to explain nearly all aspects of acupuncture and meridian theory, but there remains a definite prejudice against human energetic theories in the

6. A hand point measurement taken with the electrodermal screening device, EDSS (Department of Physics, Soochow University, Taipei, Taiwan)

7. A four quadrant measurement taken with the EDSS Department of Physics, Soochow University, Taipei, Taiwan, earlier model. Reprinted from Tran J.J. The Pain, Present, and Future of the Electrodermal Screening System (EDSS) Journal of Advancement in Medicine, 1995; 8(4):217-232.
medical-scientific community, which must be overcome before integration can take place.

The EDST and EDSR are outgrowths of the scientific, electro-magnetic understanding of meridian theory. The EDST may appear similar to other modern diagnostic techniques such as MRI, but there are important differences. The EDST is also based on ancient principles and is safer and more holistic, versatile, and cost effective. The device is evidently simple and not extremely expensive. Hopefully, it will help free medical progress from its dependence on ever more expensive and specialized medical instrumentation. This alone would have a profound effect on health care cost and accessibility. The quality of health care will also improve with integration of the EDST into modern medical practice. Because the EDST makes use of the body's meridian system, it can map and help analyze the body's own signals, making it particularly useful in early diagnosis. With its solid theoretical foundation in modern physics and quantum mechanics, it is perhaps the most "modern" medical methodology available today.

References

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II. Electrical Properties of Meridians

With an overview of the electrodermal screening test

The electrical properties of acupuncture meridians, as well as their acupuncture points [1-3], have been shown to have a close relationship with the electrical properties of living organisms. In addition, the electrical properties have been thought to be of great importance in the treatment of disease and in understanding the mechanism of acupuncture and moxibustion.

In early studies, the skin was considered to be a passive conductor with a resistivity governed by its thickness and the electrical properties of the underlying tissues. However, recent studies have shown that the skin is an active conductor with a complex electrical behavior that is influenced by the underlying tissues and the electrical properties of the body as a whole.

The electrical current passes only through skin and not through other tissues. Both traditional meridian theory and experience suggest that meridians are not major pathways for electrical current. Nevertheless, the presence of electrical activity in the skin has been observed and measured, and this activity is believed to be related to the electrical properties of the skin and the underlying tissues.

Body’s Response to Small DC Stimulation

The old model failed to adequately describe measured phenomena because it was based on two restricted assumptions: 1) that a living organism can be modeled using only passive elements, and 2) that the electrical current passes only through skin and not through other tissues. Both traditional meridian theory and experience suggest that active responses are involved and that the current passes through many parts of the body. In reality, a weak electrical DC stimulus evokes three mechanisms in the body: electric conduction, dielectric polarization, and self-regulation by an organic defense system. The first two are physical and the third is biological.

The moment that a direct current of about one volt is applied to two electrodes attached to the skin, such as during the EDR test, the current is not merely propelled by the circuit but is modulated by the body, the skin, and the underlying tissues.

The mobility of electrons is influenced by cellular metabolism and the conformation of charged particles suspended in body fluids. The net effect can be described using a resistance function of time. A constant shift change takes place from the moment the circuit is closed toward a final steady state. From the point of view of statistical physics, the resistance function would be:

$$ R(t) = R_0 [1 + e^{-[(t - t_1)/t_2]}] $$

1. This standard model of the electrical properties of the skin was proposed by Rosenthal in 1994. In this model, the stratum corneum, which is the outermost layer of the skin, is modeled as a capacitor, C, and a resistor, R, in parallel connection. The skin is simply modeled by a resistor, R_0.

2. [Drawings and diagrams not shown]
against voltage $E$.

The motion of cellular charges is over-damped due to the high viscosity of cytoplasm and the relative deformation of the cellular state caused by polarization.

There also exists polarized long molecules suspended in body fluid, although these do not dominate the process. The net potential, $V_0$, is actually the sum of all types of polarization. The behavior of dipolar alignment can be expressed by the equation of motion of a driven over-damped oscillator:

$$\ddot{P} + 2\beta \dot{P} + \omega^2 P = H(E)$$

where $\ddot{P}$ is the moment, $\beta$ the damping effect, and the characteristic frequency of the type $j$ dipoles, $H(E)$ is the action of external voltage $E$ applied on $\gamma_0 P$. If the initial conditions were $P(0) = 0$ and $\dot{P}(0) = 0$, the complete solution of $P(t)$ is:

$$P(t) = (l + g \omega^2 \left[1 - \frac{l}{\left(1 + \omega^2 \tau_0^2\right)}\right]) \exp(-\omega^2 \tau_0 t) +$$

$$\frac{2}{\omega^2} \left[\frac{l}{\left(1 + \omega^2 \tau_0^2\right)}\exp(-\omega^2 \tau_0 t)\right]$$

In the above, $\tau_0$ is a constant and $\tau_0$ and $\tau_0$ are the two relaxation times for an over-damped oscillator. $\tau_0$ and $\tau_0$ are related to $\beta$ and $\gamma_0$ as:

$$\tau_0 = 1/[\beta_j \left[\gamma_0^2 - \omega^2\right]]$$

$$\tau_0 = 1/[\beta_j \left[\gamma_0^2 - \omega^2\right]]$$

And it is now possible to define:

$$Z_0 = \tau_0 / (\tau_0 - \tau_0)$$

If $N_j$ were the number of type $j$ dipoles per unit volume and $D$ the separation distance of the two electrodes, then the potential difference $V_0$ induced by dielectric polarization is:

$$V_0 = \sum N_j \frac{\rho_j}{\varepsilon_0}$$

$$= \sum N_j \left[1 - \frac{l}{\left(1 + \omega^2 \tau_0^2\right)}\right]$$

$$= \sum N_j \left[\frac{l}{\left(1 + \omega^2 \tau_0^2\right)}\right]$$

In the above, $\varepsilon_0$ is the permittivity of free space, and $\gamma_0$ is the final polarization potential of type $j$ dipoles as time $t$ tends to infinity. The summation includes all types of dipoles.

Every living organism has a strong immune system to protect itself from disturbance at all times. Naturally, polarization induced by an external voltage will provoke the cellular immune system. The immune system responds with an oppo-

1. Cells before (a) and after (b) polarization. Applying an external DC voltage, $E$, will induce a charge displacement of the cellular membrane, or a small electric dipole inside each cell, which causes all cells in the circuit temporarily to be elliptically deformed. The long molecules suspended in body fluid are also polarized and aligned along the applying direction of $E$. The induced dipole moments of both cells and molecules between the electrodes produce a polarization potential, $V_0$, which opposes the voltage $E$.

2. The circuit formed between the ESD and the patient during a measurement. $R_0$ is the resistance, and $V_0$ is the polarization potential induced by the applied voltage, $E$. The self-regulating function of the cells results in an electromotive force (emf) called lift potential, $U_0$, which acts against $V_0$.
ing behavior, a net electric energy good- 11.14

it or electrostatic force (emf), which is brought about by complicated processes
taking place inside the cells. These proc- 11.15

esses convert chemical energy (stated

within the cells in the form of bio-mass) into
electrical energy. Because this func-

tion is peculiar to living organisms and is

not found in inanimate objects, I refer to

it as life potential (E).

With the above considerations, the ef-

fective circuit for electrodialysis separating
tests, including both the device and the

patient being measured, can be depicted as

in Fig. 2. The current passing through.

the human body would therefore be:

\[ I_0 = (E + R_0I_0) / R_0 \]  \hspace{1cm} (7)

In experiments it is only possible to get

the net balance between life and polariza-

tion potentials. They cannot be obtained

separately. Balance potential (R0) is the
difference between life potential (E) and polariza-

tion potential (V0). Therefore, Eq 7 becom-

es:

\[ I_0 = (E + R_0I_0) / R_0 \]  \hspace{1cm} (8)

In healthy people, the life potential (E) be-

haves similarly to polarization potential

(V0). We have thus possible to compute current

(R0). We have done this repeatedly and

compared the observed data with a curve

based on theoretical computations made

with Eq 8 (Fig 9). The tests have taken

over 10,000 readings in the last 6 years,

and every curve line has been seen to be an-

alyzed in this fashion.

