Current and Potential Use of the AXION micro5 Microcurrent Stimulator

Clinical microcurrent stimulation has been available since the 80's as an FDA cleared Class II device. The AXION micro5 was cleared in 1991 (K911814) in the following category.

Device	Stimulator, Nerve, Transcutaneous, For Pain Relief
Regulation Description	Transcutaneous electrical nerve stimulator for pain relief.
Regulation Medical Specialty	Neurology
Review Panel	Neurology
Product Code	GZJ

Prior to, and subsequent to the device's classification, much research has been done to investigate expanded uses for clinical microcurrent. The following research citations are designed as an exchange of information among healthcare professionals and to highlight areas where VenturaDesigns anticipates conducting research in an attempt to gain expanded clearances for its device.

Decreased Healing Times for Traumatic Soft Tissue Injuries:

1. Cheng N, Van Hoof H, Bockx E, et al. (1982). "The effects of electric currents on ATP generation, protein synthesis, and membrane transport of rat skin". *Clin. Orthop. Relat. Res.* (171): 264–72. PMID 7140077

The skin of locally inbred rats was longitudinally cut in two equal parts, one was electrically stimulated and the other served as a non-treated control.

Summary: Direct electric currents ranging from 10 uA to 1000 uA increase ATP concentrations in the tissue and stimulate amino acid incorporation into the proteins of rat skin. The effects on ATP production can be explained by proton movements on the basis of the chemiosmotic theory of Mitchell, while the transport functions are controlled by modifications in the electrical gradients across the membranes.

2. BMC Complement Altern Med. 2013 Jan 19;13:17. doi: 10.1186/1472-6882-13-17.

Effects of microcurrent stimulation on hyaline cartilage repair in immature male rats (Rattus norvegicus).

de Campos Ciccone C, Zuzzi DC, Neves LM, Mendonça JS, Joazeiro PP, Esquisatto MA.

CONCLUSION:

We conclude that microcurrent stimulation accelerates the cartilage repair in non-articular site from prepuberal animals.

PMID:
23331612
[PubMed - in process]

3. Rehabilitation (Stuttg). 2010 Jun;49(3):173-9. doi: 10.1055/s-0029-1246152. Epub 2010 Jun 8.

[Effectiveness of microcurrent therapy as a constituent of posthospital rehabilitative treatment in patients after total knee alloarthroplasty - a randomized clinical trial].

[Article in German]

Rockstroh G, Schleicher W, Krummenauer F.

CONCLUSION:

This randomized trial could demonstrate statistically significant superiority of microcurrent therapy embedded in conventional postoperative rehabilitation treatment after TKA versus the combination with a sham treatment. The results indicate an early introduction of microcurrent therapy concepts into postoperative treatment.

4. **Ultra-low microcurrent in the management of diabetes mellitus, hypertension and chronic wounds: report of twelve cases and discussion of mechanism of action.**

Lee BY, Al-Waili N, Stubbs D, Wendell K, Butler G, Al-Waili T, Al-Waili A.

Source

Department of Surgery, New York Medical College, Valhalla, New York, USA.

1. BYLee2100@aol.com

5. Physiother Res Int. 2012 Sep;17(3):157-66. doi: 10.1002/pri.526. Epub 2011 Dec 7.

Microcurrent therapy in the management of chronic tennis elbow: pilot studies to optimize parameters.

Monophasic MCT of peak current intensity 50 μA applied for tens of hours may be effective in reducing symptoms and promoting tendon normalization in chronic tennis elbow. Hyperaemia may help predict treatment outcome. A full-scale trial of the therapy is warranted.

6. Int J Med Sci. 2013 Aug 7;10(10):1286-94. doi: 10.7150/ijms.5985. eCollection 2013.

Microcurrent electrical nerve stimulation facilitates regrowth of mouse soleus muscle.

1. Ohno Y[1], Fujiya H, Goto A, Nakamura A, Nishiura Y, Sugiura T, Ohira Y, Yoshioka T, Goto K.

Microcurrent electrical nerve stimulation (MENS) has been used to facilitate recovery from skeletal muscle injury. However, the effects of MENS on unloading-associated atrophied skeletal muscle remain unclear. Effects of MENS on the regrowing process of unloading-associated atrophied skeletal muscle were investigated. Male C57BL/6J mice (10-week old) were randomly assigned to untreated normal recovery (C) and MENS-treated (M) groups. Mice of both groups are subjected to continuous hindlimb suspension (HS) for 2 weeks followed by 7 days of ambulation recovery. Mice in M group were treated with MENS for 60 min 1, 3, and 5 days following HS, respectively, under anesthesia. The intensity, the frequency, and the pulse width of MENS were set at 10 μA, 0.3 Hz, and 250 msec, respectively. Soleus muscles were dissected before and immediately after, 1, 3 and 7 days after HS. Soleus muscle wet weight and protein content were decreased by HS. The regrowth of atrophied soleus muscle in M group was faster than that in C group. Decrease in the reloading-induced necrosis of atrophied soleus was facilitated by MENS. Significant increases in phosphorylated levels of p70 S6 kinase and protein kinase B (Akt) in M group were observed, compared with C group. These observations are consistent with that MENS facilitated regrowth of atrophied soleus muscle. MENS may be a potential extracellular stimulus to

activate the intracellular signals involved in protein synthesis.

