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ENERGY MEDICINE: REVIEW AND HYPOTHESES

Perspective: Assume a spherical cow: The role of free or mobile electrons in bodywork, energetic and movement therapies

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Summary Biomedical research has led to the hypothesis that inflammation is the culprit behind almost every modern chronic illness. Hence there is interest in techniques that can resolve acute and chronic inflammation. A natural method involves connecting the human body to the earth (earthing). When done during sleep, earthing normalizes the daily cortisol rhythm, improves sleep and reduces pain and inflammation. Direct electrical connection with the earth enables diurnal (daily) electrical rhythms and electrons to flow from the earth to the body. Electrons are thought to act as natural anti-oxidants by neutralizing positively charged inflammatory free radicals. This concept requires a revision of an old idea in physiology: the human body and the cells within it are best described as volume conductors, in which charge is only conducted by dissolved electrolytes. The discussion relates to the term, "ungrounded," widely used by practitioners of bodywork, energetic and movement therapies.

The barefoot connection

Many people notice that they feel better when they walk barefoot on the earth. A worldwide *Society for Barefoot Living* promotes the benefits of taking shoes and socks off and walking naturally on the earth. On the basis of their experience, and medical research in the field of biomechanics, barefoot enthusiasts are convinced that many foot and back problems are partly caused by stresses and strains created by wearing shoes, which force us to stand and move in ways the human body was not designed for. One dramatic illustration of this appears to be the success of barefoot runners. The shod foot may explain the high injury frequency in North American runners, in contrast to the extremely low running-related injury frequency in

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barefoot populations (Robbins and Hanna, 1987). The barefoot running phenomenon has a variety of interesting explanations (see text box).

> Differences between barefoot and shod running are explainable in terms of biomechanics, energy efficiency, sensation and anti-inflammatory effects. For example, Bergmann et al. (1995) found that the forces acting on the hip joint were lower for barefoot jogging than for jogging in various kinds of shoe. Others have found that barefoot running involves lower oxygen consumption (Burkett et al., 1985; Flaherty, 1994). The ability to sense the terrain may also be a factor (Robbins and Gouw, 1990, 1991; Robbins et al., 1993). Finally, there are indications of anti-inflammatory influences of barefoot running because of reductions in planter fasciitis (Robbins and Hanna, 1987) and shin splints (Siff and Verkhoshansky, 1999).

Recent research summarized here and in Oschman (2007) indicates that there are other physiological and emotional benefits to making a barefoot connection with the earth. First, the electric field of the earth has a diurnal or daily rhythm. Diurnal refers to organisms that are active during the day. There is evidence that the earth's electrical rhythm may be involved in setting the biological clock for cortisol secretion. For example, as measured in Tucson, Arizona, the earth's field is weakest just before midnight, rises rapidly at 8 AM, reaches a peak just before noon, decreases till 3 PM, reaches a secondary peak between 5 and 6 PM, and again drops to near zero at midnight. This diurnal pattern is similar at any location on earth relative to the daily revolution of the earth (Gish, 1936). A suggested practical application of this concept arises from the frequent report that the effects of "jet lag" can be reduced at one's destination by removing shoes and socks and standing directly on the earth for 15 min.[1] This enables the electrical rhythm of the earth to reset the hormonal clocks governing sleep and activity rhythms.

Secondly, in a previous report it was hypothesized that free electrons from the earth can neutralize free radicals and thereby reduce either acute or chronic inflammation. Improved sleep, therefore, may also be a consequence of a reduction in the physical and emotional discomforts associated with painful conditions that are a consequence of inflammation. Relief from problems such as indigestion, asthma, arthritis pain and many autoimmune disorders can be obtained by direct contact with the earth.[2] The reason for this is that many disorders involve chronic inflammation, which can be reduced by free electrons from the earth. Various methods are being developed to maintain the benefits of conductive contact with the earth as much as possible throughout the day and night. We refer to connecting the body with the earth with the term, "earthing." This paper is one of a series of publications summarizing what is known about the benefits of earthing and the mechanisms involved. This paper focuses on the conceptual problem of how electrons are able to move from the earth to sites of inflammation in tissues.

These two concepts, (1) that the oscillating electric field of the earth could be the Zeitgebar or "time setter" for the cortisol clock, and (2) that free electrons can neutralize inflammatory free radicals, require further elaboration. In particular, it is necessary to explore the way these two aspects of physiology, the cortisol rhythm and inflammation, relate to each other. Key contributions to understanding this subject were made by the Canadian endocrinologist, Hans Selye (1907–1982), and his work will be discussed below.

The cortisol clock

Cortisol is widely regarded as "the stress hormone" because of its intimate involvement in the hormonal and biochemical cascades of responses to stresses of all kinds. One explanation for the effects of earthing on the cortisol rhythm is that there is a direct effect of the earth's electrical rhythms on the pineal gland (e.g. Foley et al., 1986).

The pineal gland attracted scientific attention in 1963, when its primary secretion, melatonin, was recognized as a hormone. Wurtman and Axelrod (1965) described the pineal as a "neuroendocrine transducer" that converts various rhythmic signals in the external environment (light, sound, temperature, magnetic and electric variations) into rhythmic neuroendocrine outputs. Melatonin is the

[1] At least 5 web sites recommend going barefoot for preventing jet lag. The suggestion is reasonable in view of the results of a previous report demonstrating that connecting to the earth normalizes the cortisol rhythm and improves sleep (Ghaly and Teplitz, 2004).

[2] Note that this statement is not implied to represent a medical diagnosis or treatment recommendation. If you have a medical problem, it is essential that you discuss it with a professional health care provider.

principal mediator of environmental rhythms with the biological clocks that affect many physiological systems. The pineal gland is uniquely suited for this purpose as it has one of the richest vascular supplies of any organ on a weight basis; it lies outside of the blood–brain barrier, but has direct access to the cerebrospinal fluid (CSF); it produces and/or contains high concentrations of a number of different secretions that regulate the endocrine systems; and its cells are magnetoreceptors and electric field receptors. In particular, the pineal is sensitive to both magnetic and electrical rhythms of the earth (Foley et al., 1986; Sandyk, 1995). Melatonin has been recognized as a "master hormone" involved in the control of a variety of circadian rhythms. These rhythms influence virtually every aspect of the organism, ranging from fundamental physiological and biochemical oscillations to hormones and neurohormones that profoundly influence mood and emotional state.

Free electrons as antioxidants

The second concept, that free electrons can neutralize inflammatory free radicals, is based on long-standing understandings of the nature of free radicals and their involvement in inflammatory processes. This is not a radical idea (no pun intended) as there is a substantial basis for the existence of free or mobile electrons in living systems (this topic will be discussed in more detail in another paper in this series). Moreover, there is extensive literature that electrons from antioxidant molecules can neutralize free radicals. This is a topic that has been extensively discussed in the scientific literature (at the time of writing this paper, the National Library of Medicine web resource, Pub Med, lists 7021 studies and 522 review articles from a search of antioxidant +electron+free radical); the phenomena involved are also covered in a number of books and international symposia. What is being suggested is that free or mobile electrons within the body can also serve as antioxidants when they are available in sufficient quantity; that free radicals act as electrophiles, attracting free or mobile electrons; that contact with the surface of the earth is the most natural way of obtaining free or mobile electrons; and that disconnection of the body from the earth can reduce the availability of free electrons in the tissues to the point that the normal response to injury is compromised. Specifically, free electrons in tissues can protect tissues surrounding a site of trauma from being damaged, can facilitate the completion of the injury repair process and can prevent or resolve chronic inflammation.

These findings come at a time when questions have been raised about the benefits of dietary antioxidant supplements. Specifically, Cook et al. (2007) followed more than 8000 women at high risk for cardiovascular disease who took Vitamins C, E, and beta-carotene, either alone or in combination, for close to a decade. There is considerable evidence that oxidative damage at the cellular level is involved in heart and vascular disease, and the hypothesis was that dietary anti-oxidants would be cardioprotective by reducing oxidative stress. Cook et al. (2007) found that no evidence of reduced risk of heart disease emerged from the study, although there were no negative effects. While more study is needed, the results are consistent with other studies indicating that powerful antioxidant effects identified through basic research may not carry over to the intact animal (e.g. Virtamo et al., 1998; Hercberg et al., 2004; Vivekananthan et al., 2003). A plausible and testable explanation for this is that the inflammatory barricade is relatively impermeable to both free radicals and circulating antioxidants.