The above theoretical discussion is true for

all skin areas, but there are also implications

specific to EDST readings, particularly

Eqs. 6 and 7. The first being in the

EDST curve, generally the highest

point on the curve, is the peak value of

the response current, which is in reverse

related to the electric resistance of the meas-

ured point. Vogl developed standard

interpretations for clinical EDSS readings

which are discussed briefly in the preced-

ing article by Julia Tsim. Curve behavior after

the peak is an expression of the com-

petition between life potential and polariza-

tion potential. A representation of the

five standard curve types and their inter-

pretations using values from Eq 7 are found

in Fig. 2.

The figure does include an example of

a reading drop, but possible variations in

the drop are not depicted. These variations

are commonly observed: steep drop, gradu-

al drop, and see-on drop. A steep slope

generally corresponds to acute disease,

while a gradual sloping may indicate

chronic conditions, such as cancer. If a

gradual drop is found, it is crucial that the

measurement be taken until the dropping

starts, so that the complete amount of the

drop can be noted. An uneven, wavy slope

is probably due to either anesthetics func-

superior performance or electro-chemi-

cal reactions taking place within the body

during the measurement.

Theoretical Properties

Specific to Medicines

We have continued this line of theoretical

research in the hope of understanding

properties specific to medicinals. It would

have been possible to continue the process

of fitting mathematical formulas to experi-

mental curves. Thus this would have been

an extremely difficult process in-

volving many parameters. The decision

was made to proceed with a further evolu-

tion of the equation analysis based on two

indicators, one to show conductance (L0)

and one to show polarization (FD).

Preliminary research shows that results

obtained by continuing the process of Di-

ting curves would have yielded very simi-

lar results.

Relaxation time, t, of resistance func-

tion (R0) is usually less than 50 ms, while

the relaxation times of balance function

(R0) is always several seconds. The re-

sponse current reaches its peak value, I0,

much earlier than the reaction of the bal-

dance function. One could say that the hu-

man body functions as a resistor during

the first 50 ms following the closing of the

circuit and then as a semi-diode. The

peak current, I0, can be expressed as:

\[ I_0 = E / R_0 \]  \hspace{1cm} (9)

I0 is the final resistance. It is clear from

Eq 9 that the magnitude of I0 is an equiva-

lent measurement of conductance.

After the charge is closed for a time

much longer than t, the resistance R0 will

reach its final constant value, R0, and bal-

ance potential (R0) will reach a value very

close to its asymptotic value, R0. Hence the

final current I becomes:

\[ I_f = (E + R_0) / R_0 \]  \hspace{1cm} (10)

It is now possible to introduce a new

vector, called fractional drop (FD):

\[ FD = (I_f - I_0) / I_0 = -R_0 / E \]  \hspace{1cm} (11)

R0, which can be measured using the

FD value, is the final balance of the mea-

sured medicin under the application of the

external voltage.

The phenomenon behind the FD (Eq.

11) and Vogl's ID is the same. The only

difference is the mathematical expression.

Strictly speaking, the ID is expressed as:

\[ ID = I_f - I_0 = -R_0 / E \]  \hspace{1cm} (12)

Note that there are two inter-dependent
variables in Eq. 12, so it is much more difficult to resolve the equation, possibly resulting in misinterpretation of the readings. For this reason, I prefer PD as an expression of the polarization phenomenon.

Clinical Measurement of Meridian Properties

We have completed two small studies to test the above theoretical formulations, one in 1991 of arm points on the large intestine meridian [14], and one in 1993 of arm points on the pericardium meridian [15]. The following is a description of the pericardium meridian study, though the same methods were used in both. All data quoted below are from the pericardium meridian study.

In the pericardium meridian study, there were 30 volunteers: 19 males and 11 females, ages 19 to 30, average age 25.06. Electrodes were affixed over two genuine acupuncture points ("Chiu-tai" HE3 and "Ne-xuan" HE5) and two non-meridian points located 1 cm away from the two above mentioned points (Fig. 6). Points were located using both traditional methods and by measuring skin conductance. Applied voltage, E, in this case 1.5 V, was turned on and off from a distance to avoid any direct or indirect contact between the technician and the subject. After each measurement, the electrodes were shortened in order to erase the resulting polarization around them. The time interval between any two successive measurements was at least 20 s, to avoid any carry over effect. Both pairs of points were measured 20 times on each subject, switching current direction so that we had 10 readings in each direction. The current direction and order in which the various pairs of points were tested was determined randomly. The data were recorded and analyzed using a computer. Wilcoxon signed rank test was used to discriminate the properties of meridian-point and control-point groups. The paired t-test was used to determine preferential direction.

Both meridians demonstrated higher conductivity than the non-meridian skin areas (P<0.01). Table 1, which is in agreement with work of Nakatani [14], Niboyet [3], and Reichmanns et al. [7]. This finding means that meridians are good paths for electric current, because less energy dissipates flowing through meridians than when flowing through neighboring (non-meridian) tissues. Analysis of the PD shows that less polarization occurs along meridians (P<0.05, Table 1). The effect of this property is that meridians have a smaller dielectric contrast than neighboring tissues. Because of this, electromagnetic waves move faster through meridians than through non-meridian tissue. It is the combination of these two characteristics, higher conductivity with lower polarization, that makes the meridian system an effective bio-information communication network [6]. We then organized the data according to the direction of energy flow and did further analysis (Table 2). Less resistance results in higher conductance, as the preferential direction of conductance would be the direction of less resistance. The preferential direction of conductance along the pericardium meridian is from the finger toward the body (P<0.005).

Electric current moving along the pericardium meridian toward the body will encounter less resistance and eliminate less. Polarization in meridians is a different facet, which must be analyzed separately. The lower the polarization, the faster electromagnetic waves will be able to move, so the preferential direction of electromagnetic wave propagation (EMWP) is in the direction in which there is less polarization. The preferential direction of EMWP on the pericardium meridian is from the body to the finger. (P<0.001) Moving in this direction, there would be less delay in bio-information carried by EMWP [15]. To our surprise, this is the one major area where the two studies differed. On the large intestine meridian, the

5. Examples of typical readings taken with the EDSD.
preferential direction of both conductance and EMWP is from the finger to the body. The phenomenon of preferential direction in meridians, as observed in our study, agrees completely with rules of chi circulation in traditional Chinese medicine, including those expressed in the *The Yellow Emperor's Classic of Medicine* (ca. 100 B.C.E.), also referred to as the *Neijing*. The *Neijing* describes two types of chi: meridian chi (AC) and subcutaneous chi (SNC) [10]. The MC is all of the twelve regular meridians is said to flow from the distal points toward the body. SNC can flow in either direction. If the meridian runs along the outside of the arm or the inside of the leg, the SNC flows inward toward the body. If the meridian runs along the inside of the arm or the outside of the leg, the SNC flows outward toward the distal point (Fig. 3). SNC flow directions correspond with the preferential direction of EMWP. The preferential directions of leg meridians, also in agreement with the Neijing, were observed in another study in [19] (unpublished). Rosenthal observed this phenomenon in the form of differences in DC and cardiac skin conductance, though he incorrectly interpreted the phenomenon as the result of an electrolyte enhancement diffusion process in the stratum corneum [17].