The following is an excellent study showing the effect of microcurrent on diabetic foot pain.

The Effect of Microcurrent Electrical Stimulation on the Foot Blood Circulation and Pain of Diabetic Neuropathy

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[2)] Department of Physical Therapy, College of Medical Life Science, Silla University

Abstract. [Purpose] This study was performed to investigate the effect of microcurrent electrical stimulation on the foot blood circulation and the degree of pain experienced by diabetes patients. [Subjects] Twenty nine patients with diabetic neuropathy over the age of 60 were randomly divided into an experimental(16 patients, 67.9 ± 8.0 years) and a control group(13 patients, 70.4 ± 4.4 years). [Methods] Both groups walked on a treadmill at a comfortable pace for 50 min/day, 5 days/week for 4 weeks, and each participant's body weight, body composition, and blood lipid were examined at the baseline and 4 weeks later. [Results] The results show that the foot blood flow rate increment after the intervention was significantly different between the experimental group and the control group, and the VAS was also significantly different. [Conclusion] Based on the results of this study, we consider that microcurrent electric stimulation of the foot may be helpful for preventing the pain and diabetic ulcers by increasing the foot blood circulation in diabetes patients.

The following is a paper in its entirety by Paul Lathrop phd that attempts to explain, with citations one of the mechanisms of action of microcurrent stimulation.

PHY SIOLOGICAL EFFECT S OF MICROCUR RENT ON T HE BODY
PETER H. LATHROP, Ph.D
WHAT IS MICROCURRENT OR MICROCURRENT THERAPY?

Microcurrent is a current in millionths of an ampere (micro amperage range). Bioelectric currents in the body are generally found to be in the micro ampere range. Microcurrent therapy is a low-volt pulsed micro amperage stimulation delivered to the body. Microcurrent therapy is based on the evidence that micro amperage currents closely approximate the naturally occurring bioelectric currents in the body and therefore effectively augment the body's tissue healing and repair. Microcurrent therapy produces electrical signals like those naturally occurring when the body is repairing damaged tissues. It works because of its ability to stimulate cellular physiology and growth. One classic study showed that micro amperage stimulation could increase ATP generation by almost 500%. Increasing the current actually decreased the results. This study also demonstrated the ability of microcurrent to enhance amino acid transport and protein synthesis.
One can see an illustration of the true therapeutic effect of microcurrent through the mechanism in which trauma affects the electrical potential of damaged cells. Whenever there is tissue trauma or dysfunction, there is a decrease in ATP and disruption of the sodium pump. The cells increase their electrical resistance and the injured area will have a higher electrical resistance than the surrounding tissue. This decreases electrical conductance through the injured area and decreases cellular capacitance, leading to impairment of the healing process and inflammation. The cells become less able to receive nutritional input, water, minerals etc. nor are they as able to remove toxins. All of these events are perceived by an individual as pain. This is not an environment that supports healing and tissue repair. Damaged tissue cells produce an electrical current

through the loss of intra-cellular ions and the disruption of the sodium pump mechanism. This phenomenon is termed the current of injury. The current then changes the normal electrical potential patterns. The uninjured cellsattempt to restore normal function to the damaged tissues by restoring the normal electrical potential.

Correct application of microcurrent to injured tissue augments the endogenous current flow, allowing cells in the traumatized area to regain their capacitance. Resistance is reduced, allowing bioelectricity to flow through and reestablish homeostasis. This process helps to initiate and perpetuate the many biochemical reactions that occur in healing. ATP is replenished in injured tissues and the membrane active transport is increased, thus allowing the intra-cellular flow of nutrients and the extra-cellular flow of waste materials. This process allows the emergence of healthy tissue. ATP also provides the energy source that tissues need to build proteins. Electrical signals initiate the healing process by replenishing ATP, increasing the membrane transport of ions, and facilitating protein synthesis. This allows the external microcurrent to run parallel with the body's current. Therefore microcurrent electrical therapy can be viewed as a catalyst helpful in initiating and sustaining the numerous chemical and electrical reactions that occur in the healing process.
Preclinical studies have shown that externally applied stimulation can:

- ♦Cause migration of epithelial and fibroblasts into a wound site
- ♦Increase ATP (adenosine triphosphate) concentrations in tissues
- ♦Increase protein and DNA synthesis
- ♦Promote healing of soft tissues or ulcers
- ♦Accelerate the recovery of damaged neural tissue
- ♦Reduce edema, and
- ♦Inhibit the growth of various pathogens.

In order for us to look at this more closely let's start by looking at some of the basics.

