TOWARDS THE DEVELOPMENT OF A MATHEMATICAL MODEL FOR ACUPUNCTURE MERIDIANS

Mark J. Friedman, Ph.D., Associate Professor
Department of Mathematical Sciences, University
of Alabama in Huntsville, Huntsville, AL 35899

Stephen Birch, Lic. Ac., B.A., Faculty and Research Director
New England School of Acupuncture, 30 Common street, Watertown, MA 02172

William A. Tiller, Ph.D., Professor
Department of Material Science and Enginering,
Stanford University, Stanford, CA 94305

(Received March 28, 1989; Accepted with revisions December 10,1989)

ABSTRACT

Traditional concepts of classical acupuncture and Chinese medicine come from a culture which is very different from ours, and there has been considerable problems in their accurate presentation. Our approach is to attempt the development of a mathematical language that links these traditional concepts theoretically to models that can be experimentally tested.

We first review some of Manaka's findings, confirmed also by our results, having to do with low intensity stimuli. In particular, Manaka applied polarized agents such as Cu(+) and Zn(-) to nonacupuncture points on a meridian and to the so called "mother and child" points on a meridian. In both cases he observed the pressure pain reaction which increased for one orientation of Cu and Zn on the meridian and decreased for the opposite orientation. Note that in the case of "mother and child" points the observed reaction was in agreement with the so called "five phase (five element)" theory. Also, in the case of the "mother and child" points the effect usually lasted considerably longer than in the case of nonacupuncture points on a meridian.

Taking into account the connection between Manaka's results and skin electrical measurements by some electrodermal diagnostic instruments such as Motoyama's AMI, we discuss some equivalent electric circuits for a single meridian and relate them to the nervous system response. In particular, an electrical circuit model similar to the synapse membrane with two ionic channels seems to be especially useful when we try to explain Manaka's clinical

results and Motoyama's results on the velocity of propagation of electrical impulses along meridians. We also develop a mathematical model in the form of a linear five dimensional dynamical system of the so called "five phase (five element)" laws such as "creative" cycle, "controlling" cycle, etc., in the case of a single meridian. We connect this model with the membrane type model mentioned above by assuming a simple mass action law, for the dependence of the conductances in the ionic channels on the input signals. This combined model is used to describe the development of a "disease" and its treatment according to the "five phase" theory. Here we interpret the "disease" as a blockage in a meridian, while the treatment initiates the unblocking process.

KEY WORDS: Meridians, Pressure pain reaction, Vacancy and repletion, "Five phase" theory, Electrical circuits, Membrane type equations, Mathematical modeling, Dynamical systems.

1. INTRODUCTION

There have been considerable problems in the accurate presentation of traditional concepts from acupuncture and Chinese medicine. It is only recently that appropriate philological and scholarly standards have begun to appear (see Unschuld [1, 2]). This has been compounded by a tendency to try to westernize these concepts by reducing them to concepts which typically do not address the traditional theoretical concepts themselves. This is like trying to relate concepts from one culture to concepts in another culture without having found the language that bridges the two cultures. The result is a mass of contradictory information that often seems irreconcilable. In a simple attempt that pays attention to the traditional concepts themselves, the authors propose the development of a mathematical language that tries to link these concepts theoretically to models that can be experimentally tested. To our knowledge, this is the first attempt to build such a bridge and should be recognized as being only a working model in its infancy. Our use of mathematics here is in the spirit of the development of dynamical system models of complex neural phenomena (see Carpenter and Grossberg [3]). The mathematical models we derive here, draw from three sources: (i) knowledge (very limited) of the underlying physical mechanisms, (ii) observed clinical phenomena and (iii) the translation of the traditional theoretical concepts into their minimal realizations as mathematical laws.