**Role of the Meridian System in Biological Development**

A fertilized egg first splits into two cells, but then two cells are still physiologically dependent on each other. They are members of an integrated, though relatively simple, living system. They must maintain an extremely high level of integration in order to develop into a human fetus, an extremely complicated living system. To maintain integration between the two cells of a new embryo, both cells must constantly exchange matter, energy, and information. If this is not done, the two cells will develop separately, and the embryo will die or twins will be born. The communication of matter includes the movement of ions, resulting in an electric current flowing between them through the cellular membrane gap junctions [18]. This pathway must be of lower resistance or higher conductance. The types of energy used in embryonic biocommunication include heat, electromagnetic waves, and electrical potential energy. All of these are transferred back and forth between the two cells at extremely fast speeds, ensuring the integration of the larger organism, the embryo. To be as simple and efficient as possible, living organisms channel current and energy waves along the same path. Therefore, one can assume that the various types of information-carrying media in the early embryo travel along the same meridian running between the two cells. Because the circulation, nervous, and hormone systems have not yet developed, this first meridian is the primary route for biological communication and control within the system. The first meridian actively brings about integration of the embryo by controlling cellular generation. When the two cells split into four cells, the meridian connecting them must become more complicated in order to integrate the

![Diagram](image_url)
are more primary and flexible than the differentiated systems, and can adjust more quickly to external forces. Differentiated tissues, such as blood vessels and nerve fibers, are more rigid due to their pipe-like structure.

Though the meridian system itself does not have a definite physiological structure, it creates and maintains a structure, a role is plays for the entire life of an organism. This role was made clear in the preceding example of embryonic development. However, how does this function express itself in the mature organism? One of the most important functions of the mature meridian system is the control of cellular regeneration. An example of this is the electrical properties discovered by Becker to be active during limb regeneration in salamanders [20]. Though limb regeneration is not possible for humans, the body is capable of healing processes. One such process, the repair of biological structures by the generation of cellular mass, is controlled primarily by the human meridian system. We have found that preferential meridian direction is reversed in some cases of disease, which is similar to the reversal of magnetic polarity that Becker observed in salamander leg stumps during the regeneration process.

Conclusion
A model of electrical properties of the skin had been accepted scientific standard for decades. But this model was based entirely on mechanistic principles and failed to explain many biological phenomena, particularly those relating to acupuncture points and meridians. I have developed a model which, unlike the standard model, includes an active biological response and the fact that the electricity passes through different types of tissue, not just skin. This model not only explains much of acupuncture physiotherapy, in general, but can also be used to explain all possible EDST readings.

We followed the studies of electrophysiological properties with studies of qualities specific to meridians. We discovered that meridians have higher conductivity, faster EMFP, and patterns of preferential direction. Because of these factors, the meridian system acts as a particularly good network for the communication of bio-information and thus plays an essential role in biological function. It is very interesting that much of what we have learned through our studies (in which the most modern equipment and methodologies were used) is in agreement with meridian theory dating from 100 B.C.E. and earlier.

Acknowledgments
The results discussed in this article were obtained from a series of projects begun in 1956, which were made possible by support from the National Science Council of the Republic of China. The author would also like to express his sincere gratitude to Prof. Juji Tsuci for his concern and assistance.

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16. Lu HC: The Yellow Emperor's Book of Acupuncture. Academy of Oriental Heritage. (Vaccno) 1973. (This is a partial translation of a section of the Neijing, called the Lianduo. The material related to meridian and skin nutrition is included between pages 120 and 226, though Lu does not use the same translation of the term.)
III. Applying Quantum Interference to EDST Medicine Testing

In 1945, Dr. Roelofd Voll, the inventor of the electrodermal skin testing device (EDST, referred to in Voll's writings as EDA, electroacupuncture according to Voll), discovered by accident that medicine placed in contact with a patient's body affects the readings of the electrodermal screening device (EDSSD). Voll writes:

"I diagnosed one colleague as having chronic prostatitis and advised him to take a homeopathic preparation called Echinacea 4X. He replied that he had this medication in his office and went to get it. When he returned with the bottle of Echinacea in his hand, he tested the pressure measurement point again and made the discovery that the 4X reading which he had previously was up to 90 had decreased to 64, which was an enormous improvement of the pressure value. I had the colleague put the bottle aside and the previous measurement value returned. After holding the medication in his hand the measurement value went down to 64 again, and this pattern repeated itself as often as desired" [1].

Dr. Voll studied this phenomenon and found it to be consistent in all of his patients, thus allowing him to develop electroacupuncture [3]. Many clinical tests have been done to support medicine testing [4,5], and a variety of related applications have been developed for both diagnostic and treatment [6-9]. These will be discussed in detail in the fourth article in this series by Tsuei, Lam, and Chou. I have researched medicine testing and have come to the belief that the mechanism involved is quantum mechanical quantum phase matching. My previous article in this series addressed the bio-energetic aspects of the meridian system. This present article addresses the bio-informational aspects of the meridian system. The following will concentrate on the mechanism behind EDST medicine testing, though I believe this mechanism to be present in all meridians. Both traditional theory and my work suggest that this type of biological communication is the very "purpose" of the meridian system.

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It has long been suggested that biological self-regulation is not the result of the function of the nervous system and biochemistry alone and that as additional bio-informational mechanism must exist. Important work in this area has been done by Fritz-Albert Popp and his associates [10-11]. The main area of disagreement between their theory and mine is the exact nature of the physical mechanism. Popp sees bio-photon emission as the result of delocalized coherent electromagnetic fields within the tissue, while my theory concerns the localized coherent quantum states within tissues or organs. The information itself is expressed through these quantum states. The quantum states trigger various processes, including bio-photon emission and reception, which in turn triggers other reactions within the body. Bio-photon emission is critical to the communication process, and the process can be monitored by way of bio-photon emission, but communication by way of quantum states is primary.

According to quantum mechanics, in modern electrical systems, such as computer technology, energy is used to carry information. Theoretically speaking, it is possible to transfer information in this way but in a practical sense, this is not possible. In the human body, information for a long time was carried along the body's "wiring." With includes both the meridian and nervous systems. In the case of the meridian system, one could argue that the information contained in meridian energy is primary and the energy itself is secondary, but this is more. They are inseparably linked, thought they can be analyzed separately by means of their expression. For example, in the EDST, the initial reading is primarily an expression of energy, while the indicator deep (DD) and its manipulation through medicine testing is primarily an expression of bio-information.

Phase Modulation of Electron Waves and the Electromagnetic Potentials of Matter

Traditional and physical properties of matter are nothing but the features of the electron populations around their component nuclei. However, the distribution of electrons will result in a characteristic potential space surrounding matter with a more or less specific range. All electron potentials are dynamic, not static. The oscillatory behavior of electrons is a basic characteristic of matter and is the result of their continuous interactions with the matter that surrounds them. Therefore, the corresponding potential of a given type of matter oscillates according to the atomic characteristics of its components. According to quantum mechanics, even the special derivative of this potential has no effect on electromagnetic fields. The electromagnetic potential is still significant to the quantum states of all systems in a given space.

As long as an electron wave continues to pass through the potential space of matter, it will experience an action $S(t)$, which in principle can be calculated using the following integral:

$$S(t) = \int (\psi^* \cdot \dot{\psi} - A \cdot A^\prime)$$

(1)

The potential space consists of scalar part, V, and vector part, A.

According to quantum mechanical significance of gauge transformations, as

[Image]
Quantum mechanical quasi phase matching may be the very purpose of the meridain system
electron wave in such a potential space is transformed by a phase shift:
\[ \exp(i\theta_2/\hbar) \]
In the above, \( i \) is the imaginary unit and \( \hbar \) is Planck's constant \( \hbar \) divided by 2\( \pi \). When a beam of electron waves passes through the potential space of matter, the beam will be phase modulated. Therefore, this beam dynamically carries characteristic information of the matter in its shifted phase.
The beam-like electron wave traveling along an EDS circuit, including the effect of matter placed within a circuit (i.e. medicine testing) can now be expressed as:
\[ \psi_{2}(x,t) = \psi_{1}(x) \exp(i\theta_2/\hbar) \]
which is a real amplitude determined by the driving voltage of the circuit, and \( \theta_2(x,t) \) is the phase of the modulated electron beam. The time dependence of the phase is determined by the sample of matter in the circuit, i.e., the medicine being tested.