The earth as a source of electrons

It is well established, though not widely appreciated, that the surface of the earth possesses a limitless and continuously renewed supply of free or mobile electrons. The earth's surface is electrically conductive and is maintained at a negative potential by an atmospheric electrical circuit (Williams and Heckman, 1993; Anisimov et al., 1999).

There are three main components to the global electric circuit: the solar wind entering the magnetosphere, the ionospheric wind and meteorological activities (Volland, 1984; Williams and Heckman, 1993). An estimated 1000–2000 thunderstorms are continually active around the globe, creating a constant current of thousands of amperes transferring positive charge to the upper atmosphere and negative charge to the surface of the earth. The earth's molten core may also liberate free electrons because it is composed of iron and nickel at high pressure and temperature, conditions known to produce free electrons. Because of the conductivity of the surface layers, these phenomena make the entire earth's surface an abundant source of free electrons (Geophysics Study Committee, 1986). While electrons are plentiful at the surface of the earth, the atmosphere is a relatively poor conductor; it is an insulator. Hence there is very little electron transfer from the ionosphere to the earth's surface except by lightening, and there is little charge transfer from the earth's surface to the human body except by direct conductive skin contact or by systems that connect the body with the earth.

Effects of earthing

Ghaly and Teplitz (2004) demonstrated that connecting the human body to the earth during sleep normalizes the daily rhythm of cortisol, widely recognized as the "stress hormone." Using an "earthing sleep system" (Figure 1a), the researchers noted improvements in sleep, reduction in pain and inflammation and other beneficial effects. A number of questions have arisen about the study of Ghaly and Teplitz (2004) and two appendixes have been included here to cover these issues.

The earthing sleep system consists of an electrically conductive mattress pad or sheet woven with carbon- or silver-coated fibers that couple to a wire that extends out a window and connects to a foot-long metal rod inserted into the earth (Figure 1a). Another technique is referred to as an earthing patch (Figure 1b) and is useful in the clinical setting. The patch has a peel-away strip over a conductive adhesive layer, and can be applied to any area of the body, such as an inflamed joint. As with the earthing sleep system, the patch connects to a grounding rod in the earth.

The movement of electrons from the earth to the body and vice versa was established in a study by Applewhite (2005). Connecting the body to the earth greatly reduces the currents and voltages induced on the body (documented by Ober, 2004; Ghaly and Teplitz, 2004; Applewhite, 2005). The physical effects are known, and evidence is gathering for physiological effects. Electric fields in the environment induce readily measurable voltages on and in the human body because the body has conductive components such as blood and extracellular fluid. This is technically referred to as capacitive coupling between a voltage source and the body. Home electrical wiring is an example of such a voltage source. Connecting the body to the earth essentially insulates the body from ambient electrical fields, and therefore has a protective or stabilizing effect on the electrons on and in the body. Appendix A explains this phenomenon and its implications in more detail.

A standard electrical engineering method for measuring the flow of electricity through a conductor is by determining the voltage drop between two points in a circuit. When there is a voltage drop

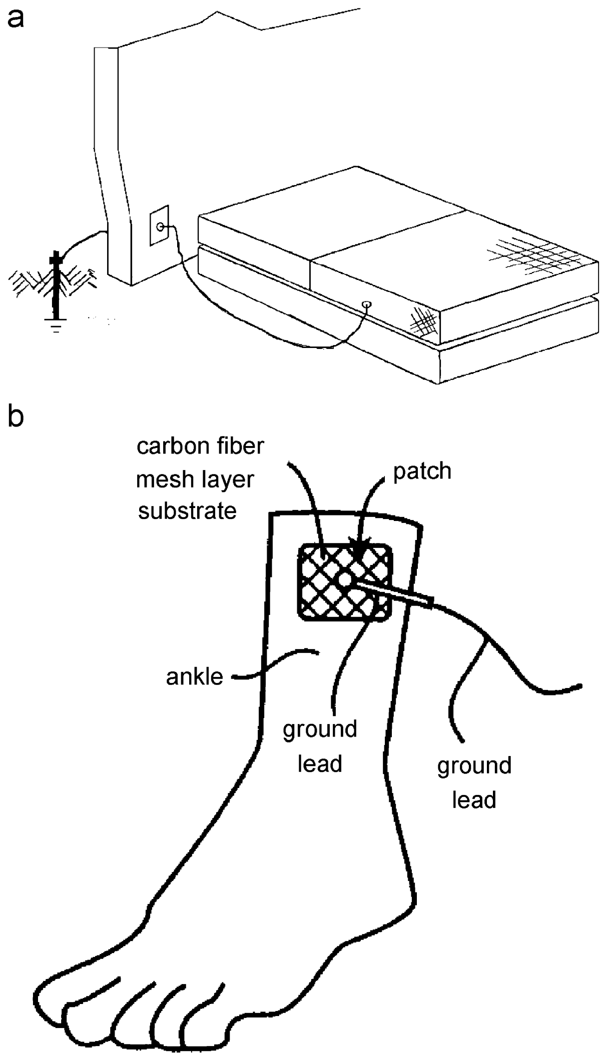

Figure 1 Earthing systems. (a) The sleep system consists of an electrically conductive mattress pad or sheet woven with carbon or silver fibers that couple to a wire that extends out a window and connects to a foot-long metal rod inserted into the earth. Pad covers the bottom third of the bed so that feet make conductive contact with it during sleep. (b) Earthing patch used in the clinical setting. The patch has a peel-away strip over a conductive adhesive layer, and can be applied to any area of the body, such as an inflamed joint. As with the earthing sleep system, the patch connects to a grounding rod in the earth.

there must be a current flow. Figure 2 shows oscilloscope recordings of the voltage induced on the ungrounded body from 60 Hz sources (top trace), the greatly attenuated body voltage with earthing system in place (middle trace) and the voltage drop across a 4.7 MΩ resistor in line with the lead to an earthing patch on the left palm (lower trace). Electric charge is being drawn through the grounding lead from the earth to the body and vice versa with each oscillation of induced

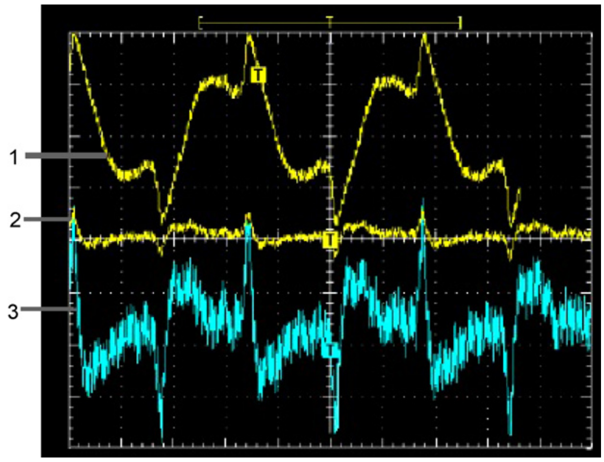

Figure 2 Oscilloscope recordings of voltages induced on the ungrounded body from 60 Hz sources (top trace); attenuated body voltage with earthing system in place (middle trace); and the voltage drop across a 4.7 mΩ resistor in line with the lead to an earthing patch on left palm (lower trace). Voltage drop is indicative of current flow. Electric charge is being drawn through grounding lead from earth to the body and vice versa with each oscillation of induced voltage. In other words, the earth is alternatively serving as a "source" and "sink" for electricity induced on the body, greatly reducing the induced voltage. The shape of the voltage drop waveform is similar to the shape of the body voltage waveform. This finding establishes the movement of electrons from the earth to the body and vice versa.

voltage. In other words, the earth is alternatively serving as a "source" and as a "sink" for electricity induced on the body, greatly reducing the induced voltage. The shape of the voltage drop waveform is similar to the shape of the body voltage waveform. This finding establishes the movement of electrons from the earth to the body and vice versa, and raises a number of questions about electron flow in the body. The purpose of this paper is to further discuss the mechanisms and therapeutic implications of the earthing phenomenon and the mechanisms of charge transfer in tissues.