THE HUMAN BODY AS A ELECTROMAGNETIC FIELD

Physical tissue is a collection of biochemicals which are formed, folded and aligned in particular configurations to create a biological/biochemical/ bioelectric system. However, if you look deeper, down to the molecular level, then even deeper into the subatomic level, you will discover bits of energy that are vibrating at great speeds. Electromagnetic bonds hold this energy together in an energetic relationship. If you were magically able to make yourself small enough to view molecules at the subatomic level, you would likely discover that there is far greater space being occupied by energy, than by the matter of the actual atoms. This energy may "behave" as particles, or it may behave as waves. "In the quantum world classical particles such as electrons are at the same time waves, and waves can do things that particles cannot do." (Oschman, 1996). At the level of the atom, we know that electrons whirl about the nucleus in certain energetically defined orbits. As electrons race around atomic nuclei, they first move in one direction then another. This oscillation back and forth occurs at a specific frequency, which is determined by the type of sub- atomic particle and its level of energy. In order to move an electron from a lower to a higher orbit, a quantum of energy with very special frequency characteristics is required. An electron will only accept energy of the appropriate frequency to move from one energy level to another. If the electron falls from the higher to the lower orbit, it will radiate energy of that very same frequency. This required atomic frequency is referred to as the resonant frequency. Atoms and molecules have special resonant frequencies that will only be excited by energies of very precise vibratory characteristics. For instance, the singer who is able to shatter a wineglass by delivering a high amplitude note does so by singing in the precise resonant frequency of the glass. For our purposes, the significant point is that everything exists in a state of vibration, and every electromagnetic field is characterized by vibration, and every electromagnetic field is characterized by vibrational rates (or frequencies), which can be measured. The human organism is no exception. To grossly over simplify a highly complex situation one can visualize an individual human being as existing at a particular vibrational frequency

which may change dynamically every second depending on the mental state of the person, internal or external stresses, illness, etc.
Medical science has established that there are extensive electrical fields at work in the body. The nervous system, for example, has long been known to work through both electrochemical and purely electrical signals. In fact, electrical bonding at the atomic level holds all molecules together. A cell, like all units comprised of atomic and molecular assemblies, thus has an electronic moment which results from the interaction of all its electrochemical constituents.

We now know that the body is composed of an interconnected semiconductor fibrous matrix that extends into its every nook and cranny. Macroscopically, this system consists of the connective tissues that form bones, tendons, fascia, cartilage, and ligaments and that also form the matrix of all organs and glands. All of the systems of the body, the musculature, vasculature, nervous system, digestive tract, integument, and lymphatics are composed of connective tissue that gives them their characteristic form and physical properties. Cell biologists have now discerned how this continuous fibrous system connects with cell surfaces and cell interiors via trans membrane proteins such as the integrins.
There is a continuum between the brain and the rest of the body through the perineurium (tissue of mesodermal origin consisting of collagen fibroblasts and fatty cells; supports organs and fills spaces between them and forms tendons and ligaments) and an electromagnetic field deep within.
THE EFFECTS OF TRAUMA OR DYSFUNCTION
The electromagnetic field holds energetic vibrational or frequency patterns that are characteristic of specific events that had occurred which have been either traumatically physical or emotional. This explains how the effects of physical injury remain in the tissue long after the tissue should have healed. This also explains how emotional trauma and memory is "stored" in physical tissue and then affects physical function.
Trauma and internal disease manifest themselves as a dysfunction of the autonomic homeostasis. Areas affected by a disease are shown to be detectable as more electro-conductive than the surrounding skin. Therefore, any physical disorder which increases autonomic activity can be measured at specific points using a point-specific probe. If the biochemical system is in a state of imbalance or non-homeostasis, it is probably due to the fact that the capacitive elements of the cells are not relaying the energy distribution system properly. Either there is not enough energy or there is too much energy stored in the capacitors in the cell. This state of misalignment resulting from imbalance in the capacitor system in the cell is thus an imbalance in energy flow, resulting in a state of systemic trauma caused by the body's attempt to compensate for the imbalance. This trauma results in pain-producing signals being transmitted throughout the involved areas of the central nervous system. As these tissue areas receive the correct flow of electrical energies, circulation is improved and the normal healing process is quickened. This is characterized by an immediate reduction in pain. Case in point, after the body receives a bioelectric therapy, there is electronic input into various points regulating the functioning of cells and neuro-muscular systems of the body. Glycogen utilization of the muscle tissue increases and the amino acid content of the brain tissue also increase. At the same time, activities of some enzymes in the tissue are stronger. These changes indicate that treatment can promote the metabolic process of tissues in their apparent movement to help invigorate the body's power of resistance to unfavorable factors, thereby promoting the recovery of damaged tissues.
CELL STRUCTURE AND FUNCTION
The study of cells in a conventional biological and organic chemistry approach, usually views cells as a membrane filled with little organs (called organelles), which process reactions through simple diffusion. As we go deeper we find a more detailed explanation. The cell is filled with a microtrabecular lattice that forms the ground substance within the cell. All of the organelles are suspended and interconnected by the microtrabeculae. Glycoproteins extend across the cell surface from the cell interior to the exterior. These proteins connect with the filamentous network within the cell. The filamentous network is a crystalline gel lined by water molecules.

Hydrogen ions aligned along the crystalline gel that forms the intra-cellular matrix form tetrahedral structures with space for four electrons. The semiconductor function includes electrons and spaces where electrons are absent in an outer shell. The spaces where electrons are missing are relatively positive in charge. The relative

positive charges serve to pull the negatively charged electrons along and move current through the tissue quickly, almost instantly. The electromagnetic field created by the crystalline gel and the water molecules forms the matrix that can convey and store charge, current and vibrational information.