Organ and Tissue Condition
All physiological and pathological phenomena can in some manner be viewed as an expression of characteristic distributions of resident electrons over any volume of organ or tissue mass. These distributions oscillate and evolve according to life processes and environmental interactions. Within the limited time interval used in the EDS, it is reasonable to assume that such electron distributions will change appreciably in some point, \( T \). The oscillating distribution of electrons at \( T \) can now be expressed using a state function:

\[ \psi(T) = \psi_{1}(x) \exp(i\theta_2/\hbar) \]

where \( \psi(T) \) is a real amplitude and \( \psi_{1}(x) \) is its corresponding phase function.
This expression can be used to denote normal or abnormal physiological states of the human body, i.e., it can describe a state of health or of disease. When it denotes health, the electron distribution over the organ or tissue is correct. In an unhealthy state, the distribution is physiological wrong. When the strength of the improper electron distribution is greater than the intrinsic tolerance of a human body, one begins to feel uncomfortable or ill. If the strength of the improper electron distribution is weaker than bodily tolerance, then one would still feel fine and may have no evident symptoms.

Quantum Interference and Medicine Testing
When a medicine sample is put on the metal plate of the EDS circuit, the electron waves passing through the plate will be phase modulated. When these waves later pass through the patient's body, a given signal is transported to the proper organ or tissue by resonant absorption. The signal waves mix with local electron waves reduced in organs or tissues according to the principle of superposition. The resulting wave is:

\[ \Psi(x,t) = \psi_{1}(x) + \psi_{2}(x) = \psi_{1}(x) \exp(i\theta_2/\hbar) + \psi_{2}(x) \exp(-i\theta_2/\hbar) \]

According to quantum mechanics, the probability density of electrons existing in such a state is related to the intensity of \( \Psi(x,t) \). However, the intensity is proportional to the time average of the absolute square of resultant waves \( \Psi(x,t) \), i.e.,

\[ \langle \Psi^* \Psi \rangle = \langle B^2 + M^2 + 2BM \rangle = \sum \cos(\theta_{1} - \theta_{2})d\theta_{1} d\theta_{2} \]

where \( T \) is the test duration. The last term of the above equation is the interaction of electron waves entering and already existing within the body.
The phase difference, \( \theta_2(x,t) - \theta_1(x,t) \), can now be divided into time dependent and independent parts:

\[ \theta_2(x,t) - \theta_1(x,t) = \theta_0(x,t) - \theta_0(x,s) \]

In order to obtain a non-vanishing interaction term for Eq. 6, it is clear that the time dependent part of phase difference \( \theta_0(x,t) \) must tend to zero.

Under this requirement, Eq. 6 becomes roughly:

\[ \langle \Psi^* \Psi \rangle = B^2 + M^2 + 2BM \cos(\theta_0) \]

If the constant phase difference \( \theta_0(x) \) is zero, then Eq. 6 can be rewritten:

\[ \langle \Psi^* \Psi \rangle = B^2 + M^2 > B^2 \]

This is the result of constructive interference. In the case, the body electron distribution wave \( \psi_{B}(x) \) is enhanced by phase modulated electron wave \( \psi_{M}(x) \). If the phase constant \( \theta_0(x) \) is equal to \( \pi \), then Eq. 6 will become:

\[ \langle \Psi^* \Psi \rangle = (B - M)^2 > B^2 \]

which is an expression of destructive interference. The body electron distribution wave \( \psi_{B}(x) \) is now depressed by the phase modulated wave \( \psi_{M}(x) \).

Diagnosis and Treatment
The condition \( \theta_0(x) = 0 \) for the interaction term in Eq. 6 means that both the phase-modulated electron waves emitted by the EDSD and the electron distribution waves existing within the body must have similar and approximately equal phase spectra, cancelling their DC components. It is very probable that this relationship is the scientific basis for the similarity principle in homeopathy, though that is a complicated matter that must be discussed separately. In other words, what we have here is quasi-phase-matching between those two electron wave groups. In practice, it is impossible to find a medicine which has a phase characteristic spectrum identical to that of the disease. Only similar ones can be found for treatment of a disease. This principle holds true for all types of medicine, including traditional, herbal, and anipathic.

Constructive interference results in the enhancement of body wave \( \psi_{B}(x) \) by the phase modulated electron beam \( \psi_{M}(x) \), while destructive interference depresses it. If the physiological state of the body is favorable, constructive interference is a supplement mechanism and destructive interference is one of reduction. On the other hand, if the state of the body is pathological, the condition will be intensified by constructive interference (Eq. 9) or weakened by destructive interference (Eq. 10). Both kinds of interference can be employed in diagnosis and treatment. For example, samples of bacteria or virus that.

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have been treated to reverse these signals are commonly used in the EDST. When a point with an indicator drop is located, the power is retasted with various such samples plated on the medicine testing plan. If bacteria sample X improves the reading, it is very possible that the patient is suffering from a condition caused by or marked by the presence of bacteria X. One could then test various possible antibiotics to find the one that best improves the point reading. It is also possible to test the antibiotic against other points to test for possible side effects. For example, in most cases, antibiotics will cause a drop in some points associated with the digestive tract because of their effect on the "good bacteria" needed for proper digestion.

Disease can be treated quite well by using the signals of the material collected from the body. The reason is that the signals from such a sample is very similar, perhaps even identical, to the signal of the disease present in the patient. A theoretical treatment for cancer is a good example of this method has yet to be thoroughly tested. I use it here as an example only. A sample of the cancer tissue is taken and it is signal is reviewed. The indicated signal is administered to the same site, the cancer, the cancer tissue in the body detected by the method of the method, and the entire body by way of the blood-body system. The results should be similar, no matter how the DC current is used. The expected signal was the signal of the cancer's signal (quantum interference, Eq. 10), either diminishing or removing the signal. This might have a negative effect on the cancer cell, either killing them or slowing their growth. At the very least, it should improve the patient's feeling of well being because the treatment counteracts a large portion of the cancer's effect in the rest of the body, hopefully also strengthening the body's own defense and repair systems.

Conclusion

Both traditional meridians theory and modern applications such as the EDST demonstrate an essential link between bio-information and meridian phenomena. From the theoretical and clinical work thus far performed by many researchers, it is clear that meridians and bio-information are essential elements of the functioning of the human body. There are many possible clinical applications of the human meridian system and the body's bio-informational processes, including differential diagnosis and therapy to individual practices which is practicable, systematic, and effective, even in the case of complex, multi-faceted medical conditions. Although this article is almost entirely theoretical, it is in complete agreement with and helps illuminate numerous clinical studies (see the following article in the series by Tsuji, Lam, and Chen). It is my hope that because of the agreement between theory and practice, we are much closer to realizing a broad scientific acceptance of all facets of the meridian theory and the EDST, including medicine testing.

References


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Electrical Properties of Meridians (continued from page 63)


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IV. Clinical Applications of the EDST

With an investigation of the organ-meridian relationship

The basic facts regarding the electrodynamical, quantum acupuncture points have been adequately described and proven by Becker, et al. [1]. Chen (preceding article, and others) has shown that acupuncture theory most in need of clarification is the relationship between the meridians and internal organs, i.e., proof that internal organs and systems (both their structure and function) are the primary source of the energy present in meridians and acupuncture points.

Many clinical studies of acupuncture treatment have shown the possibility of such a connection. However, it is extremely hard to definitively prove this point in studies of the efficacy of treatment because there are too many confounding factors. There may be one of many factors or a combination of factors responsible for the success of the treatment being observed. Besides, if the goal of a study is to demonstrate therapeutic effectiveness, the exact nature of the mechanism of action is often not considered important. In an excellent review article by Jobe [2] on acupuncture treatment of pulmonary disease, the importance of study design and the definition of effectiveness are discussed in detail. The following is in regard to study blind and its effect on results: "These issues are only of paramount importance if the specific effects of acupuncture are to be researched. They are not as important if the efficacy of acupuncture as an intervention, including its ability to mobilize the placebo or self-healing response, on the outcome of measures of breathlessness is the subject of inquiry."