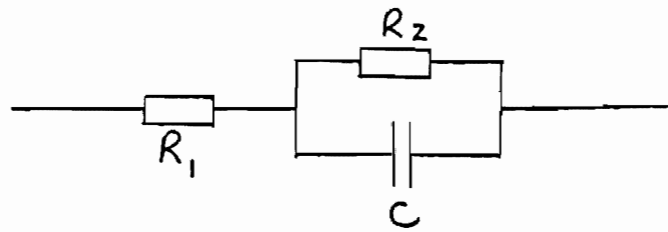
Anecdotal evidence supports a connection between the results of the classical acupuncture diagnostic procedures and the results of some electrodermal diagnostic instruments such as Motoyama's AMI and Nakatani's Neurometer. Motoyama discusses the match between his AMI readings and traditional descriptions of the meridians (see [14], especially pages 10–15). There are also examples in the literature where the imbalances found by electrodermal instruments matched those imbalances found by more traditional assessments such as radial pulse, abdominal palpations, symptoms, etc. (see [12] for a clear case where treatment also corrected the imbalance found both by electrodermal (Neurometer) and traditional assessment methods). These electrical measurements lead to simple electrical equivalent circuits of the skin discussed recently in Tiller [4]. In Section 2 we first review these circuits and then try to relate them to clinical practice by examining the clinical findings and clinical results of Manaka, which investigate the validity and applicability of certain traditional ideas. Exploration of these clinical findings and results show the need to extend the simple model to be able to explain the observed clinical phenomena. Such an extension is explored mathematically with suggestions for further clinical experiments to establish its validity and further extension. In particular Manaka applied copper and zinc to nonacupuncture points on a meridian and the so called "five phase (five element) points" and observed the meridian responses. To explain his results we introduce an electric circuit model similar to synapse membranes with two ionic channels. In Section 3 we assume an interpretation of "disease" as a phenomena closely associated with a blockage in a meridian, and assume that treatment initiates the unblocking process. We

hypothesize an appropriate dependence of the conductances in ionic channels on inputs and consider a simple dynamical systems model to account for the development of disease and its treatment according to the "five phase (five element) laws".

The "meridian" is an important concept in acupuncture. It is described as having several functions, probably, the most important of which is the distribution of a kind "energy", called "qi". The treatment loci of acupuncture lie mostly on meridians. Considerable efforts have been made to understand, measure and demonstrate the existence of meridians. Measurements made by many researchers have shown that the meridians have electric characteristics (see e. g. [4] and [5] which has an extensive bibliography). More recently Omura and his associates [6–9] has provided striking evidence for the existence of "meridian-like networks", corresponding to specific internal organs, and their exact location in living humans and cadaver using the "Bi Digital O-Ring Test Imaging Technique", which show significant agreement to the classical meridian systems, with minor discrepances. While the exact nature of "meridians" is not yet clear, there is more than clinical evidence to support the premise that they exist.

2. EQUIVALENT ELECTRICAL CIRCUITS FOR A SINGLE MERIDIAN

The simplest electrical equivalent circuit corresponding to a single meridian used for skin measurement analyzed in Tiller [4] has the form:



Here R_2 and C correspond to the epidermic layer of skin and R_1 corresponds to the dermic layer. Note that the parameters of the circuit depend in general on the voltage. Motoyama's AMI instrument applies a DC potential of $V_0 = 3$ volts between a number of meridian terminal points and a large indifferent electrode on the wrist and measures the short-time current response (1–100 microsec). In what follows we use the term "meridian" as the corresponding electrical circuit pathway. Clinical evidence of Manaka [12] and others suggests the possibility that the initial electric current BP$= V_0/R_1$ is a parameter corresponding to traditional acupuncture diagnostic measurements (such as radial pulse palpation, abdominal palpation, visual inspection, etc.) though we are not aware of rigorous research that confirms this suggestion. More precisely, for a particular meridian, a high BP compared to the average taken over all meridians corresponds to "repletion". In traditional terms, "repletion" , (Chinese "shi"), is a condition of too much so called "qi" from various causes. A law BP compared to the average corresponds to "vacancy". In traditional terms "vacancy" , (Chinese "xu"), is a condition of insufficient so called "qi" from various causes. Here, BP refers to the initial current response at time $t = 0$ before any polarization has occurred. Because of known occurrence of circadian rhythms (see e. g. Manaka [12]), where current readings have been found to fluctuate according to the time of day, we feel that further experimental evaluation is required to validate these definitions. The acupuncture points are known to have a positive potential of several millivolts (see e. g. Tiller [4] and the discussion there). To account for this we need to add a battery E to the circuit above.