The primary organizing factor of the body now appears to be electromagnetic. That is, electricity not only influences the metabolism of the individual cell, but also tells the cell where it fits into the larger scheme of things, i.e., in the organism. At the cellular level electricity is pervasive. A large percentage of the cell's total energy budget goes to the separation of ions (charged atoms and molecules). When positively and negatively charged ions are separated, the result is an electrical potential (voltage). Cells are enormously active in creating ion separations across closed membranes. These separations occur across the cell membrane and across organelle membranes within the cell. Once an electrical charge has been built up, it represents an important source of stored energy for the cell, rather like water stored behind a dam, or electricity store in a battery. There are two forces at work. One of them is electrical – a positively charged ion would like to migrate across membrane toward the more negative side. Unlike charges attract and like charges repel each other. The other force is concentration. Any highly concentrated ion would like to diffuse into an area where it would be less concentrated. The cell uses both of these forces. Ion pumps in the cell membrane actively move sodium ions out of the cell and potassium ions in. The large buildup of sodium ions outside the cell is then used to power other forms of transport, just as forcing water flow through a turbo generator powers electricity production. For example, sodium ions are allowed to flow down their concentration gradient into the cell, powering the active transport of glucose and amino acid molecules up their concentration gradients in to the cell. But transport within the cell is even more interesting and more relevant to our concerns.

MITOCHONDRIA AND ATP'S ROLE

The mitochondrion is an organelle within the cell and is made up of a set of closed membranes. Mitochondria have been called the "powerhouses" of the cell, because all the reactions of aerobic metabolism take place within them. Within the mitochondrion is a set of special enzymes called cytochromes. These enzymes take the hydrogen ions released by the metabolic degradation of glucose and fats and move them across the mitochondrion's internal membranes. The ions are then allowed to flow back across the membrane, but as they do so they power the creation of ATP (adenosine triphosphate), the major source of chemical energy for the cell. ATP molecules are the storage and distribution vehicles for energy in the body. ATP is, in fact, the energy currency for our bodies. The ATP (adenosine triphosphate) molecule consists of a nucleotide (with a ribose sugar) and three phosphate groups. Energy is stored in the covalent bonds between phosphates, with the greatest amount of energy (approximately 7 kcal/mole) in the bond between the second and third phosphate groups. This bond is known as a pyrophosphate bond. ATP transfers energy from chemical bonds to endergonic (energy absorbing) reactions with the cell. Virtually every cytological, histological and physiological process is ATP-mediated, which makes ATP clinically important.

The total quantity of ATP in the human body is approximately 0.1 mole. The energy used by human cells requires the hydrolysis of 200 to 300 moles of ATP every day. Thus, each ATP molecule is recycled 2000 to 3000 times during a single day. ATP can't be stored; hence its consumption must closely follow its synthesis. It is the breakdown of ATP into ADP that yields the energy or more specifically it is the cleaving of the phosphate bond that yields the energy. The chemical formula for the expenditure or release of ATP energy can be written as: ATP + ADP + energy + Pi or Adenosine Triphosphate produces Adenosine Diphosphate + energy + inorganic Phosphate. An analogy between ATP and rechargeable batteries can be made. The batteries are used, giving up their potential energy until it has all been converted into kinetic energy and heat/unusable energy. Recharged batteries (into which energy has been put) can be used only after the input of additional energy. Thus, ATP is the higher energy form (the recharged battery) while ADP is the lower energy form (the used battery). When the terminal (third) phosphate is cut loose, ATP becomes ADP (Adenosine Diphosphate) and the stored energy is released for some biological process to utilize. The input of additional energy (plus a phosphate group) "recharges" ADP into ATP (the spent batteries are recharged by the input of additional energy). The chemical reaction for the formation of ATP is: ADP + Pi + energy ATP or Adenosine Diphosphate + inorganic Phosphate + energy produced Adenosine Triphosphate.

Two processes convert ADP into ATP: 1) phosphorylation; and 2) chemiosmosis. Phosphorylation is the addition of a phosphate group to a protein or a small molecule. ATP is synthesized in the mitochondrion by

addition of a third phosphate group to ADP in a process referred to as oxidative phosphorylation. ATP is also synthesized by substrate level phosphorylation during glycolysis. Chemiosmosis is the process by which ATP is produced in the inner membrane of a mitochondrion. Chemiosmosis involves more than the single enzyme of a substrate-level phosphorylation. Enzymes in chemiosmotic synthesis are arranged in an electron transport chain that is embedded in the mitochondrion. During chemiosmosis H+ ions are pumped across an organelle membrane into a confined space (bound by membranes) that contains numerous hydrogen ions. The energy for the pumping comes from the coupled oxidation-reduction reactions in the electron transport chain. Electrons are passed from one membrane-bound enzyme to another, losing some energy with each transfer (as per the second law of thermodynamics). This "lost" energy allows for the pumping of hydrogen ions against the concentration gradient (there are fewer hydrogen ions outside the confined space than there are inside). The confined hydrogen cannot pass back through the membrane. Their only exit is through the ATP synthesizing enzyme that is located in the confining membrane. As the hydrogen passes through the ATP synthesizing enzyme, energy from the enzyme is used to attach a third phosphate to ADP, converting it to ATP.