Silent inflammation and inflammatory pockets

Biomedical research from around the world is revealing that chronic or "silent" inflammation is the culprit behind virtually every chronic disease (summarized by Oschman, 2007). Inflammation is defined as a localized response to trauma or infection that can wall off damaged tissues until the immune system removes foreign matter, damaged cells and/or bacteria. When the inflammatory response does not completely wind down, palpable "inflammatory pockets" can persist for many years, slowly releasing toxins that can damage organs anywhere in the body. The phenomenon was described by the famous stress researcher, Hans Selye (1956), in his classic book, *The Stress of Life* and in various articles published in the *Journal of the American Medical Association* (e.g. Selye, 1953) and other periodicals. A search of Pub Med revealed 1082 references to the inflammatory pouch, with some specifically referring to the use of the "Selye Pouch" for the study of inflammatory reactions (e.g. Davis et al., 1981).

Selye's work tied inflammatory responses with stress, cortisol secretion and adaptation. Selye and others have obtained evidence that necrotic tissue breakdown products from inflammatory pockets can leak into the blood and lymphatic circulation, producing slow but progressive atrophy in various organs a distance from the original site of trauma. For example, on page 161 of the first edition of *The Stress of Life*, Selye mentions that he was able to inject inflammatory pouches in rats with irritants and microbes that produced a syndrome characterized by an inflammation of the heart valves (endocarditis) very similar to that which occurs in children suffering from rheumatic fever. Under some conditions this was accompanied by inflammation of the kidney (nephritis) and excessive stimulation of the blood-forming organs.

This inflammatory pouch concept explains how local pockets of inflammation can trigger a diversity of chronic diseases and disturbances, many of which frustrate the physician because it is difficult to locate the cause. "Silent inflammation" refers to a condition in which the inflamed site is not painful, and may go unnoticed, even though it is causing problems elsewhere in the body. The phenomenon was described long ago in dentistry, beginning with 25 years of root canal research by Dr. Weston Price (see Meinig, 1994), but currently receives little attention except by "biological" dentists.

Inflammation and bodywork

The existence of walled off areas such as described by Selye is known to practitioners of bodywork, energy and movement therapies. For example, Ida P. Rolf, in her book, *Rolfing*, stated that, "In practically all bodies, in one muscle or another, small lumps or thickened non-resilient bands can be felt deep in the tissue. The lumps may be as small as small peas or as large as walnuts." Rolf reproduced Selye's picture of an inflammatory

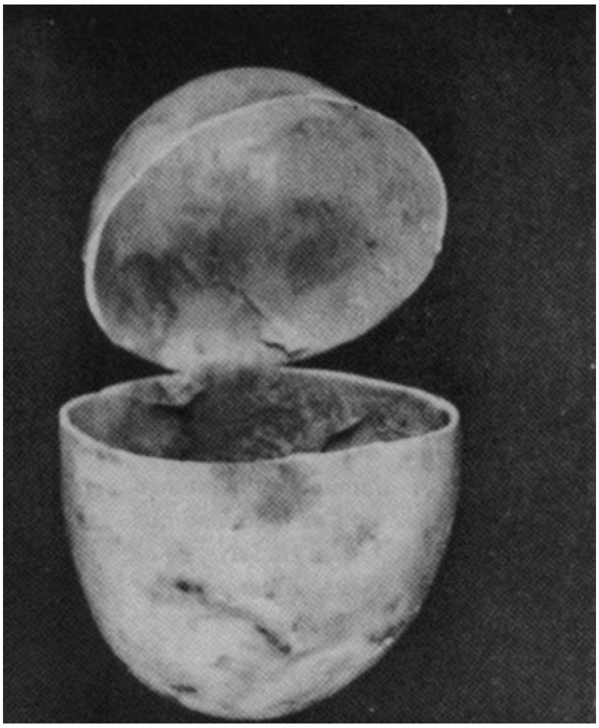

Figure 3 Inflammatory pouch (Selye pouch) produced by injecting air into fascial sheaths. Reproduced from Selye H. 1953 and reproduced by permission of the American Medical Association. Copyright © 1953, American Medical Association. All Rights reserved.

pouch produced by injecting air into fascial sheaths. The picture is reproduced here as Figure 3. ''Some similarly injurious process no doubt gives rise to the lumpy knottings we have noted''(Rolf, 1989).

Some of the benefits of Rolfing® (Structural Integration) and other bodywork, energetic and movement techniques may derive from their ability to reduce or eliminate these pockets of inflammation, and thereby relieve chronic illnesses. Likewise, a variety of therapeutic technologies introduce or induce electric currents that flow within tissues. Examples include Frequency Specific Microcurrent (McMakin, 2004); Pulsing Electromagnetic Field Therapies (Bassett, 1995); and Ondamed (Oschman and Kosovich, 2007). It is worthwhile to explore the possibility that successes with these techniques may in part be due to induced movements of free electrons across inflammatory barricades.

> The original clinical trials of 20 subjects using medical infrared imaging can be found at http://www.earthfx.net/pdf/EFX_science_Amalu.pdf. A summary can be found in Oschman (2007).

Clinical trials

Clinical trials (see box) have used medical infrared imaging and clinical outcomes to assess changes taking place when the body is connected to the earth. Because it measures heat, medical infrared imaging easily detects acute or chronic inflammatory conditions. The value of the method has been documented by countless research studies (reviewed by Amalu et al., 2006). Experts in medical infrared imaging are particularly interested in ''hot spots'' and left-right imbalances corresponding to areas of discomfort that are therefore indicative of inflammation. The data obtained by medical infrared imaging and the corresponding clinical changes are documented in a previous paper (Oschman, 2007). The mechanisms involved in charge transfer from the skin to sites of inflammation are discussed in the next paper in this series.

Sleeping on the earthing sleep system significantly reduced inflammation and restored normal thermal symmetry. The earthing patch was also tested in a clinical setting. The patch provided permanent reductions in pain, improved overall health and return to a normal lifestyle. In some cases the clinical changes took place within 30 min of the first use of the earthing patch; in others steady improvement took place during multiple treatments. Conditions treated included acute sprains, chronic myofascial pain syndrome, muscular strains, ligamentous sprains, peripheral neuropathies, carpal tunnel syndrome, inflammatory joint conditions, Lyme disease, chronic sinusitis, and a variety of other maladies. Up to 80% improvement took place in over 60% of the cases within 2–4 weeks of half-hour treatments given 2–3 times per week. These results are summarized and discussed in Oschman (2007).

Physiological effects, performance and recovery

Chevalier et al. (2006) published a double-blind study of the effects of earthing on 58 healthy adult subjects. Earthing produced statistically significant and nearly instantaneous reductions in overall stress levels and tensions in the body as measured by electroencephalograms, electromyograms and blood volume pulse. The physiological changes indicate reductions in overall stress levels and tensions, and a shift in autonomic balance upon earthing. The electromyography studies showed that muscles that are tense relax, and muscles that are hypotoned are restored to normal tension.

Finally, the effectiveness of connecting the body to the earth in enhancing performance, speeding injury repair and facilitating recovery was documented by Dr. Jeffrey Spencer during the most recent three *Tour de France* victories of the US Cycle Team lead by Lance Armstrong and the 2007 victory by Alberto Contador and the US Team. Connecting the cyclists to the earth during sleep and also during the acute phases of injury seemed to enhance overall performance, speed injury repair and facilitate recovery. For more details, see Oschman (2007).

Taken together, research and experience with the earthing systems suggest that it is desirable to maintain contact with the earth as much as possible throughout the day and night. Free or mobile electrons from the earth appear to be responsible for reduction in inflammation and correlate with a variety of other benefits.