Manaka's clinical practice and experimental research in acupuncture has led him to suggest the existence of a biological signaling system of which the above electrical characteristics are a significant part.Working from the premise that traditional concepts work at the level of this signaling system, Manaka began exploring the properties of the system to see if this were so. His experiments utilized very small intensity stimuli such as

the application of copper and zinc plates, north and south poles of a magnet to acupoints and meridians. The use of such polarized agents, in particular, allow for observation of their repeatable and reversible effects [10, 11]. Assessment of these effects was made through observation of pressure pain and muscle tone at acupoints on the meridians investigated and on related reflex points. If the application is favorable to the meridian under investigation, pressure pain and muscle tone will decrease. If unfavorable, pressure pain and muscle tone will increase. We have repeated his simple tests and experiments and obtained the same results.

According to traditional theory the meridian has "qi" flowing in it in a particular direction. In an effort to relate this concept to the electrical model of the meridian and to determine if there is an electric current flowing in one direction, he applied copper and zinc plates to nonacupuncture points on a meridian and observed the meridian responses. For example, for pressure pain and tension at right LI-4, on the flesh in the center of the web between the first and second metacarpals, placing copper upstream and zinc downstream, proximal to the wrist on the large intestine meridian, decreases these reactions. Reversing the copper and zinc causes the reactions to return.

Manaka interprets his findings as describing a current flow in the meridian which agrees with the traditional description of the flow of "qi". In our electrical model, high BP relates to "repletion" and low BP to "vacancy" of the meridian. However, it is known that pressure pain can arise from both repletion and vacancy (in the traditional terms). From a simple electrochemical viewpoint, copper is electropositive relative to zinc so that the application of copper upstream and zinc downstream should increase BP. We hence assume that this adds a voltage and thus is able to describe what happens in the the case of vacancy. But in the case where BP is already high, repletion-pressure pain should only increase when we do this. However for this case, clinically the pressure pain decreases which would indicate a contradiction to our model. Consider next two possible mechanisms of the observed phenomena. The first is that the pressure pain response arises from an influence of the treatment on the neural response in the vicinity of a particular point. The chain of effects for this would be as follows: (i) surface treatment leading to (ii) changes in the local meridian that ultimately manifest as electrical charges in the equivalent circuit which lead to (iii) electrolyte and voltage changes in the vicinity of the key neural channels leading to (iv) excitatory or inhibitory response in the neural fibers leading to (v) pressure pain response at the point. The second possibility is that we need to change the meridian model, specifically to change R_1 by a circuit similar to one that describes the excitatory and inhibitory responses of a neural fiber. In both possibilities we choose the same model to resolve the contradiction. Release of pressure pain from repletion or vacancy can be explained in either case by the effect of stimulation on the inhibitory and/or excitatory channels of either the neural membrane, the equivalent meridian channels or, possibly, both. In the case, where treatment influences the two channels of the neural fibers, the effects on the pressure pain are relatively straightforward. In the second case where treatment influences the two channels of the meridian to effect pressure pain changes, the following are evidence in support of this model: a) Pressure pain responses do not arise solely from neurological causes and therefore do not necessarily require a model of the neurological effects (see e. g. Melzack [13]). b) Motoyama's results regarding the velocity of qi supports this model (see p. 75 especially of [14]). He found the velocity of propagation of electrical impulses along the meridians to be in the range 4 cm/ sec. – 50 cm/sec. which is considerably smaller than the velocity of propagation of nervous impulses which are in the range 50 cm/sec. – 100 m/sec. It appears that the propagating impulses measured by Motoyama are traveling waves, the mathematical equations which have as their solution traveling waves are of form similar to equation (1) below. We therefore feel justified in the use of this model and equation (1) for the meridian. c) Our analysis below shows that the use of this two ionic channels model for the meridian is able to resolve the above contradiction and describe qualitatively many other phenomena.