For acupuncture and the electrodynamical screening test (EDST) to become accepted medical procedures, their mechanisms of action must first be thoroughly studied and at least partially accepted; and an essential part of the mechanism of action is the organ-meridian relationship. Clinical trials of the EDST cannot completely prove this connection. But they do bring us much closer, hopefully to the point that the scientific and medical communities are adequately convinced that a definitive form of relationship exists. We have found that results from standard testing procedure are similar to results of skin-level measurements of electrical properties of acupuncture points, and that changes in measurements can be predicted based on traditional organ-meridian relationships. This is an extremely important point, which cannot be emphasized enough. This consistent relationship demonstrates a link between organs and meridians. Hopefully, someday soon, we will be able to measure quantitatively meridian energy on the inside of the body at the source organ, on the surface of the body, and along all of the interconnecting tracts of the meridian system. Only then will it be possible to definitively prove the organ-meridian connection.

Advantages and Challenges of Clinical Studies

Basic scientific medical research usually emphasizes in vitro and in vivo analysis of the chemical composition of a regimen or the body's physiological response to a regimen or process. For most medical products and procedures, issues of the mechanism of action are addressed during the basic research phase. Today, basic research alone is not enough for a medical product or process to be accepted by the medical community. Applied research, in particular various designed clinical trials, is the only convincing way to establish the efficacy of a drug or procedure. This is also true of the EDST and the electrodynamical screening device (EDSD) and system (EDSS), but here we also have the extra burden of questions regarding the mechanism of action, which have not been resolved in basic research.

Fundamental clinical trial procedures must be followed in studying the effectiveness of any new modality. They must be compared to conventional, established modalities, even though this is extremely difficult in the case of acupuncture related modalities. Since the presence and movement of vital energy is not expressed chemically, it is impossible to monitor quantitatively or qualitatively using standard chemical-based testing procedures. For this reason, researchers such as Jobe had to be content with the study of the therapeutic effect on the patient, something which often can be confirmed using physiological measurements.

There are other difficulties specific to EDST research. Since the purpose of EDST measurements is to record vital phenomena in real time, the measurements need to be taken within a specific range of hours during the day. For example, in a study, readings might be taken...
over the course of months, but all readings must be taken between 11 AM and 1 PM. Due to the large number of variables, a large sample size is preferable, usually requiring highly-selected study populations. A typical study group might be the patients at a large hospital or in a community with well-organized public health services, where records are maintained and standardized. In order to establish a uniform baseline, much time and effort must be spent collecting and reading all varieties of personal and health data of the study population, much more so than in standard clinical trials.

The EDS2D currently available are all manually operated. The technique is not difficult, though training and practice are required. It is our experience that a technician must have at least three months of hands-on experience before he is competent enough to participate in clinical studies. The tester and subject sit across from each other and make some physical contact during testing. There is thus an interesting physical field that emanate from their bodies. It is possible that there are interactions on that level which could affect results, a possible confounding factor to consider during data analysis. There are EDS2D models currently available that have electrodes that are affixed to the body, so that no direct examiner participation is required while the reading is taken. We have tried various such, but they are still less effective than manual EDS2D.

Hopefully, future developments in the device and streaming procedure will address such limitations.

A requirement of all scientific procedures is reproducibility. In the EDS2D, reproducibility can be a problem because the target of the measurement, the meridian system, is extremely dynamic and complex. The more sensitive the device, the more inconsistent the readings. Furthermore, a healthy person’s meridian system is more flexible and is able to adjust to the environment more quickly. At the moment of testing, this environment includes the DC stimulus created by the EDS2D. Because of this flexibility, a healthy person’s readings may be less reproducible than an ill person’s. In clinical studies, all of these factors have a profound impact on data collection and analysis.

Other aspects of our clinical trials are common to all such trials. For each study group, a definite diagnosis is made using internationally accepted parameters, such as blood pressure for hypertension and blood sugar level for diabetes mellitus. A complete biochemical profile is usually obtained at the same time to rule out other medical problems. Similar data are collected for both the study and control groups. All clinical trials require a great deal of human labor and other resources, making them extremely expensive. This problem is compounded in our case because research in alternative medicine is, in general, greatly under-funded.

Pretreatment is another critical issue for all clinical studies. For treatment studies, it is usually necessary to withhold all other treatments or therapies to traditional medicine. The control group might receive ineffective or no treatment at all, which could cause discomfort or much worse. In our studies, the EDS2D is often used in conjunction with alternative practices such as acupuncture, Chinese herbal remedies, or homoeopathic remedies. Both the device and the treatments are non-standard and syner
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<td>OD-I/L</td>
<td>Organ degeneration (cellular metabolism) CMP</td>
<td>Left hand</td>
</tr>
<tr>
<td>OD-I/L-R</td>
<td>Organ degeneration (cellular metabolism) CMP</td>
<td>Right hand</td>
</tr>
<tr>
<td>PA-I/P</td>
<td>Paresis CMP</td>
<td>Right foot</td>
</tr>
<tr>
<td>PA-I/P-R</td>
<td>Paresis CMP</td>
<td>Right foot</td>
</tr>
<tr>
<td>PA-I/P-R</td>
<td>Function of platelet formation and protein metabolism</td>
<td>Right foot</td>
</tr>
<tr>
<td>PA-I/P-R</td>
<td>Function of carbohydrate enzymes and metabolism of carbohydrates</td>
<td>Right foot</td>
</tr>
<tr>
<td>PA-I/P-R</td>
<td>Function of atherosclerosis and lipid metabolism</td>
<td>Right foot</td>
</tr>
<tr>
<td>SK-I/L</td>
<td>Small intestine CMP</td>
<td>Left hand</td>
</tr>
<tr>
<td>SK-I/L-R</td>
<td>Small intestine CMP</td>
<td>Right hand</td>
</tr>
<tr>
<td>SL-I/L</td>
<td>Peritoneum in the region of the duodenum I-II and the terminal ileum</td>
<td>Right hand</td>
</tr>
<tr>
<td>SL-I/L-R</td>
<td>Peritoneum in the region of the duodenum I-II, jejunum, and ileum</td>
<td>Left hand</td>
</tr>
<tr>
<td>SL-I/L-R</td>
<td>Small intestinal CMP</td>
<td>Left hand</td>
</tr>
<tr>
<td>SK-I/L</td>
<td>Skin CMP</td>
<td>Right hand</td>
</tr>
<tr>
<td>SK-I/L-R</td>
<td>Skin CMP</td>
<td>Left hand</td>
</tr>
<tr>
<td>SP-I/L</td>
<td>Spleen CMP</td>
<td>Right foot</td>
</tr>
<tr>
<td>ST-I/L</td>
<td>Stomach function of red pulp</td>
<td>Left foot</td>
</tr>
<tr>
<td>ST-I/L-R</td>
<td>Stomach CMP</td>
<td>Right foot</td>
</tr>
<tr>
<td>TW-I/L</td>
<td>Endocrine (Triple Warmer) CMP</td>
<td>Left hand</td>
</tr>
<tr>
<td>TW-I/L-R</td>
<td>Endocrine (Triple Warmer) CMP</td>
<td>Right hand</td>
</tr>
<tr>
<td>TW-I/L-R</td>
<td>Gastro and adrenal</td>
<td>Left hand</td>
</tr>
<tr>
<td>TW-I/L-R</td>
<td>Gastrointestinal adrenals</td>
<td>Right hand</td>
</tr>
<tr>
<td>TW-I/L-R</td>
<td>Endocrine pancreas function</td>
<td>Left hand</td>
</tr>
<tr>
<td>TW-I/L-R</td>
<td>Endocrine pancreas function</td>
<td>Right hand</td>
</tr>
</tbody>
</table>