Assume a spherical cow

The research summarized above shows that connecting the body to the earth leads to reduction of inflammation, and also shows that the effects are correlated with the flow of electrons from the earth to the body and thence to sites of inflammation. The most plausible explanation is that free electrons neutralize the free radicals that are the hallmark of chronic inflammation.

This phenomenon raises some questions about the biological roles of free electrons. In the past it has been assumed that all electrical currents developed within the human body are conducted by dissolved electrolytes rather than electrons. According to the Arrhenius theory of dissociation, salts react with water to form separate ions, such as Na^+ and Cl^-, and these ions give solutions their ability to conduct electricity. This is referred to as electrolytic charge transfer. It has also been assumed that the interior of the human body is best described as a continuous *volume conductor*. In other words, to simplify the application of the principles of electrical engineering to living systems, the body and the cells within it are regarded as simple bags containing homogeneous solutions of proteins and electrolytes.

The situation in relation to inflammation has to be more complex than this because of the ways inflammatory areas can be walled-off from surrounding tissues within the inflammatory pouches originally described by Selye. Moreover, the volume conductor assumption disregards significant areas of biomedicine: anatomy, histology and cell biology. The volume conductor assumption, when taken as fact, promotes a distorted perspective on life and health that is incompatible with the actual structure and function of living systems.

This paper begins to look beyond the volume conductor and electrolytic charge transfer assumptions so that we can explore the existence and movement of free or mobile electrons from the earth and through the body and through the inflammatory barricade, where the electrons can neutralize free radicals. A subsequent article expands on the role of electrons in bioenergetics and physiological regulations.

The spherical cow (Figure 4) comes from a story that is often told in physics classes. A farmer is having trouble getting enough milk from his cows, and consults a physicist. After pondering the problem for a while, the physicist begins his analysis with the statement, "Assume a spherical cow."

The story draws attention to a method widely used by scientists: they make simplifying assumptions to make it easier to tackle problems that would otherwise be too complex. Such assumptions have played vital roles in helping us understand a wide variety of biological and medical problems.

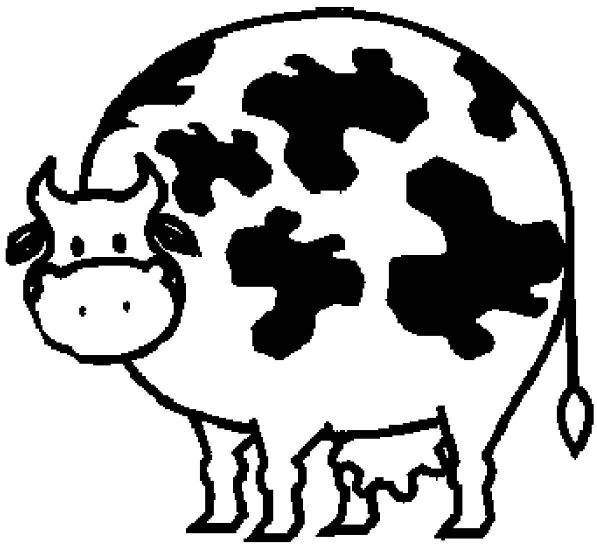

Figure 4 The spherical cow comes from a story that is often told in physics classes. A farmer is having trouble getting enough milk from his cows, and consults a physicist. After pondering the problem for a while, the physicist begins his analysis with the statement, "Assume a spherical cow." This illustrates a situation that arises frequently in science: a tentative assumption is made to simplify calculations. It begins with, "assume a spherical cow"; progresses to "it can be assumed that cows are spherical"; and finally leads to "cows are spherical." This article concerns the progression from "assume the body is a volume conductor" to "the body is a volume conductor."

A difficulty arises, however, when we forget that an assumption is an assumption and is meant to be tentative. Over a period of time, an assumption can go through several stages:

1. to simplify our calculations, we assume a spherical cow
2. it can be assumed that cows are spherical
3. cows are spherical

Meaning invariance

This type of problem occurs again and again in science. It is always instructive to examine tentative assumptions about living systems that were temporarily useful, but that have gradually come to be taken as facts. This tendency, to retain the definitions of terms that were acceptable in early stages of a study or science, is called 'meaning invariance.'

Philosopher of science, Paul Feyerabend (1981) wrote:

> ...any form of meaning invariance is bound to lead to difficulties when the task arises either of giving a proper account of the growth of knowledge, and of discoveries contributing to this growth, or of establishing correlations between entities which are described with the help of what we will later call incommensurable [unmeasurable] concepts. ... it will usually turn out that a solution of these problems is deemed satisfactory only if it leaves unchanged the meanings of certain key terms and it is exactly this condition, the condition of meaning invariance, which makes them insoluble.

In other words, we are discouraged from discussing electronic conduction in living tissues because it would be inconsistent or incompatible with the volume conductor assumption and all of its consequences and implications, which extend throughout the fields of physiology and medicine.

On the same subject, Northrop (1959) comments:

> One of the basic problems in the unification of scientific knowledge is that of clarifying the relation between those concepts which a given science uses in the early natural history stage of its development and those which enter into its final and more theoretical formulations as a verified deductive theory.

In the context of inflammation, and a wide range of other physiological and biomedical issues, meaning invariance poses deep problems. The *volume conductor assumption* actually confuses our conceptualization of ourselves, our health, disease and the healing process. The volume conductor assumption perpetuates an intangible or incommensurable barrier to the integration of conventional biomedicine with complementary and alternative therapies, and vice versa. It is necessary to look closely at the volume conductor assumption to understand the phenomenon of earthing. In the process, we may clarify some other unsolved problems in physiology and medicine, as well as in bodywork, energetic and movement therapies. The mobile electron has many potential roles in vital processes such as bioenergetics, regulation and communication.

Assumptions and deductive logic

The dictionary tells us that an assumption is a tentative proposition that is taken for granted. In other words, assumptions are treated for the sake of a given discussion *as if* they are true. In logic, in the context of deductive reasoning, an assumption is made in the expectation that it will be *discharged* in due course, once the goals that necessitated the assumption have been achieved, or when more details are known so that more realistic assumptions can be made. Logical processes that begin with simplifying approximations must, of necessity, give rise to simplified or approximate answers. Some philosophers who explore the methods of science recognize that virtually all scientific discoveries are based on assumptions or approximations of one kind or another, and that scientific truth is therefore always relative or approximate (e.g. Singer, 1986; Ratcliffe, 1983).

To understand earthing and other methods that stimulate the movement of electrons within the body, we must appropriately *discharge* the volume conductor assumption and replace it with assumptions that are closer to reality and that can therefore lead us to conclusions that are closer to reality.

Going beyond the cell as a volume conductor

We begin with the cell, widely held to be the fundamental unit of life. Since Virchow (1858) the cell has also been considered the source of all pathology and the focus for treatments. It is often assumed that the cell is a bag containing a solution of electrolytes and proteins, with a nucleus and some organelles such as mitochondria floating around within. Outside of the cell is a connective tissue matrix that is also immersed in a salt solution. This scheme, depicted in all texts, is shown in Figure 5.

In the late 1960s and 1970s the author conducted extensive research in the field of membrane transport. At that time considerable progress was being made in the study of how water, ions and organic molecules are transported across layers of cells (epithelia) such as are found in intestine, kidney, liver, choroids plexus, cornea, various glands and so on (Berridge and Oschman, 1972). In 1958, Koefoed-Johnsen and Ussing published a classic transport model (Figure 6) to account for the electrical and permeability properties of the frog skin, one of the most widely used systems for studies of active transport across biological membranes. This is a classic example of a "black box" model in which the skin cell is represented as two membranes with differing active and passive transport properties. In the model, the cell interior is assumed to be a bag containing a homogeneous solution of electrolytes and organic molecules. Studies of Hodgkin and Keynes (1953) seemed to support this view, since potassium ions appeared to diffuse freely through the axoplasm of the squid giant nerve fiber.