To be specific, assume that a meridian is described by the equation of the type used in the neurophysiological model for synapse membranes with two ionic channels:

$$c\frac{dv}{dt} = (v^+ - v)\,g^+ + (v^- - v)\,g^-, \tag{1}$$

where v^+ and v^- are excitatory and inhibitory saturation points, respectively: $v^+ > v^-$; $g^+ > 0$ and $g^- > 0$ are the corresponding conductances of two ionic channels, while c is the capacitance which we can assume to be unity, for simplicity. Thus, depending on the values of g^+ and g^-, v can take any value between v^+ and v^-, which we interpret as being related to the most replete and most vacant states of the meridian, correspondingly. When the meridian becomes vacant, let us presume that the resistance of the excitatory channel becomes large (the excitatory channel closes) so that g^+ becomes small and v is close to v^-: i.e. we have blockage in the excitatory channel. Similarly, if g^- becomes very small, we presume that it is due to the meridian being replete and v is close to v^+. This we interpret as blockage of the inhibitory channel (the inhibitory channel closes). Thus for the case of application Cu upstream and Zn downstream the homeostatic effect of reduction of pressure pain can be explained as follows: *in the case of vacancy g^+ is increased which makes the meridian more replete; in the case of repletion g^- is increased so that the meridian becomes more vacant.* These simple copper and zinc tests of Manaka appear to demonstrate that the meridians have direction of flow. The north and south pole magnets of strength 600 - 800 gauss have also been used to check meridian flow, and the results are essentially the same as found for copper and zinc. The pressure pain responses are qualitatively similar when the north pole replaces the copper and the south pole replaces the zinc.

Omura's results [15] seem to support our model. He has shown that certain types of low energy electrical field, magnetic field and electromagnetic field (light beam with certain wavelength) can change body muscle tone. In general, some of these low energy signals do not usually create sufficient voltages to cause excitation of isolated nerve fibers. Our model describes such signals as effecting changes in conductances and not voltages. This is similar to the negative resistance circuit suggested by Omura [15] as a possible mechanism of the above effects.

These experiments have so far used nonacupuncture points on a meridian. Next Manaka applied these same polarities to certain acupoints, in particular, the "mother" or "tonification" and "child" or "dispersion" points [10, 11]. These acupoints are important in traditional practice. Their names derive from their association with the so called "wu xing", the "five phases". We have done some exploration of the five phase model mathematically and formulated mathematical models that match traditional descriptions of their interaction [16]. Looking only at the mother and child points, they can be modeled according to the five phase model by the following equation, which is a simplification of equation (9) below:

$$\frac{dS_j}{dt} = aS_{j-1} - dS_{j+1}.$$

Here S_j is the amount of stimulation of the j-th point on the meridian under investigation, where this point belongs to the same phase as the meridian and $a, d > 0$ are the coefficients. S_{j-1} is the amount of stimulation of the "mother phase", according to traditional concepts, we treat the "mother" in the cases of "vacancy". S_{j+1} is the amount of stimulation of the "child phase", according to traditional concepts we treat the "child" in cases of "repletion". We assume that stimulation of the meridian is proportional to S_j.

Manaka observed polarity dependent reversible changes associated with these points. Repeating his experiments we have been able to confirm his findings. Placing copper to the mother point and zinc to the child point reduces pressure pain on the meridian or at associated meridian points. Reversing these so that zinc is on the mother with copper on the child points causes the pressure pain to return. Replacing the copper with the north pole of a magnet and zinc with the south pole has the same effects on the pressure pain. In general, applying a positive electrical polarity to the mother point and negative to the child point has the same effects. These are described extensively in Manaka [11] with many case histories.