A point to note: the concentration of hydrogen ions in the mitochondrion (electrochemical proton gradient) and the chemical ATP are interconvertible and equivalent storage forms of cell energy and are used to power virtually all cell processes from synthesis of proteins to ion pumps to muscle contractions. The total energy of the cell can be estimated chemically by the amount of ATP available, or electrically from the total ionic charge separation (capacitance).

Effect of Microcurrent: We can now see that if an electrical current of appropriate magnitude and direction were to flow through a cell, hydrogen ions formed by electrolysis of water at the anode (positive electrode) would migrate through the cell. When they reached the mitochondria membrane they would power the formation of ATP at an increased rate. Thus any cell activity for which energy availability was the limiting factor would be accelerated by an electrical current.

ATP AND ITS ROLE IN CELL REPARATION

In addition to being integral to the function of virtually every cell in our body, we can also look at ATP function by categories of activity. Such essential functions include: 1) muscle contraction; 2) protein biosynthesis; 3) nerve transmission; and 4) active transport across cell membranes.

In muscle contraction, the process occurs as such: each muscle spindle is composed of muscle fibers. Inside the muscle fibers are many muscle fibrils. These muscle fibrils are suspended in a fluid matrix called sarcoplasm. Suspended in the sarcoplasm are thousands and thousands of mitochondria, which contain large amounts of ATP. It is ATP that energizes the muscle contraction process by the ATPase activity of the exposed myosin head. When ATP is exposed to the myosin head, it is cleaved and energy is released. It should be noted that along with ATP, magnesium is very necessary in ATP energy releasing reactions. Before ATP can become "active ATP," magnesium must bind between the second and third phosphate. Clinically, magnesium deficiency may be related to such conditions as fibromyalgia and chronic fatigue syndrome.

Synthesis of almost any chemical compound requires energy. The energy, ATP, is critically important to the biosynthesis of proteins, phospholipids, purines, pyrimidines and hundreds (if not thousands) of other substances. Take ATP involvement in protein synthesis as a case in point: a single protein may be composed of many thousands of amino acids. It takes the breakdown of four high- energy phosphate bonds to link two amino acids together. Maximally, ATP could serve as energy to join two amino acids together, so if our protein is composed of 10,000 amino acids, it may take 20,000 ATP to form just this one protein. It should also be noted that the amino acids themselves utilize ATP indirectly as they are first co-transported into the cells.

ATP is necessary for nerve transmission. Nerve transmission entails the release of nerve transmitter substance from the pre-synaptic terminal into the synaptic cleft, which simply put is a space between one nerve and another. The nerve transmitter substance spans the cleft and attaches to the receptor of the other cell. The nerve transmitter substance must be constantly formed anew in the pre- synaptic terminal for future release; the energy for this formation is supplied by ATP. There are many mitochondria in the pre-synaptic terminal to form and store the ATP for this process. At the post-synaptic terminal, the next nerve cell down the line, it is through active transport of sodium, potassium and calcium that concentration differences across the nerve cell membrane cause nerve firing and propagation of nerve signals to travel to the next pre-synaptic terminal.

These concentration gradients could not be accomplished without ATPase active transport across nerve cell membranes. Active transport is brought about by the energy release of ATP in the breakdown of its phosphate bonds. Active transport is a means of getting molecules across the cell membrane, either into or out of the cell, against a concentration gradient. That concentration gradient may be electrical or a pressure gradient. Sodium, potassium, calcium, glucose, amino acids and many other compounds are transported this way. Large amounts of energy are required to move ions in and out of the cell. When the pump is not functioning, cellular metabolic waste builds up in toxic concentrations. What we have when the sodium pump is not functioning is a hypo-polarized, toxic, starving cell, not a pretty sight. Re-establishment of the sodium pump occurs as ATP concentrations rise. Thus, ATP provides the energy for the movement of metabolites and metabolic waste across the cell membranes as well as the re-establishment of cellular bioelectronic ionic concentration gradient.

Effect of Microcurrent: The work of Cheng has shown that under the influence of microcurrent electrical stimulation ATP concentrations increase when the applied electrical flow is in the 25 to less than 1000 micro amp range. What this means is that nerve cell membrane potentials, which normally are about -85 mV in healthy tissue, are re- established by microcurrent stimulation. Levels of intra- cellular metabolic waste (i.e. lactic Acid) are reduced and fresh concentrations of usable cellular metabolites are introduced unto the exhausted cell. At this point, the cell can enter its regenerative phase, pain levels are noticeably reduced and tissue regenerative functions can be re-established.