All points designated CMP are control measurement points and all other points are branch points. Readings at CMPs can be used to ascertain the general biomechanical condition of a complete system. Branch points usually offer more specific information on one organ or function, as their names suggest. The far right column shows the special set of cardiovascular related (1) and non-related (1) points used in the second hypothesis study [18] and one of the clinching studies [25]. The ones not marked include both cardiovascular-related and non-related points that were not examined in those two studies.
### Table 2: Bioenergy of healthy subjects, analysis of variance of whole-body (quadrant) measurements

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Mean %S (N)</th>
<th>d.f.</th>
<th>HHH</th>
<th>LHH</th>
<th>RHH</th>
<th>FF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
<td>1</td>
<td>2712.5(^*)</td>
<td>1455.9*</td>
<td>1038.8*</td>
<td>262.9</td>
</tr>
<tr>
<td>Age</td>
<td>2</td>
<td>2206.1*</td>
<td>2917.1*</td>
<td>3167.9*</td>
<td>3379.9*</td>
<td></td>
</tr>
<tr>
<td>Tester</td>
<td>2</td>
<td>666.0</td>
<td>1562.9*</td>
<td>1243.5*</td>
<td>7.8</td>
<td></td>
</tr>
<tr>
<td>Residual</td>
<td>458</td>
<td>200.2</td>
<td>150.5</td>
<td>173.5</td>
<td>191.2</td>
<td></td>
</tr>
</tbody>
</table>
*Highly significant (p<0.01)

### Table 3: Bioenergy of healthy subjects, least-squares means and standard errors of whole-body measurements. Chin values (1 Chin = 0.5 standard ESST value).

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>HH</th>
<th>LHH</th>
<th>RHH</th>
<th>FF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>168.39±0.87</td>
<td>159.99±0.71</td>
<td>157.24±0.74</td>
<td>170.67±0.76</td>
</tr>
<tr>
<td>Females</td>
<td>2.77±1.44</td>
<td>154.87±1.29</td>
<td>82.62±1.33</td>
<td>168.03±1.29</td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Young</td>
<td>170.38±1.49</td>
<td>162.68±1.22</td>
<td>160.84±1.27</td>
<td>175.05±1.33</td>
</tr>
<tr>
<td>Middle</td>
<td>166.81±0.99</td>
<td>150.03±0.98</td>
<td>154.26±0.94</td>
<td>170.01±0.98</td>
</tr>
<tr>
<td>Old</td>
<td>159.54±1.86</td>
<td>152.10±1.56</td>
<td>149.66±1.41</td>
<td>163.95±1.49</td>
</tr>
<tr>
<td>Testor</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>159.65±1.35</td>
<td>156.86±1.11</td>
<td>153.72±1.15</td>
<td>168.82±1.27</td>
</tr>
<tr>
<td>B</td>
<td>162.28±1.51</td>
<td>153.70±1.06</td>
<td>157.84±1.12</td>
<td>169.54±1.18</td>
</tr>
<tr>
<td>C</td>
<td>167.30±1.29</td>
<td>150.22±1.06</td>
<td>157.24±1.10</td>
<td>169.94±1.16</td>
</tr>
</tbody>
</table>

### Table 4: Bioenergy of healthy subjects, analysis of variance of point measurements

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>Mean Squares</th>
<th>d.f.</th>
<th>RLLamp</th>
<th>RHLamp</th>
<th>LAClamp</th>
<th>RPLamp</th>
<th>LPLamp</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
<td>1</td>
<td>0.8</td>
<td>661.5</td>
<td>862.3</td>
<td>4.5</td>
<td>1428.6</td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td>2</td>
<td>661.1</td>
<td>667.5</td>
<td>1542.9</td>
<td>753.8</td>
<td>645.5</td>
</tr>
<tr>
<td>Testor</td>
<td></td>
<td>2</td>
<td>1941.8</td>
<td>458.3</td>
<td>1200.3</td>
<td>1352.0</td>
<td>5003.5</td>
</tr>
<tr>
<td>Residual</td>
<td></td>
<td>458</td>
<td>479.3</td>
<td>459.0</td>
<td>524.1</td>
<td>613.1</td>
<td>644.1</td>
</tr>
</tbody>
</table>
*Highly significant (p<0.01), Significant (p<0.05)

Risk might be involved, so finding study participants can be extremely difficult.

In case-control studies, data from healthy and sick individuals are analyzed and compared, increasing the possible accuracy of ESST readings in describing actual conditions. With the EIST, this type of analysis is needed because there are many variables involved in interpretation of readings. For example, no measurement decrease at a specific organ-related point means, theoretically, that the organ probably is healthy, but this is not certain. All we really "know" from this finding is that the structure and function of the systems tested are balanced at the time of the measurement. In most cases, an indicator-drop (ID) of less than two points might be due to either a minor condition or a technical error. This ID may be negligible, but depends on the system being measured as well as the expected condition. An ID of more than two points may imply a minor to major problem. One attempt to clarify such findings by noting the spread and extent of the ID and by medicine testing. There will always be an amount of "art" involved in the process, if only because of the complexity of the full-body system being measured. However, through much proper research, it is possible to continually study and standardize the ESST.

There are some elements of clinical study work that track in one favor, particularly because ours are studies of a screening process, not a diagnosis. Unlike the studies of acupuncure therapies described by those, warts of screening effectiveness allow the easy comparison of different study populations and the testing of multiple, control-selected points and meridians, which reduces confound- ing factors.

The twin foundations for East-West Medicine were established in 1989, though a number of people, particularly Julia Thai and Fred Lam, have cooperated tradition in traditional Chinese medicine research projects for many years previously. The foundations are located in Honolulu, Hawaii and Taipeh, Taiwan. We have done cooperative research with two major universities the University of Hawaii (John A. Burns School of Medicine, Center for East-West Medicine Projects in Honolulu) and National Yang-Ming University School of Medicine in Taipei. To date, we have compiled over 20 studies on bio-energy and the EPDS. These studies offer proof of a significant correlation between meridians and organ and demonstrate that knowledge of this connection has practical implications. These are not the only clinical studies of electrodermal diagnostics, but they constitute the largest body of data on this subject collected by one research group. Other interesting studies include cancer detection using EAV [3] and the Ryodoraku technique [4].

Our research, which began in 1992, was designed in accordance with the accepted steps for scientific approval. Due to its complexity, all research planning was done with the assistance of experts in clinical study design. These experts in-
It is possible to define much of the meridian system with the electrodermal screening device (EDSD)

data, allowing researchers to analyze and compare results from different studies. Such standardization is necessary for proper EDSD research and device development.

In 1987, the first in a continuing series of comparative/descriptive studies was completed (total of six, two currently available in English). In these studies, the bio-energy of varying population groups was analyzed, such as those exposed or not exposed to dangerous materials such as pesticides at the workplace (9), those who had or had not received metal fillings (10), and those who did or did not perform a specific activity (such as chewing, see below). These studies were followed by major clinical research projects on electrodermal screening for diagnosis of allergies and hypertension (also discussed below).

The study of the effect of metal dental fillings involved 160 subjects (10). Statistically significant relationships were found that suggest (a) a relationship between the major meridians and galvanic resistance of the teeth and (b) a substantial negative effect of dental fillings on dental galvanic properties, which by extension can effect the primary meridian associated with that tooth and other parts of the body associated with that meridian. For example, we found a statistically significant relationship between metal fillings in any of the third molars and problems in the small intestines and the heart. In this study, diagnosis was done using both standard Western and traditional Chinese procedures.