These observations can be explained via the above model of the meridian. *Essentially the positive agent applied to the mother point and negative to the child point opens the ionic channel pores as described above:* in the case of vacancy g^+ is increased which makes the meridian more replete; in the case of repletion g^- is increased so that the meridian becomes more vacant. *Reversing the polarity agents closes the pores, reversing the changes in current flow, causing the pressure pain to return.* In Section 3 we have a more detailed mathematical model for this. It is also important to notice that *in eight out of the twelve meridians, the order of application of polarities to the mother and child points is reverse of that when applied to nonacupuncture points on a meridian.* Another experimentally observed difference is that *in the case of applying copper and zinc to to nonacupuncture points on a meridian, the effects are short lasting; while the effects are long lasting in the case of the mother and child points.* We postulate that in the first case part of the effects is due to adding voltage to the meridian, and part of the effect is due to opening the ionic channels, thus changing the meridian conductances; while in the second case changing the meridian conductances seems to be the primary mechanism. This and other of Manaka's research, such as application of colored light and ink to these acupoints [11, 18, 19], give clinical evidence to what the Chinese called the "five phases". However, more rigorous clinical research is required to investigate this.

3. A DYNAMICAL SYSTEMS MODEL FOR THE "FIVE PHASE LAWS" IN THE CASE OF A SINGLE MERIDIAN

We consider the effects of different signals on the excitatory conductance g^+ (for g^- the analysis is similar). Our approach here is similar to the one in Carpenter and Grossberg [3]. We use a simple mass action law. To be specific, assume that (1) describes a wood (liver) meridian. Let T_1 be a signal leading to vacancy of liver meridian, i.e. decreasing g^+, say, due to emotional and dietary factors, acting for a long time (i.e. several years) from time t_0 to t_1. At time t_1 the diet was changed, and there was a treatment by needles, electrical polarities or light, according to the "five phase" laws, for a short time from t_1 to t_2 by a signal T_2. We thus have:

$$T_1(t) = \begin{cases} 0, & t \le t_0, \\ T_1 = const, & t_0 < t \le t_1, \\ 0, & t > t_1; \end{cases} \tag{2}$$

$$T_2(t) = \begin{cases} 0, & t \le t_1, \\ T_2 = const, & t_1 < t \le t_2, \\ 0, & t > t_2. \end{cases} \tag{3}$$

The simplest mass action law is defined by

$$\frac{dg^+}{dt} = (H + JT_2(t))(g_0 - g^+) - JT_1(t)\,g^+, \quad t \ge t_0, \tag{4}$$

where g_0 is the maximal number of opened pores (when $T_1(t) = 0$). Equation (4) says that closed pores, which number $g_0 - g^+$, open at a rate $H + JT_2(t)$ (when $T_2(t) = 0$ the rate is H); and that the signal $T_1(t)$ closes open pores, which number g^+, at a rate J. We also assume that at time $t = t_0$ all pores were open i.e. no blockages:

$$g^+(t_0) = g_0. \tag{5}$$

Solving (4), (5) for different time intervals gives:

$$g^+(t) = \frac{H}{H + JT_1} g_0, \quad t_0 \ll t \le t_1, \tag{6}$$

for time t "long enough";

$$g^+(t) = g_0 - g_0 \frac{JT_1}{H + JT_1} \exp\left(-(H + JT_2)(t - t_1)\right), \quad t_1 \le t \le t_2; \tag{7}$$

$$g^+(t) = g_0 - \left(g_0 - g^+(t_2)\right) \exp\left(-H(t - t_2)\right), \quad t \ge t_2. \tag{8}$$

Equation (6) shows that the excitation channel of the liver meridian is now partially blocked (the conductance g^+ decreased). Equation (7) models the unblocking process (increase of g^+) due to the treatment. Equation (8) says that the unblocking process continues after the treatment stopped, but with a slower rate than during the treatment. Substitution of (6), (7) and (8) into (1) and solving it will show how the voltage v changes in time. Clinical experiments are required to test this model.