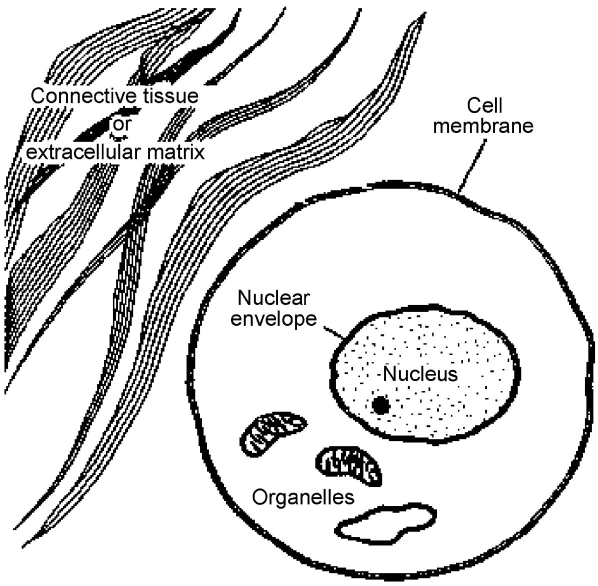

Figure 5 Image of the cell and its surroundings as described in most texts. It is assumed that the cell is a bag containing a solution of electrolytes and proteins, with a nucleus and some organelles such as mitochondria floating around within. Outside of the cell is a connective tissue matrix that is also immersed in a salt solution.

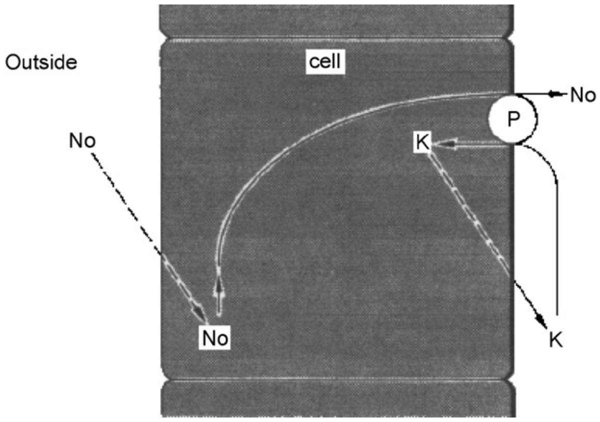

Figure 6 Classic model of a cell in the skin of a frog, a widely used model for studying active transport across cell membranes. This is a classic example of a "black box" model in which the skin cell is represented as two membranes with differing active and passive transport properties. The cell interior is assumed to be a bag containing a homogeneous solution of electrolytes and organic molecules. Based on Koefoed-Johnsen and Ussing (1958), reference 21.

The "bag of solution" model was supported by the first electron microscope pictures of sections of cells, which showed a lot of seemingly empty spaces. This eventually proved to be an artifact. Until 1962, the only satisfactory fixative for electron microscopy was buffered osmium tetroxide. Osmium preserved cellular structures by combining with lipids, especially in membranes, and by precipitating some of the proteins. The osmium atom contains 76 electrons, making it is very dense in the electron microscope, and giving contrast to everything it sticks to. But osmium penetrates tissues very slowly, and extracts most of the protein and RNA from cells. A large part of cellular structure simply does not show up in the electron microscope when osmium is used as the fixative.

This picture changed dramatically in 1963, when glutaraldehyde was introduced as a fixative (Sabatini Bensch and Barrnett, 1963). Glutaraldehyde rapidly penetrates into tissues and insolubilizes proteins. Glutaraldehyde forever transformed electron microscopy as well as our understandings of cell structure. It was soon realized that the "empty spaces" seen in early electron micrographs were actually crowded with structures. Over the years, it has been recognized that the cell interior is virtually packed with microtubules, microfilaments, intermediate filaments, vesicles, membranes, RNA particles and many other objects. And every cell has an internal "skeleton" called the cytoskeleton. There is so much cytoskeleton and other structure tightly packed inside of cells that some biologists think there is virtually no space left over for a solution of electrolytes and proteins (reviewed by Luby-Phelps, 2000). Edelmann (2002) has devised an electron microscope technique in which tissues are frozen-dried in a manner that appears to preserve macromolecular structures with their natural hydrated structure. The images obtained reveal cellular cytoplasm with very fine granularities and well-defined membranes in negative contrast.

It was also discovered that the internal cytoskeleton is directly and continuously connected to the fibers of the extracellular matrix by molecules now known as integrins (Gille and Swerlick, 1996). Deep inside the cell, the cytoskeleton also interconnects with the nuclear matrix (Pienta and Coffey, 1992; Maniotis Chen and Ingber, 1997). Figure 7 shows a much more realistic image and detail of the cell and its relationships with the surrounding matrix than Figures 5 and 6. The whole system, connective tissue plus cytoskeletons plus nuclear matrix has been termed *the living matrix* (Oschman, 2000).

Glutaraldehyde fixation and the discovery of the integrins were big advances, but the images of the cell interior as a bag of solution had become ingrained in the thinking of many biologists. Hence when new biology and medical textbooks are written, the model shown in Figure 5 is repeated again and again. Most of these texts include an inaccurate drawing of the cell in the introductory chapter. This means that the beginning student is immediately exposed to an erroneous picture of the cell that influences all of their subsequent thinking about structure and function in living systems. In a few texts, the cytoskeleton is mentioned, but not in the context of the overall structure of the cell. This inaccuracy persists to the present day in all biomedical textbooks.

In contrast, texts related to bodywork, energetic and movement therapies often include images of the cell similar to that shown here in Figure 7. Examples include Myers (2001), Chaitow (2005), Lee (2005), Frederick and Frederick (2006), and Oschman (2003). With the exception of cell and membrane biologists, biomedical researchers rarely question textbook images of cell structure. In contrast, those seeking a more holistic perspective prefer to base their thinking on images that are more accurate in terms of structural detail. The concepts that follow from Figure 7 are holistic in that the matrix provides a rigorously scientific description of a continuous mechanical and energetic system that extends into every part of the organism. A model of this kind provides the basis for whole-person phenomena such as peak performance, spontaneous healing, acupuncture and the martial arts. Specifically, the matrix appears to serve as an "energetic nervous system" that conducts packets of energy and information much faster than nerve impulses.

In Germany a sophisticated school of research and clinical medicine developed around the discoveries of Alfred Pischinger, Hartmut Heine and their colleagues. The important book describing this work, *The Extracellular Matrix and Ground Regulation; Basis of a Holistic Biological Medicine*, has been difficult to obtain in English, but a new and updated translation has now been published (Pischinger, 2007). In contrast to Virchow's cellular pathology, this group regarded the fundamental unit of life, and the place to look for pathology, to be a triad consisting of the capillary, the cell and the matrix between them (Figure 8).

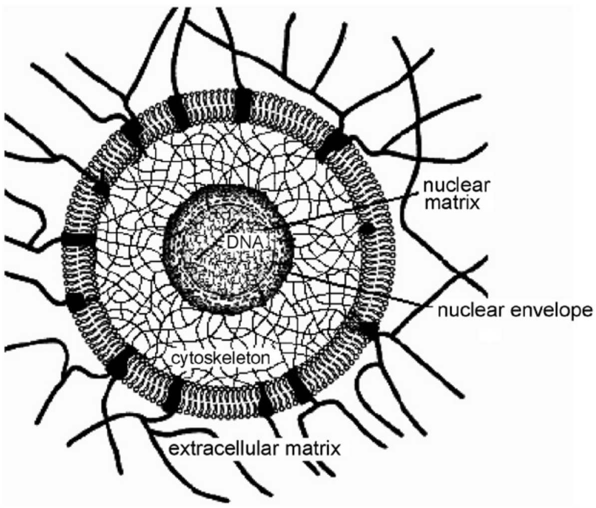

Figure 7 More accurate and realistic image of the cell and its relationships with the surrounding matrix. The whole system, connective tissue plus cytoskeletons plus nuclear matrix has been termed *the living matrix* (Oschman, 2000).