The sodium-potassium pump follows the ATP-driven model of active transport, oscillating between two conformational states. Because the pump hydrolyzes ATP in the process, it also acts as an enzyme, which is referred to as the sodium-potassium ATPase. In one conformational state, a binding site selective for Na+ faces the cytoplasmic side of the membrane. Sodium binding stimulates the transfer of a phosphate group from ATP to the protein. This, in turn, induces the protein to flip to its other conformation, which exposes the sodium site with its bound ion to the extra-cellular side of the membrane. In this state, the binding site has a low affinity for Na +, and the ion is released outside the cell. Another binding site, this one receptive to K+, picks up an ion from the extra-cellular fluid. Binding of a potassium ion causes the protein to lose its phosphate group, and the protein reverts to the conformation that has the ion-binding sites pointed toward the cytoplasm. The protein releases the potassium ion to the cytoplasm, picks up another sodium ion and repeats the cycle. By moving a substance across a membrane against its gradient, a membrane pump stores energy. The substance will tend to diffuse back across the membrane down its gradient. Analogous to water that has been pumped uphill performing work as it flows back down, a substance that has been pumped across a membrane can do work as it leaks back by diffusion. If diffusion of the ions is affected only by their concentration gradients, then K+ and Cl- will diffuse across the membrane until the concentration of each ion is the same on both sides of the membrane. Switching on a battery (the membrane potential) makes one side of the membrane negative in charge and the other side positive. The K+ and Cl- will redistribute themselves across the membrane by diffusing in response to this new driving force. A dynamic equilibrium will again be reached, but this time the K+ and Cl- will each be distributed unequally across the membrane. Since opposite charges attract, K+ will be more concentrated on the negative side of the membrane, and Cl- will be more concentrated on the positive side. At the equilibrium point, the tendency for further diffusion due to electric attraction is offset by the tendency of the ions to diffuse down their concentration gradients. The sodium- potassium pump (ATP ase) pumps three sodium ions out of the cell for every two potassium ions it pumps into the cell. There is a net loss of one positive charge from the cell with each cycle of the pump. The selective permeability of the plasma membrane allows K+ to leak out of the cell down its concentration gradient faster than Na + leaks in, a difference that contributes to the net charge of the cytoplasm being negative compared to the outside of the cell.

An ATP-driven pump stores energy by concentrating a substance on one side of the membrane. As the substance leaks back across the membrane through specific transport proteins, other substances are co-transported against their own concentration gradients.

ATP AND ITS MAINTENANCE OF THE ELECTROCHEMICAL BALANCE

An ATP synthase complex is incorporated into a membrane such that the ATP binding site is on the outside. ATP is added, the nucleotide starts to be hydrolyzed to ADP + Pi and protons are pumped into the vesicle lumen. As ATP is converted to ADP + Pi the energy available from the hydrolysis steadily decreases, while

the energy required to pump further protons against the gradient which has already been established steadily increases. Eventually equilibrium is attained. If this equilibrium is now disturbed, for example by removing ATP, the ATP synthase will reverse and attempt to re- establish the equilibrium by synthesizing ATP. Net synthesis, however, would be very small as the gradient of protons would rapidly collapse and a new equilibrium would be established. For continuous ATP synthesis a primary proton pump is required to pump protons across the same membrane and replenish the gradient of protons. A proton circuit has now been established. This is what occurs across energy-conserving membranes: ATP is continuously removed for cytoplasmic ATP consuming reactions, while the gradient of protons is continuously replenished by the respiratory or photosynthetic electron-transfer chains. Mitochondrial and bacterial membranes have not only to maintain a proton circuit across their membranes, but must also provide mechanisms for the uptake and excretion of ions and metabolites. The diffusion potentials due to the maintained concentration gradients across the plasma membrane play the dominant role in determining the membrane potential. In the case where K+, Na+ and Cl- gradients exist across the membrane, the membrane potential is a function of the ion gradients weighted by their permeabilities. The electric message is carried along the nerves as a result of changes in the quantities of potassium and sodium salts inside and outside the cell. Outside the cell is an abundance of sodium salt and little potassium, inside is an abundance of potassium and little sodium. The effect is like that of a wet battery where different solutions separated by a semi- permeable membrane give rise to an electric current.

ATP can be produced by the body by many means other than those mentioned above. However, it is a very dynamic energy source, and at the site of injury or at a site of overuse and micro injury, ATP supplies can become diminished. ATP deficiencies are common in areas of chronic pain, and sufficient ATP is essential to power the processes of cell respiration. ATP supplies the energy to the sodium pump, the active transport mechanism that removes metabolic waste from the cell's interior and imports metabolic substrates (food) from the bloodstream into the cells. In Cheng's study, he demonstrated that the ATP concentrations were increased by as much as 300 to 400 percent in cells stimulated with currents between 25 micro amps and 1000 micro amps (the micro amp range).

Effect of Microcurrent: While our bodies in theory can produce all the ATP we need, the fact is that they don't. Microcurrent stimulation between 200-800 micro amps is a way of supercharging the tissue with ATP, which will reside there until needed. By this means, much of the research that shows a 200% increase in healing rate can be explained as it applies to hundreds of conditions. In a clinical sense, any healing process takes a great deal of ATP and may be accelerated through a means of increasing ATP in the tissue. Microcurrent stimulation accomplishes this in ATP production.

Hydrogen ions are not the only ions whose movement would be affected by electrical currents. Another very important ion is cell physiology is calcium. Calcium ions has long been recognized as one of the two important "internal messengers" of the cell (the other being cyclic AMP). The nerve impulse along an axon opens calcium gates in the axon terminal. This allows an influx of calcium ions which signals the membranes of the synaptic vesicles to merge with the presynaptic membrane, releasing neurotransmitter into the synaptic cleft. But this is only one example. The presence of calcium in the form of a calcium protein complex helps in the secretion, ATP recycling, and many other cell processes. Thus the entry of calcium into the cell can be implicated in the control of cell growth and gene expression (i.e., differentiation and dedifferentiation). There are electrically controlled calcium gates in the cell membranes of human fibroblasts, and these gates can be opened by appropriate electrical current applied experimentally. Electrical stimulation of human fibroblasts also increases the synthesis of protein and DNA. While evidence is not yet totally conclusive, there is a strong case for the notion that microcurrent triggers productive mechanisms involving the calcium gates in cell membranes.