We next look more closely at the treatment process, e.g. how $T_2(t)$ can be obtained. Clinical experiments of Manaka and ours seem to agree with the traditional so called "five phase" theory [11].

The simplest conceptual model of the classical "five phase" theory in the case of a single meridian can be formulated as follows. Given a stimulation of one or several of the five acupoints corresponding to different phases, on the meridian under consideration, the five acupoints stimulate each other according to what the traditional theory calls "creative" and "controlling" cycles. Then the stimulation of the meridian is proportional to the resulting stimulation of the acupoint that belongs to the same phase as the meridian. The simplest mathematical interpretation of this conceptual model gives a linear five-dimensional dynamical system. We illustrate this approach in the case of our original example of the *wood* (liver) meridian.

Let $S_j(t)$, $j = 1, ..., 5$, (assume $j = 1$ for *water*, $j = 2$ for *wood* etc.) denote the amount of stimulation of the j—th point on the *wood* meridian. Suppose our treatment was to tonify the *water* point by a signal R. Then the simplest mathematical model describing the effects of this treatment is given by the system of five linear differential equations (see also [16]) :

$$\begin{aligned} \frac{dS_1}{dt} &= aS_5 - bS_4 - cS_1 - dS_2 - eS_3 + R(t), \quad t \ge t_1, \\ \frac{dS_j}{dt} &= aS_{j-1} - bS_{j-2} - cS_j - dS_{j+1} - eS_{j+2}, \quad j = 2, 3, 4, 5, \end{aligned} \tag{9}$$

where $R(t) = R = const > 0$, for $t_1 \le t \le t_2$ and $R(t) = 0$ otherwise; with the initial conditions

$$S_j(t_1) = 0, \quad j = 1, ..., 5. \tag{10}$$

Here $a, b, c, d, e > 0$. The first equation in (9), for example, says that the rate of change of stimulation of the *water* acupoint is proportional to the stimulation ("creative") S_5 of the *metal* acupoint, to negative stimulation S_4 (controlling) of the *earth* acupoint, to the negative stimulation S_1 (homeostatic, see [16] for the discussion) of the *water* acupoint, to the negative stimulation S_2 (countercreative) of the *wood* acupoint, to the negative stimulation S_3 (countercontrolling) of the *fire* acupoint, to the stimulation $R(t)$ from the treatment.

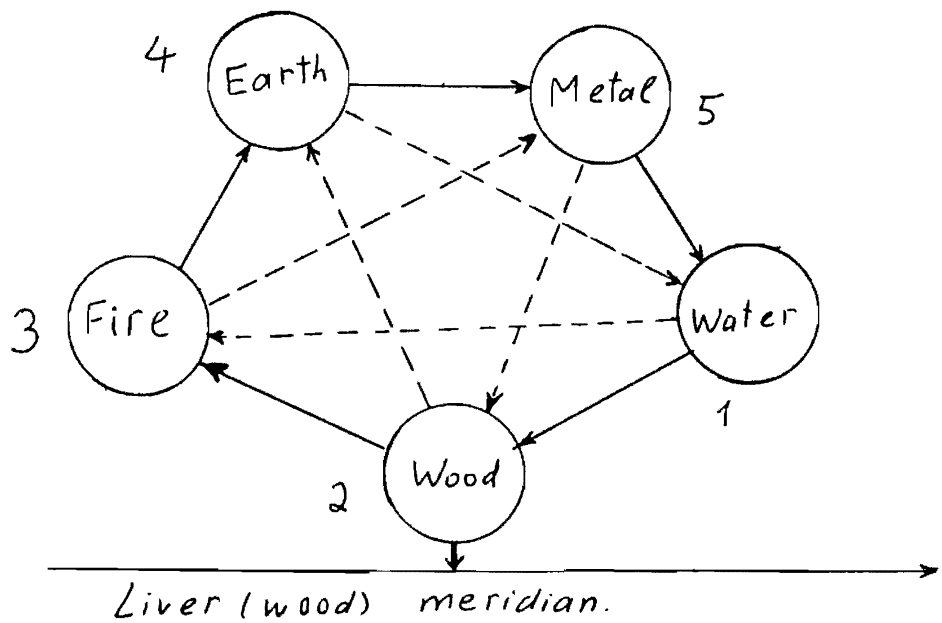
Solving (9), (10) we obtain, in particular, $S_2(t)$ which gives us the resulting effect of the treatment on the *wood* acupoint on the *(wood)* liver meridian. For the treatment signal $T_2(t)$ we can set $T_2(t) = S_2(t)$ or, to account for our simplified assumption on the form of $T_2(t)$ in (3),