In the study of pesticide exposure (9) there were a total of 120 subjects, employees at a factory that produced organophosphate (DDVP). Of these, 60 were workers who came in regular contact with DDVP and its components. The 60 control subjects were office workers who did not come in direct contact with the finished products or the materials used. The control measurement points/points that show the general condition of an organ or sys-

### Table 5: Hypertension screening, 7 groupings of points.

<table>
<thead>
<tr>
<th>Group</th>
<th>Left Ventricular Mass</th>
<th>Systolic Pressure</th>
<th>Diastolic Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.029^*</td>
<td>0.013</td>
<td>0.034</td>
</tr>
<tr>
<td>2</td>
<td>0.041</td>
<td>0.078^*</td>
<td>0.072^*</td>
</tr>
<tr>
<td>3</td>
<td>0.059^*</td>
<td>0.315</td>
<td>0.001</td>
</tr>
<tr>
<td>4</td>
<td>0.044</td>
<td>0.007</td>
<td>0.028</td>
</tr>
<tr>
<td>5</td>
<td>0.001</td>
<td>0.001</td>
<td>0.005</td>
</tr>
<tr>
<td>6</td>
<td>0.000</td>
<td>0.010</td>
<td>0.030^*</td>
</tr>
<tr>
<td>7</td>
<td>0.006</td>
<td>0.003^*</td>
<td>0.022^*</td>
</tr>
<tr>
<td>1 ID</td>
<td>0.049</td>
<td>0.106^*</td>
<td>0.107^*</td>
</tr>
<tr>
<td>2 ID</td>
<td>0.035</td>
<td>0.045</td>
<td>0.023</td>
</tr>
<tr>
<td>3 ID</td>
<td>0.041</td>
<td>0.038</td>
<td>0.042</td>
</tr>
<tr>
<td>4 ID</td>
<td>0.018</td>
<td>0.023</td>
<td>0.019</td>
</tr>
<tr>
<td>5 ID</td>
<td>0.008</td>
<td>0.003</td>
<td>0.007</td>
</tr>
<tr>
<td>6 ID</td>
<td>0.003</td>
<td>0.009</td>
<td>0.002</td>
</tr>
<tr>
<td>7 ID</td>
<td>0.004</td>
<td>0.017</td>
<td>0.007</td>
</tr>
</tbody>
</table>

Regression analysis R2 values:

*Significant (p<0.01), **Significant (p<0.005)
Table 6: The positive effect of chikung meditation
(16-person chikung study)

<table>
<thead>
<tr>
<th>Measurement Point</th>
<th>Positive Sign Rank</th>
<th>Probability &gt; .05</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ly-cmp-L</td>
<td>30.0</td>
<td>0.0280</td>
</tr>
<tr>
<td>Ly-cmp-R</td>
<td>38.0</td>
<td>0.0184</td>
</tr>
<tr>
<td>Lu-cmp-L</td>
<td>118.0</td>
<td>0.0040</td>
</tr>
<tr>
<td>Lu-cmp-R</td>
<td>104.0</td>
<td>0.0227</td>
</tr>
<tr>
<td>Li-cmp-L</td>
<td>108.0</td>
<td>0.0070</td>
</tr>
<tr>
<td>Li-cmp-R</td>
<td>126.0</td>
<td>0.0010</td>
</tr>
<tr>
<td>Cr-cmp-R</td>
<td>70.0</td>
<td>0.0244</td>
</tr>
<tr>
<td>Al-cmp-L</td>
<td>111.0</td>
<td>0.0119</td>
</tr>
<tr>
<td>Al-cmp-R</td>
<td>86.5</td>
<td>0.0410</td>
</tr>
<tr>
<td>Oxc-cmp-L</td>
<td>70.0</td>
<td>0.0253</td>
</tr>
<tr>
<td>S-I-cmp-L</td>
<td>96.5</td>
<td>0.0218</td>
</tr>
<tr>
<td>S-I-cmp-R</td>
<td>91.0</td>
<td>0.0262</td>
</tr>
<tr>
<td>Sp-cmp-L</td>
<td>89.5</td>
<td>0.0254</td>
</tr>
<tr>
<td>Sp-cmp-R</td>
<td>81.5</td>
<td>0.0092</td>
</tr>
<tr>
<td>L-v-cmp-R</td>
<td>119.0</td>
<td>0.0060</td>
</tr>
<tr>
<td>Bl-cmp-L</td>
<td>124.5</td>
<td>0.0020</td>
</tr>
<tr>
<td>Bl-cmp-R</td>
<td>121.0</td>
<td>0.0014</td>
</tr>
</tbody>
</table>

Wilcoxon sign rank test for the differences between ID values measured before and after 30 minutes of chikung meditation (statistically significant 17 of 49 control measurement points). In case of a tie, the following adjustment was made:

\[ E(\bar{X}) = \frac{N(N-1)}{4} + \frac{d(N+1)}{8}, \quad \text{where } N \text{ sample size} \]

\[ \bar{V}(\gamma) = \frac{1}{24} (N(N+1)(2N+1)-\sum_{i=1}^{N} (d_i^2 - 1 + 1(2d_i + 1))), \]

\[ + \frac{1}{48} \sum_{i=1}^{N} (d_i^2 - 1 + 1(2d_i + 1))) \]

where \(d_i\) difference among number

...were tested with the EDST. Readings from seven points showed a statistically significant correspondence (P < 0.05) separating study and control groups. In general, measurements from people in the study group had a higher initial reading and a larger indicator drop at those seven points. Readings from the same seven points also corresponded with blood ACHE (acetylcholinesterase) levels. This was also statistically significant (P < 0.05), particularly for readings from the right nervous system point (ND-cmp-R, P < 0.01).

Healthy Subjact Subject

The most important of the observational studies was one in which the bio-energy of 483 healthy subjects was measured and analyzed. The body of data that was created is extremely important for a number of reasons. We can now more clearly define norms for EDST measurements including acceptable ranges for in-consistency and natural variations. The data also taught us much about human bio-energy in general. Two reports have been written on this study, one based on the initial readings data (11), and one which emphasizes indicator drop (ID) values but also compares this to initial readings (unpublished, Zhao Z, Tsui JJ, Lam Jr P. Study of Bioenergy in Healthy Subjects. Analysis of Indicator Drop Values, 1990). The two studies are in agreement in all major points despite using different measurement parameters, which is further proof of the consistency of human bio-energetic properties, in general. Both studies analyzed reading distributions, which is particularly important for determining measurement norms (Figs. 1-4).

The data were analyzed statistically according to age and sex to determine, in general, what effect these two parameters have on bio-energy. Quadrant measurements (hand to hand, foot to face, right hand to foot, and left hand to foot) were found to be related to age and sex, though individual point measurements showed no such relationship. Younger males generally had the highest quadrant readings, but quadrant readings were found to decrease steadily with age for males. Quadrant readings for females were more consistent for all age groups (Tables 1-3). The difference between whole-body (quadrant) measurements and point measurements is an important topic that is discussed in both articles. Quadrant measurements measure general biological energy levels, which could consistently vary among age groups and sexes. Point measurements represent the energy and balance of an individual organ system at the time of measurement. These appear to be a basic difference between the two types of energy being measured, i.e., different levels of the body’s energy being measured. Zhou et al. noted that ID values in whole-body measurements were significantly lower (average 0.61 to 1.48) than those found during acupuncture point readings (average 0.60 to 7.69).

It became clear to us during this study that the presence of individual sensors can have an effect on readings, and that this must be treated as a possible confounding factor. As mentioned above, the magnetic fields of the subject and technician often interfere during a measurement and the learned technique is important, but there are other ways in which the presence of the technician can effect the readings. There were three technicians participating in the healthy subjects study, and one of them had a statistically significant negative effect on the readings taken on males but not females. As we were analyzing the data, still blinded to the identity of the technicians, one of us jokily that it must be an attractive female. We later found out that the technicians were all female and that the one that was attractive was much more attractive than the others. This finding suggests that physical attraction also affects bioenergy, though much more re-
search is needed before anything definitive can be said. More important, it is an example of possible confounding factors specific to this type of research.