ELECTROCHEMICAL GRADIENTS

The basis of all electrical currents through cells is the electrochemical gradient of the particular ion involved. These gradients are maintained across the plasma membrane at the expense of cellular energy. In many animal cells, for example, the resting membrane potential is largely a potassium diffusion potential, and leakiness to ions other than potassium is compensated for by various ionic pumps such as the Na^+ - K^+ - ATPase. These pumps may be electrogenic and may or may not contribute directly to the resting potential by a significant amount. In any case, virtually all cells have a negative membrane potential (that is, the cytoplasm

is electrically negative with respect to the surrounding medium), and the physiologically important ions are maintained in non equilibrium distribution across the plasma membrane.
The electric message is carried along the nerves as a result of changes in the quantities of potassium and sodium salts inside and outside the cell. Outside are a lot of sodium salt and little potassium, inside lots of potassium and little sodium. The effect is like that of a wet battery where different solutions separated by a semi-permeable membrane give rise to an electric current. If a very fine electrode tube is inserted inside an individual nerve and another tube is bathed in the external sodium predominating liquid, an electric difference of 65 – 95 mV can be measured between the two points. When a nerve is stimulated, sodium flows into it at the point of stimulation and potassium flows out, discharging the local voltage difference across the membrane. The voltage difference is then discharged in the next bit of membrane a little further along and so on - thus, the message travels along the nerve. Consequently, each cell can be viewed as possessing its own immediate magnetic environment, or magnetic field, which combines with the fields of like and adjacent cells, thereby giving rise to the magnetic field of a particular system within the human body. For example, the magnetic field of the skeletal system can be seen as distinct from that of the nervous system. In practice, however, the individual magnetic fields of all the body's cells and of all the body's systems combine to yield an overall somatic magnetic field, resulting from all of the body's physical, electrochemical, magnetic producing processes taken collectively.

WATER AS CARRIER OF CURRENT

The human body consists of over 95% water. Water is universally recognized to be particularly susceptible to magnetic influence. The chemical explanation given for this is that since the nucleus of the oxygen atom has no magnetic moment, and should therefore not respond to an external magnetic field, it is the single proton of the hydrogen's nucleus that is thought to be so amenable to magnetic fields, with the result that water can be easily polarized by an external magnetic force. Thus, under normal circumstances, some of the hydrogen protons contained in the water within the human body might be expected to line up in the direction of the earth's magnetic field. Extending this rationale, these hydrogen protons in water would realign themselves in the direction of any local or applied magnetic field whose strength greatly exceeds that of the earth's field. Hence, the body's high percentage of water is thought to be a prevailing reason for its susceptibility to magnetic influences. Fluid systems of the body, including the circulatory system and extra-cellular fluids of various kinds, act as virtual antennas for externally applied fields. These fluids are highly conductive because they contain electrically charged ions, predominantly sodium, potassium, and chloride. More subtle but perhaps far more significant effects occur because the proteins and other molecules comprising the tissues are semiconductors.

THE CELL AS A CAPACITOR

A capacitor is an electronic device capable of storing and separating opposite charges, and a resistor offers a direct path to current flow but impedes the current to some extent. A capacitor consists of two metal plates separated by a nonconducting material. If these two plates are connected to a voltage source such as a battery, current will initially flow onto the two plates. Positive charges will accumulate on the plate attached to the positive battery terminal and negative charges on the plate connected to the negative battery terminal. Charges will flow until the two plates have a voltage difference equal to that between the two battery terminals. At this point there is no longer enough electrical force to oppose the repulsive force of adding more like charges on the respective positive and negative plates. Also, it will take a certain amount of time to charge the plates up to this level just as it will take some time to discharge the plates.
The cell membrane effectively acts as a capacitor by separating an equal number of intra-cellular negative charges aligned with extra-cellular positive charges. Because the capacitor is being discharged and current is flowing, a voltage difference exists. As a result, a certain amount of the total current is lost through the capacitor of the membrane; there is a smaller amount to travel down the length of the nerve axon and discharge the next capacitive element of the adjacent membrane. This process continues until there is no longer any longitudinal current because it has all effectively passed through the membrane. A small amount of the current can also escape from the axon's interior by allowing potassium ions to pass through the potassium gates. Because not all of the current can exit through the limited number of potassium gates, the membrane in effect offers some resistance to this path of current flow. The membrane can thus also be said to act as a resistor through the trans membrane passive ion channels in addition to a capacitor when speaking of current

flows. For example, if the resistance of the nerve axon is significantly less than the capacitance and resistance of the cell membranes, then the current would preferentially pass down the interior of the axon as opposed to exiting through the membrane. In an unmyelinated nerve, however, the intra- cellular resistance is such that the current preferentially discharges the membrane capacitor first and flows through the membrane's aqueous resistor channels. The remaining current is then capable of traveling along the length of the axon. A smaller total amount of current is then available for each subsequent membrane segment as one proceeds down the axon. Less current produces less of a voltage change. The net result of current loss through adjacent portions of the membrane is a potential difference diminishing sequentially down the nerve, or an electronically declining potential difference.