$$T_2(t) = \begin{cases} 0, & t \le t_1, \\ \frac{1}{t_2 - t_1} \int_{t_1}^{t_2} S_2(t)\, dt, & t_1 < t \le t_2, \\ 0, & t > t_2. \end{cases} \tag{11}$$

We thus assume that the stimulation of the liver *(wood)* meridian equals the (average) stimulation of the *wood* acupoint.

4. DISCUSSION

We have explored mathematically some concepts and clinical data from classical acupuncture. Though we are not aware of any rigorous experiments to support our analysis, still the abundance of anecdotal data convinced us that our attempt was worth while. We have started with a simple electrical circuit model of the skin, which accounts for measurements of some electrodermal instruments such as Motoyama's AMI. The initial electrical current BP is interpreted as an indication of the condition (as determined by traditional acupuncture procedures) of a meridian. High BP corresponds to repletion, low BP corresponds to vacancy, in traditional terms. Rigorous experiments are required to verify this correspondence. Manaka's clinical results (confirmed by our own) show that application of a small voltage to nonacupuncture points on a meridian and to the so called "mother" and "child" points reduces pressure pain independently of whether the meridian was vacant or replete. In view of the importance of this homeostatic mechanism we intend to conduct triple blind experiments to verify this. To account for these results we introduce a mathematical model similar to that of a synapse membrane with two ionic channels and assume that applied voltage affects the conductances in the ionic channels. Further research is required to determine actual mechanisms. We further develop a phenomenological model of the "five phase" laws in the case of a single meridian and use it to describe in real time the development of a disease (which we interpret as a blockage in a meridian) and its treatment (which we interpret as the corresponding unblocking process). Again, we plan to conduct clinical experiments and monitor them using AMI or a related equipment. We also intend to examine detailed parametric properties of solutions of our differential equations models, both analytically and numerically and compare the mathematical predictions with related data. An extension of equation (1) will replace it by an appropriate partial differential equation to account for the traveling wave fronts measured by Motoyama [20]. We also plan to develop a mathematical model for the complete meridian system.



ACKNOWLEDGMENTS

The authors wish to thank Dr. Yoshiaki Omura, Director of Medical Research, Heart Disease Research Foundation and Dr. Phillip Shinnick, Research Associate, Heart Disease Research Foundation for their useful comments.

REFERENCES

[1] Unschuld P., Medicine in China: A History of Ideas, University of California Press, Berkeley, 1985.

[2] Unschuld P., Medicine in China: Nan Ching, The Classic of Difficult Issues, University of California Press, Berkeley, 1986.

[3] Carpenter, G.A., Grossberg, S., Dynamic models of neural systems, in *Oscillations in Mathematical Biology,* Hodgson, J.P.E. (Ed). Springer-Verlag lectures in Biomathematics, pp. 102–196, Springer-Verlag, 1983.

[4] Tiller, W.A., On the evolution of electrodermal diagnostic instruments, *J. of Advancement in Medicine* vol. 1, pp. 41–72, 1988.

[5] Zhu Zong-Xiang, Research Advances in the Electrical Specificity of Meridians and Acupuncture Points, *Amer. J. of Acupuncture,*vol. 9, pp. 205–216, 1981.