**Diabetes Mellitus Case Control Studies**

We have compared four case control studies, two of diabetes mellitus (DM) and two of hypertension (see below). These two conditions were chosen because both have universal acceptance and have been used as endpoints in several other research studies. All four studies clearly show that there is significant increase in the risk associated with specific factors on the skin. It is possible to differentiate normal from abnormal function of internal organs and systems.

The first study was done in Honolulu in 1987 with a total of 53 DM cases and 95 people in the control group [12]. The diabetes generally had lower quadrant measurements values (hand/feet measurements p 0.01), but point measurements were more useful in screening for DM. Ten points were chosen for study because of their possibility to be associated with diabetes according to traditional acupuncture therapy or the theories of Reinhart Voell. There was a highly statistically significant difference (p 0.01) between the values of diabetics and non-diabetics for all ten points. The mean ID values for diabetes for the points TW-1-1 and TW-1-1-R, respectively were 7.4 and 8.2 times that of the control group. The ID at PA-3 (which was identified by Voell as the carbohydrate metabolism point) was the most significant of all. (Refer to Table 1 for a listing of all specific points mentioned throughout this article.)

Statistical analysis of all readings was done to determine which were particularly affected by DM. Nine readings were isolated (initial reading for PA-2 and PA-3; ID values for PA-2, PA-3, OD-comp-L, OD-comp-R, PA-comp-L, PA-comp-R, TW-1-1-L and TW-1-1-R) and used to create a discriminant function to screen for DM. All study subjects and control group members were screened very successfully (>95% agreement with standard diagnostic procedures).

The second study was done in 1988-89 with diabetic patients (total 50) and healthy people coming for standard physical checks (total 20) at Veterans General Hospital, Taipei [13]. This time, measurements were taken at the 4 quadrants; all 40 control measurement points, and 4 branch points (PA-3, SP-3, TW-1-1-L and TW-1-1-R). Once again, it was found that quadrant measurements were lower and point measurements values larger among those with DM. Using the Wilcoxon sign-rank test and logistic regression analysis, the following three ID values were found to be the most significant in DM; PA-3, ND-comp-L, and LV-comp-L. (Kappa value = 0.3406, p = 0.0006) Screening done using these three values resulted in sensitivity of 59.1%, specificity 95%, positive predictability 0.703, and negative predictability 0.647.

**Two Hypertension Case Control Studies**

We have compared two studies of electrodermal screening for hypertension, one in 1992 [14] and one in 1995 [15]. The results were similar, though the following discussion will center on the second study, in which we did more thorough statistical analysis. Participants totaled 336, age range 20-83, 171 normal-tension and 165 hypertensive. Measurement points were selected based on either traditional meridian theory or Voell's theories. Forty control points and sixteen branch points were measured on each individual. Of the total of 56 points, 19 represented cardiovascular function and 38 measured the general condition of organs or systems not part of the cardiovascular system (Table 1). The non-cardiovascular points were measured because hypertension is a systemic condition, which most likely would have an effect on various body organs and systems.

Through factor analysis and regression analysis it was possible to divide the 56 points into 7 groups, according to the relationship between the readings and hypertension:

1. Major points on the hands except left lung and left large intestine
2. Branch points on the hands
3. 11 secondary points on the feet
4. 9 major measuring points on the feet
5. Left lung and left large intestine
6. 7 foot branch points
7. Corony measuring points on both hands

Groups 3-5 were all non-cardiovascular, groups 6 and 7 were cardiovascular, and groups 1 and 2 included both cardiovascular and non-cardiovascular related points. In three statistically-based groupings, both foot and hand points were separated from each other, as were control and branch points.

We then compared the data from all seven groups with standard medical meas
Chikung Studies

Like acupuncture, the ancient practice of chikung (also spelled gigping) meditation is also based on meridian theory. Chikung meditation is usually done sitting still with "regulation" (a relaxed concentration of) breath. This practice supposedly improves the circulation of both blood and chi energy. Intermediate practitioners of chikung begin to learn how to consciously monitor the flow of chi through their bodies. Advanced practitioners can control the flow of chi within their bodies. Very advanced practitioners and masters can emit chi that can be measured by some scientific devices. Master chi is said to have curative powers and can be used therapeutically.

We have had numerous clinical experiments involving the EDSST and chikung masters and practitioners. Many masters are able to effect the readings of a sick person by emitting chi toward them during the time. In effect, they are using their own chi to affect the chi of the patient, and improve the patient's reading, at least temporarily. We also suggest chikung meditation to many of our patients and often see a definite improvement after they have practiced for a period of time.

A series of studies have been conducted attempting to define better emitted chi. Studies by Lee [16] and Chien, et al. [17], have isolated infrared light as part of the energy present in emitted chi. In both studies, a InSb detector was used to measure the level of infrared radiation (3 to 5 micrometers) at the palms of advanced chikung practitioners. Both studies reported that the two types of emitted chi produced opposite results. "Facilitating chi" increased infrared levels, while "inhibiting chi" reduced infrared levels. Chien, et al. [17] also studied the effect of the two types of emitted chi on human fibroblasts, RS-4 cells and boar sperm. Facilitating chi increased cell proliferation, protein synthesis, and cell growth in human cells, while inhibiting chi decreased all three. In the case of boar sperm, facilitating chi increased sperm motility, while inhibiting chi demonstrated an increase in motility and viability.

We have completed two studies on the effect of chikung meditation on EDSST measurements. The first was a study of 16 relatively advanced practitioners (age 35-68, mean age 50), all of whom had practiced the Ta Alle Ching Kuang style of chikung meditation for at least 20 minutes daily for 3 years or more (19). Quadrant measurements and all 40 control measurement points were measured before and after a 30 minute meditation session. All quadrant measurements became more evenly distributed and all initial reading values of specific points came closer to the standard value of 20. The mean ID value of 17 of the 40 specific points measured showed a positive significant change, i.e., became more balanced (Table 6). A larger comparative study was completed with a group of 72 beginning to intermediate chikung meditation practitioners (20). Stratified randomization was used to divide the 72 into a study group (mean age 42) and a control group (mean age 39). EDSST measurements were taken...
before and after a 30 minute session, during which the study group meditated and the control group just sat and waited. A total of 34 acupuncture points were measured in each individual, including 18 believed related to cardiovascular function and 16 believed to represent most other body functions. The same points as used in the hypotension study, Table 1.) Measurement readings, inaccuse skin points representing circulation, improved significantly after just 1/2 an hour of chihung meditation. The whole body benefits from chihung meditation, though there is an immediate clear effect on circulation. All bodily systems are interrelated, and positive and negative effects on one system eventual effect other parts of the body, such as the negative effect of hypotension on renal function.

Conclusion

The acupuncture and meridian system of traditional Chinese medicine is an important, real biophysical aspect of the living body. With the electrodermal screening device (EDSD), it is possible to define, both quantitatively and qualitatively, much of the meridian system. The meridian system is essential to man or possibly all bodily functions. The EDSD is a non-invasive procedure and is valuable in delivering valuable information on nearly every facet of body function. The EDSD can serve as the standard of "normal" by which biological energy is measured, similar to body temperature and blood pressure. In other words, it is conceivable that someday the EDSD will be as commonplace on the thermometer and sphygmomanometer.

The EDSD is non-invasive and economical. With its further refinement and acceptance, along with that of the associated testing methodology (EDST) and health management system (EDSS), it may be possible to chart even the tighter functions, including emotional, cognitive, and psychosomatic. The EDST has the potential of developing into a useful complete test of the body, making possible levels of international medical standardization and meta-analysis unknown today. The device, test, and system may prove to be the greatest set of tools against disease created this century. But since what is needed is much more research. It is the doctors' sincere hope that many others in the medical/scientific community will see the EDST's potential and initiate further research projects.

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