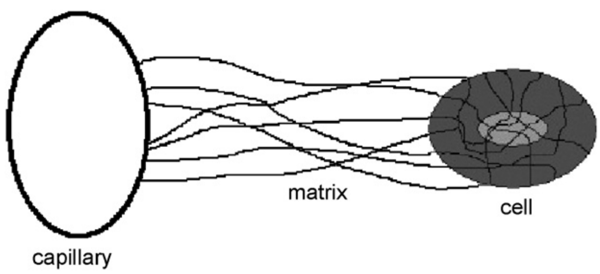

Figure 8 Pischinger's model of the fundamental unit of life, consisting of the triad: capillary, cell and extracellular matrix. See *The Extracellular Matrix and Ground Regulation: Basis for a Holistic Biological Medicine*, by Pischinger (2007).

The body as a volume conductor

The main goal of this article is to raise the question of how electrons move about within living systems. The volume conductor concept and electrolytic charge transfer are assumptions that greatly simplify the quantitative study of the movement of molecules and electrical charges in the human body. But the body obviously contains many layers and compartments and structures such as bones and connective tissues and organs, and each of these elements has particular permeability properties as well as electrical, dielectric, electronic and other aspects. For the electrical engineer or the biochemist, this picture is usually much too complicated to think about all at once.

To model the movement of molecules and charges in the body, it is convenient to make the simplifying assumption that the body consists of the five compartments shown in Figure 9: mouth, gut, circulatory system, extracellular matrix and cell. Food or drugs taken into the mouth enter the gut, where they dissolve. Water, ions, nutrients and drugs are then absorbed across the wall of the gut, into the circulatory system, are carried throughout the body, diffuse across the walls of the blood vessels, and enter the extracellular matrix, the so-called volume conductor. Substances then diffuse through this volume conductor to the cells. Once a molecule gets to a cell, it can affect the cell surface or it can enter the cell, which is also approximated as a volume conductor. In either case, the molecule influences cellular behavior. Hence the simplest model of how nutrients, oxygen, hormones, growth factors, neuropeptides, and drugs move through the extracellular space is simple random diffusion through a uniform dilute solution of electrolytes. The simplest model of the flow of electricity to and from organs such as the heart and brain is that the charges are moving back and forth between the skin surface and internal organs, with the currents carried by flows of ions, such as sodium and potassium, in a uniform volume conductor.

Of course, this model does not take into account the way human bodies are actually constructed. However, the assumption that cells and the human body as a whole form a volume conductor has gone through the stages described above:

1. to simplify our calculations, we assume the body is a volume conductor
2. it can be assumed that the body is a volume conductor
3. the body is a volume conductor

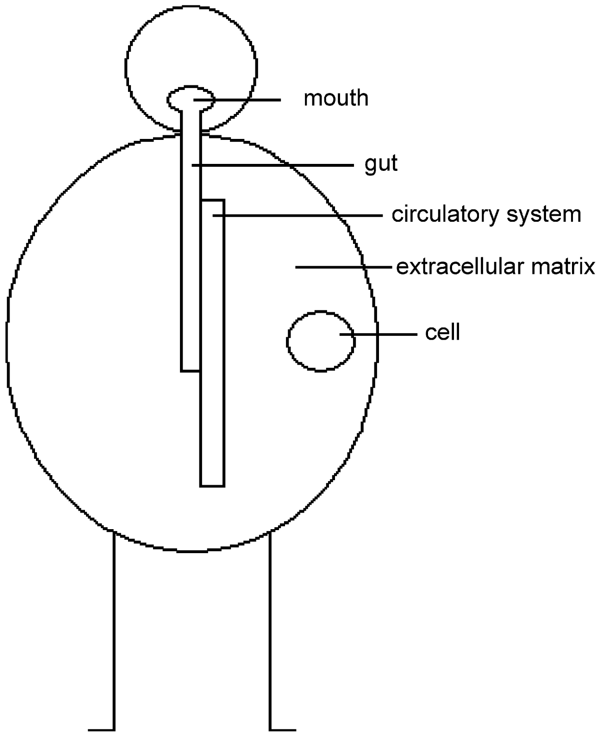

Figure 9 Over-simplistic model the movement of molecules and charges in the body based on the assumption that the body consists of five compartments: mouth, gut, circulatory system, extracellular matrix and cell. Food or drugs taken into the mouth enter the gut, where they dissolve. Molecules are then absorbed across the wall of the gut, into the circulatory system, are carried throughout the body, diffuse across the walls of the blood vessels, and enter the extracellular matrix, the so-called volume conductor. Substances then diffuse through this volume conductor to cells. It is also assumed that the flow of electricity between the skin and organs such as the heart and brain involves electrolytes acting as charge carriers in a uniform volume conductor.

References to the body as a volume conductor are widespread in medical research. A search of the National Library of Medicine web site, Pub Med, reveals 537 references to the term, *volume conductor*, with 26 references in the year 2006. The volume conductor assumption is applied in studies of cardiology, magnetic resonance imaging, brain stimulation, tumor detection, muscle stimulation, epilepsy, edema, vision, drug action and so on. Malmivuo and Plonsey (1995) have an extended discussion of volume conduction in the context of bioelectromagnetism. They also provide a detailed discussion of the "distortion factors" that influence the quality of signals such as those recorded from the heart. These distortions arise because of the inaccuracies in the volume conductor and other assumptions. For example, the heart is not a simple dipole in a fixed location; the thorax does not have a uniform shape; and the thorax is not homogeneous.

Going beyond the volume conductor assumption

There is a detailed literature on the structure and properties of cellular and extracellular matrices. Reviews of the literature on the composition of the "ground substances" found in the nuclear matrix, the cell interior and the extracellular material revealed that they are electrically charged polymer networks (Oschman, 1978, 1981). Biomedical researchers rarely reference this information because the connective tissue and myofascial systems have not received the same attention as other organ systems in the body, even though they form the largest and most pervasive and ubiquitous of all of the body systems. It can be reasonably stated that the living matrix is the organ system that all of the other organs and tissues are made of. The connective tissue consists of the superficial and deep fascia, including the myofascial coverings of muscles, the periosteum of bones, and the bones themselves.

Blood is considered part of the connective tissue, as are cartilage, ligaments, and tendons. The tough layers surrounding the digestive tract, blood vessels, and nerves are also connective tissue. Research done in the 1960s revealed that the intercellular material is composed of polyelectrolytes, mostly soluble acidic glycoproteins, which are cross-linked by calcium ions to each other and to other carbohydrate groups anchored in cell membranes. These molecules form a meshwork upon which various small serum proteins are adsorbed and/or precipitated. For a review of this topic, see Oschman (1978). The negative charges on the carbohydrate chains of the intercellular polyelectrolytes are due to the presence of sulfate, carboxyl and phosphate groups, which have as their counter ions Na^+, K^+, Mg^{++} and Ca^{++}. Anions may also be associated with positive charges (e.g. of the basic amino groups) on the adsorbed proteins. The spatial arrangement of the various charged groups, their field strengths and their concentrations are key factors in determining the conductance and selectivity and diffusivity of the extracellular domain. The extracellular space thus has similarities to an ion-exchange resin, a molecular sieve, a gel filter, and a strongly adsorbing chromatographic column (e.g. Comper and Laurent, 1978).

The properties of the matrix can also be described in terms of its electronic, semiconductive, dielectric, capacitive, and electrolytic characteristics (e.g. Grimnes and Martinsen, 2000). For example, it is likely that both the earth's surface and the human body connected to the earth contain "clouds" of free electrons that are able to migrate to sites of inflammation. This topic is beyond the scope of this publication, and will be taken up in the next in this series of publications on earthing. However, it is obvious that it is a huge stretch to equate the interior of the human body with a simple volume conductor, with charges migrating only as dissolved electrolytes.