[6] Omura, Y., Meridian networks of internal organs, corresponding to traditional Chinese 12 main meridians and their acupuncture points as detected by the Re-evaluation of the classical acupuncture concept of meridians in oriental medicine by the new method of detecting meridian-like networks connected to internal organs using "Bi-Digital O-Ring Test", *Acupuncture and Electro-Thera. Res., Int. J.* vol. 11, pp. 219–231, 1986.

[7] Omura, Y., Re-evaluation of the classical acupuncture concept of meridians in oriental medicine by the new method of detecting meridian-like networks connected to internal organs using "Bi–Digital O-Ring Test Imaging Method"; Search for the corresponding internal organ of western medicine for each meridian — Part 1, *Acupuncture and Electro-Thera. Res., Int. J.* vol. 12, pp. 53–70, 1987.

[8] Omura, Y., Takeshige, C., Shimotsuura, Y., Suzuki, M., Imaging of the stomach and localization of the stomach meridian & its acupuncture points in human cadaver by the use of the indirect "Bi-Digital O-Ring Test Imaging Technique", *Acupuncture and Electro-Thera. Res., Int. J.* vol. 13, pp. 153–164, 1988.

[9] Omura, Y., Connections found between each meridian (heart, stomach, triple burner, etc.) & organ representation area of corresponding internal organs in each side of the cerebral cortex; release of common neurotransmitters and hormones unique to each meridian and corresponding acupuncture point & internal organ after acupuncture, electrical stimulation, mechanical stimulation (including shiatsu), soft laser stimulation or Qi Gong, *Acupuncture and Electro-Thera. Res., Int. J.* vol. 14, pp. 155–186, 1989.

[10] Manaka, Y., Itaya, K., Acupuncture as intervention on the biological information system. (Meridian treatment and the X-signal system), *An address given at the Annual Assembly of the Japan Meridian Treatment Association,* March 1986.

[11] Manaka, Y., Itaya, K., Birch, S., *Chasing the Dragon's tail,* to be published in 1989 (Paradigm Publications).

[12] Manaka Y., Itaya, K., Thoughts about Ryodoraku total regulation therapy, *Nihon Ryodoraku Jiritsushinkei Gakkai journal,* March 1986.

[13] Melzack, R. et al, Trigger points and acupuncture points for pain, *Pain,* vol. 3, pp. 3–23, 1977.

[14] Motoyama, H., Biophysical Elucidation of the Meridians and Ki-Energy, *Intl. Assoc. for Religion and Parapsychology,* vol. 7, pp. 1–78, 1981.

[15] Omura, Y., Effects of an electrical field and its polarity on an abnormal part of the body or organ representation point associated with a diseased internal organ, and its influence on the bi-digital O-ring test (simple, non-invasive disfunction localization

method) and drug compatibility test- Part 1, *Acupuncture and Electro-Thera. Res., Int. J.* vol. 7, pp. 209–246, 1982.

[16] Birch, S. and Friedman, M.J., On the development of a mathematical model of the "laws"of five phases, to appear in *Amer. J. of Acupuncture;* [11], Appendix.

[17] Manaka, Y., Itaya, K., Brown, S., Abdominal diagnosis and indications in traditional Chinese medicine, *Amer. J. of Acupuncture,* vol. 13, pp. 223–234, 1985.

[18] Manaka, Y., The skin distinguishes color and sound!? An approach to qi, the origin of Oriental medicine, *Ido no Nippon magazine,* May 1987, pp. 91–98.

[19] Manaka, Y., Speculation on "qi" in Chinese medicine as media in the signal system, *Japan Skinkyu Topology Conference,* Kyoto, July, 1988.

[20] Motoyama, H., Electrophysiological and Preliminary Biochemical Studies of Skin Properties in Relation to the Acupuncture Meridians, *Intl. Assoc. for Religion and Parapsychology,* vol. 6, pp. 1–36, 1980.