The volume conductor approximation actually disallows or is incommensurate with certain phenomena that are worthy of study. This is particularly important in the study of inflammation, which, by definition, is "a localized protective response in trauma or microbial invasion that destroys, dilutes, or walls-off the injurious agent and the injured tissue" (Gallin and Snyderman, 1999). The properties of the inflammatory barricade are key to any consideration of how local pockets of inflammation can persist, how they can generate chronic disease, and how they can be treated clinically. We need to consider some important questions:

1. What are the molecular permeability properties of the inflammatory barricade?
2. Can cells of the immune system penetrate through the barricade?
3. How readily do toxins produced during inflammation leak across the barricade into surrounding tissues?
4. How readily do anti-oxidant molecules penetrate the barricade?
5. Do free radicals cross the barricade?
6. Can electrons, protons or electric currents traverse the barricade?
7. Precisely how does the barricade form, and what conditions favor its breakdown after it has served its purposes.

Hence the simplifying assumption that the human body is a volume conductor, in which electricity is conducted by mobile ions, does not apply to the important physiological problem of inflammation. From the considerations described here, we must look at other ways charge can move about within organisms, with particular interest in the charges that can neutralize free radicals. This will be done in detail in the next publication in this series.

Meaning of "ungrounded" in bodywork, energetic and movement therapies

Practitioners of bodywork, energetic, and movement therapies often use the term, "ungrounded" to describe certain patients. This is a whole-person perspective that takes into account such subjective qualities as one's mental and emotional state, one's connection with oneself, one's body and one's surroundings. Ungrounded people are sometimes described as "scattered" or quietly frenzied or simply uncomfortable. They may be pale, fatigued, uncoordinated or injury-prone. They are often described as disconnected from the earth. Psychological calmness is sometimes equated with being grounded (Kapke, 2005; Rose, 2006).

The "ungrounded" patient with a substantial amount of pain and inflammation could be a person who has become depleted of mobile or free electrons. As their pockets of inflammation are reduced during a hands-on therapy session, they could be drawing free electrons from their therapist who is in electrical contact with them. This could explain the "depleted" feeling that bodyworkers sometimes experience as a consequence of working on chronic patients. In essence, the therapist has donated his or her electrons to the patient during the session. To counter this problem, most therapeutic schools teach the importance of rinsing the hands in cold water after a treatment. Since the water system is in contact with the earth, it is likely that, among other things, hand rinsing restores electrons to the therapist's body. Hence, the phenomenon of earthing adds depth to the usual definition and understanding of the term "ungrounded" as used in the bodywork, energetic, and movement therapy professions. In many cases, the term may refer, in part, to the extent to which an individual has become electrically disconnected from the earth.

Because the atmosphere is a poor conductor of charge, the insulated shoe and modern living environments not only cause a person to become electrically disconnected from the earth, they are also responsible for a sustained deficiency of free electrons on and in a person's body. A person can live months or even years without ever coming into direct electrical contact with the earth. The ability of the body to hold an electrical charge is well known, especially in the winter, when a low humidity environment creates conditions for static charge build up on the body causing the familiar spark to jump when contacting a doorknob or other metal object. The ability to sustain a static charge (deficiency of electrons) is also well recognized in the electronics industry. Millions of electronics workers connect to the earth every day with electrostatic discharge systems to prevent them from introducing damaging static electricity into the circuits they are working on.

Conclusions

Conductive contact between the earth and the human body during sleep and at other times appears to be useful for facilitating recovery from both acute and chronic injury. The effects appear to be related to the ability of tissues to absorb from the earth mobile electrons. These mobile electrons can have a protective effect on healthy tissues and thereby eliminate or limit collateral damage from the respiratory burst. It is suggested that mobile electrons can also traverse the inflammatory barricade and thereby neutralize free radicals that have accumulated in pockets of inflammation. Semiconduction is proposed as the mechanism of conduction of free electrons within tissues. This concept requires a revision of an old concept in physiology: that the human body and the cells within it are best described as volume conductors, in which charge is conducted by dissolved electrolytes.

The findings come at a time when the inflammation theory of disease is receiving widespread support from biomedical research. Virtually every modern disease, including the diseases usually tied to aging, have been linked with chronic inflammation. The list includes some of the most serious epidemics of our times, including Alzheimer's Disease (Di Rosa et al., 2006) and Autism (Jepson and Johnson, 2007). The proposed role of electrons as anti-oxidants may account in part for the success of a wide variety of complementary and alternative therapies as well as therapeutic devices that introduce electric fields into the body. A reasonable and testable hypothesis is that these methods produce some of their therapeutic outcomes by favoring the migration of clouds of free electrons into pockets of inflammation, where the electrons neutralize free radicals, and thereby resolve chronic inflammation that can be the source of an otherwise persistent or intractable disease or disorder. For example, "hands-off" energy techniques sometimes used in Polarity Therapy, Therapeutic Touch, Healing Touch, Reiki and other methods may involve the movements of mobile electrons in response to the therapist's biomagnetic field. The ways these phenomena may interact with and influence traumatic emotional memories (Redpath, 1995; Oschman, 2006) is a topic for future investigation.

Acknowledgements

I thank Clinton C. Ober, inventor of the earthing systems described in this report, for many valuable discussions of his observations on thousands of people who have used the system he developed and patented. I am indebted to Dr. Jeff Spencer for reporting the results of applying the earthing sleep system during 4 successful competitions of the US Cycling Team in the *Tour de France*. I thank Dr. William Amalu, DC, DABCT, DIACT, FIACT for conducting and reporting the clinical trials with medical infrared imaging and clinical outcome measures. Dr. Amalu is President of the International Academy of Clinical Thermology. Valuable comments on the manuscript have been provided by Dale Teplitz and MJ Pangman. Gregory O'Kelly kindly sent his unpublished manuscripts that included discussion of the philosophy of science concerning meaning invariance and the problems with the widely held view that ions are the primary charge carriers in living systems. I thank Dr. Mae-Wan Ho for informing me about the work of Ludwig Edelmann.

Appendix A

Health effects of induced voltages

Connecting the body to the earth essentially insulates the body from the influences of ambient electrical fields. This may have significant physiological benefits. A technical description of the phenomena is given in this Appendix, followed by a simple analogy. In essence, when the body is in an alternating electrical field, each oscillation pulls the body's free electrons in one direction and then pushes them in the other direction. If the body is immersed a variety of sources of electrical fields of various intensities and coming from a variety of directions (this is common in a modern environment), it's free electrons will be pulled hither and thither in an intricate dance. When the body is connected to earth, with its unlimited supply of electrons, nearby oscillating electrical fields have virtually no effect on the free electrons within the body, and the electrons will therefore be more available to carry out appropriate functions.

The human body is exposed to household and workplace 50 or 60 Hz electric fields that are continuously radiated from electrical wiring and from cords connected to appliances. This is true even if the appliances are switched off. When the body is insulated from the earth, it becomes a "free floating" dipole antenna that attracts and resonates with ambient electrical fields. The fields then induce measurable alternating voltages on the surface of the body (Dolbear, 1901). In terms of possible health effects, these fields are particularly significant during the 6–10 h period when a person is sleeping in proximity to energized electrical wires and cords near their bed. In essence, the electrons in the body are in continuous motion and are therefore less available to neutralize free radicals in inflamed tissues and perform other functions. The magnitude of the induced voltage can be determined by touching one terminal of a voltmeter that has the other terminal connected to earth.

Electrical contact with the earth creates an entirely different physical situation in which the body is shielded from the effects of ambient electrical fields. Under these conditions, the body is maintained at the same electrical potential or voltage as the earth. Ambient fields cannot affect the potential on the body. In essence, to change the potential on the body, an ambient field would have to alter the entire field of the earth, and this is obviously impossible, given the enormous number of earth electrons that would have to be vibrated. The grounded body is not a "free floating" dipole antenna. Under earthed conditions the free electrons on and in the body are not being pushed and pulled by external fields. The body's electrons are therefore available to participate in various regulatory functions such as protecting healthy cells from oxidative stress. Indeed, one significance of sleep may be to provide an opportunity for the healing of the minor bumps and bruises accumulated during the day. Sleep in the presence of an oscillating electrical field may slow this process and thereby contribute to the General Adaptation Syndrome described by Selye.

A comparable situation exists for shielding of electronic cables and equipment by grounding their housings to the earth. Shielding is widely used to prevent external electromagnetic fields from interfering with electronic processes. The following non-technical analogy may clarify the phenomenon. Consider plunging your finger up and down in a glass of water. Each finger movement will cause the water level to go up and down dramatically. Now consider plunging your finger up and down in the water at the edge of a lake or ocean. Because of the enormous volume of water, up and down finger movements have little effect on the water level, either locally or at a distance. Similarly, a body connected to the earth's infinite supply of electrons will be at the same electrical potential as the earth, and nearby oscillating fields will not affect the potential on the body.

Appendix B

Earthing and cortisol

The study of diurnal cortisol profiles by Ghaly and Teplitz (2004) provided a foundation for subsequent investigations of earthing that are being summarized and discussed in this series of articles. This Appendix considers various questions that have arisen about the Ghaly and Teplitz study and places it in the context of other studies of cortisol. The adrenal hormone, cortisol, is widely regarded as "the stress hormone." Chronic elevation of cortisol can result in disruption of circadian rhythms, which, in turn, contributes to a multitude of adverse health conditions, including sleep disorders, hypertension and cardiovascular disease, stroke, decreased bone density, decreased immune response, mood disturbances, autoimmune disease, and abnormal glucoselevels (Alschuler, 2001). There is evidence that cortisol is involved in regulating sleep (Follenius et al., 1992). Excess cortisol secretion has been linked to chronic insomnia (Vgontzas et al., 2002) and patients with severe insomnia have high evening and nocturnal cortisol levels (Rodenbeck et al., 2002). Neurological effects of chronic elevated cortisol secretion include chronic activation of the sympathetic nervous system (flight-or-fight response) leading to hypertension and cardiovascular disease. The status of the hypothalamic–pituitary–adrenal (HPA) axis and the sympathetic nervous system have been utilized as objective markers of stress reactions (Bjorntorp, 2001).

Cortisol levels show a pronounced circadian rhythm. Lowest secretion levels typically occur during the first half of night time sleep, referred to as the quiescent period. There is an abrupt elevation during the second half of sleep. Peak levels occur shortly after awakening, and then decrease over the remainder of the day. While this is considered a normal profile, various surges in cortisol levels can become superimposed on this rhythm in response to stressors (van Cauter, 1990; Born et al., 1999; Kirschbaum and Hellhammer, 2000). Elevated cortisol levels during the normally quiescent period interfere with sleep (references).

The pilot study of Ghaly and Teplitz (2004) measured diurnal cortisol levels to test the hypothesis that earthing the human body during sleep improves sleep while reducing pain and stress (anxiety, expression, irritability). The purpose was to quantify earlier reports that individuals with pain and insomnia benefit from sleeping with their bodies in conductive contact with the surface of the earth (Ober, 2003, 2004; Ober and Coghill, 2003).

Twelve subjects with complaints of sleep dysfunction, pain and stress were earthed during sleep for 8 weeks in their own beds using a conductive mattress pad. Salivary cortisol tests were administered to establish pre- and post-earthing cortisol profiles. Subjective symptoms of sleep dysfunction, pain, and stress were reported daily throughout the 8-week test period. Measurable improvements (normalization) in diurnal cortisol profiles were observed, with cortisol levels significantly reduced during night time sleep. Symptoms, including sleep dysfunction, pain, and stress, were reduced or eliminated in nearly all subjects. The results indicated that earthing during sleep resynchronises cortisol hormone secretion with the natural 24-h circadian rhythm profile. The findings are significant because medicine is being increasingly challenged to find solutions to the widespread epidemic of sleep problems and their well-established health consequences. The intricate relations between cortisol levels and sleep dysfunction, stress, pain, anxiety, depression, irritability, inflammation, circadian rhythms, the immune response, and various chronic diseases have been the topic of literally thousands of scientific studies. For example, a search of the National Library of Medicine database, Pub Med, lists 7605 studies and 708 review articles with key words "cortisol" and "stress" and 1348 studies and 179 review articles with key words "cortisol" and "sleep." A summary of methods for measuring stress can be found in Cohen et al. (1995). See, in particular, Chapter 8, on measuring stress hormones, by Baum and Grunberg (1995). Changes in cortisol levels and their 24 h profiles have broad impact on most if not all systems in the body. Cortisol is both a mediator and a marker of the stress response and allostatic load. Allostatic load is defined as the cumulative toll or load imposed on the hypothalamic–pituitary–adrenal (HPA) axis by various stressors (Kim et al., 2007).

There is extensive discussion of the exact meaning of diurnal cortisol profiles and the best ways to interpret them. For example, the shape of the curve is considered by some authors to be less significant than the area under the curve, which is generally taken as an indicator of the total cortisol level for a day and therefore an index of allostatic load. However, the Ghaly and Teplitz study focused on individuals already complaining of sleep dysfunction, pain and stress. Since subjects were preselected for different aspects of stress, the primary purpose was not to measure allostatic load; instead the interest was in quantifying the effects of earthing on the diurnal cortisol profiles.

Each of the 12 subjects in the study served as his or her own control, in that the comparisons were made between their 24-h pre-earthing cortisol profiles and their profiles after 6 weeks of earthing with a barefoot mattress pad. This is referred to as an uncontrolled field study, in that there was not a separate control group, and the measurements were based on samples taken by the subjects themselves, as opposed to measurements made in a laboratory setting. The cortisol measurements were obtained in the same way at the beginning and at the end of the study, i.e. samples were taken at 8 AM, noon, 4 PM, 8 PM, midnight, and 4 AM. Subjects were not required to change their sleeping habits, except that they all had to awaken at the same time to take the 8 AM cortisol saliva samples on two days during the study. This is important because time of awakening can influence the cortisol awakening response or CAR (Frederenko et al., 2004).

There is agreement in the literature that sampling of this type is suitable for establishing the diurnal cortisol profile (e.g. Stone et al., 2001). The salivary cortisol samples were obtained by having the subjects chew a Dacron salvette for 2 min. They were instructed to not brush their teeth before chewing, and they placed the salvettes in their refrigerators. The samples were picked up the following day and taken to the laboratory for analysis. It has been shown that saliva samples obtained in this manner can be stored at room temperature for more than 2 weeks without appreciable degradation of cortisol levels (Kirschbaum and Hellhammer, 1989). The measurement laboratory (Sabre Laboratories, Carlsbad, CA) reports that five independent facilities have found that assays of a cortisol sample containing 3.6 ng/ml show a standard deviation of 1.17 with a range 2.33–5.51 (personal communication from the laboratory Director, Victor Selerno). Due to an omission, the units for the cortisol plots were not given in Figures 1–3 in the Ghaly and Teplitz (2004) report. The units on the *y*-axes of the plots should have been labelled as ng/ml.

A variety of cortisol measurement techniques have been devised for different situations. There are various ways of interpreting the significance of the results in relation to health and stress levels. A number of confounding variables and methodological issues can influence outcomes. For example, Kudielka and others (2006) identified a number of confounding variables. However, that study attempted to quantify confrontational psychological stress by measuring the HPA axis reactivity to simulated burnout or vital exhaustion resulting from various stressors including pharmacological stimulation. The inconsistencies and methodological issues raised are not applicable to the Ghaly and Teplitz study, which examined day-night cortisol profiles. The scientific literature makes a clear distinction between these two types of study designs.

It has been pointed out that the units for the cortisol plots were not given in the Ghaly and Teplitz study. The units on the *y*-axes of Figures 1–3 should have been identified as ng/ml. Note that the range of 0–60 is appropriate when using the "conventional" units in the United States; European researchers use the metric or SI unit, nmol/L.

A final concern is the extent to which the Hawthorne effect may have influenced the outcomes in the study. Some researchers have questioned the validity of the Hawthorne effect. In any case, the convergence of endocrine measures with subjective behavioural data in the study make a strong case for the conclusions reached.

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