THE ROLE OF DNA IN CELL CURRENT FUNCTION

Current function of a cell in any portion of its genetic cycle is maintained by a feedback ultimately between DNA and a micro-inducer liberated by the membrane by means of a protein regulator that derives from RNA activity. A new inducer may be liberated from another independent membrane globular protein under the action of an external (electrical) perturbation, which alters genetic activity and provides a different feedback loop. Changes in the environment of the cell transmit information to the nucleus, thereby triggering specific functional responses particularly in repair activity. Cells responsive to small environmental alterations are usually implicated in repair or defense mechanism response. Prime examples are those involved in bone repair (osteoblasts and osteoclasts). These new cells which are involved in the tissue regeneration process inhibit increased RNA and protein production.

Proper selection in the choice of a stimulating signal could trigger the cellular growth process of cells in the current flow path. Electrochemical information transfer can be translated in some situations by potential-dependent specific absorption at the cell membrane. This process could trigger specific enzyme or hormonal activity interpreted by the living cell as requiring a change in its function. It is conceivable that selective stimulation of a given cellular process could occur by the proper choice of the excitation signal.

USING AN EXAMPLE OF POST TRAUMA EDEMA

Let's take a look at an example of a soft tissue injury to tie together some of the key points we have discussed. Post trauma endoneurial edema eventually develops a fusiform swelling which is evident clinically, because of the low elastic modulus of the perineurium. Chronic edema conceivably is followed by fibroblast proliferation and the conversion of intraneural edema to an intraneural scar extending proximally and distally to varying degrees. The axons remain spread, fascicular diameter increases, and the large amount of endoneurial collagen, coupled with the shrinking of the basal lamina tubes, has a great influence on the quality of regeneration because of nutritive and mechanical factors.

Becker (1985) has shown that trauma will affect the electrical potential of cells in damaged tissue. As discussed earlier the injured site has a much higher resistance than that of the surrounding tissue. Electrical resistance of tissue with chronic pathology is higher than that of the immediately surrounding normal or less pathological tissue. Acute injuries generally have a combination of abnormally high and abnormally low resistances. Basic physics dictates that electricity tends towards the path of least resistance. Therefore, endogenous bioelectricity avoids areas of high resistance and takes the easiest path, generally around the injury. The decreased electrical flow through the injured area decreases the cellular capacitance (Windsor, 1993). As a result, healing is actually impaired. This may be one of the reasons for inflammatory reactions. Local vasodilatation may produce a negative effect due to chemical irritation of mast cells which release histamine and prostaglandins. And while edema may result from a variety of causes, the net effect is a fluid shift into interstitial spaces. One cause is physical disruption of blood vessels. When this happens, homeostatic mechanisms including vasoconstriction of arterioles and formation of platelet plugs at the ends of the ruptured vessels occur immediately to retard fluid loss. Pain, heat, swelling, and redness are the characteristics of inflamed tissues. If there is an inflammatory process in the area of involvement, the inflamed tissue, which naturally has a very high electrical conductance, takes the body's energy and transforms it into heat (like a toaster's elements heat up and turn red when electricity is applied). The heating process is like a constant energy leak and can easily drain the body of massive amounts of critically needed energy (like a slow drip in the bathroom can use up many gallons of water).

Regeneration is a series of endothermic electrochemical reactions. This means that electricity is used in miniscule quantities by cells to provide the energy to fuel the regenerative process. The tissue in the area of

involvement needs energy in the form of electricity. The patient's body contains more that an adequate quantity of energy to produce the desired effect. Unfortunately, the electrical resistance in the area of involvement is so elevated that the body's energy flow cannot enter the area because the laws of physics require that energy travel only via the path of least resistance. The result, energy traveling in the body will circumvent the area of pathology because it always takes the path of least resistance, which is around, rather than through, the area of pathology.

We must enable the energy to pass into the pathology. In addition, we can aid the process by increasing the body's ability to actually produce and store energy in the area of involvement. As we have discussed, this is done by charging the tissue in a manner similar to charging a battery. The greater the charge on the cell, the less resistant it is to the flow of electrical energy. Additionally, as the cell charge increases, the molecular kinetic energy in the cell increases. Physics provides the equation which reveals that at this point the electro-vibratory rate (EVR) of the cell's molecular structure must increase with the increased kinetic energy (energy of movement). An increased EVR will be coupled in direct proportion with an increased electroconductivity (decreased electrical resistance). Finally, while functioning as a battery, the charged cell provides some of the energy which is involved in the energy flow equation. Now, the entire skin layer of the body and obviously at the site of injury is composed of epidermis and dermis and ranges in depth from less than 0.5 to 3 to 4 mm. It can be represented by an electrical circuit consisting of resistors and capacitors. One way to increase current density beneath the skin is to increase carrier frequency. An increase in frequency decreases the capacitive resistance and the general health of the cells improve. As a result, a greater amount of current density should be available beneath tissue layers. Biologically, the capacitance of the cell is directly proportional to the concentration of ATP in the cell and ranges from about .1 to 3 microfarads. Restated, ATP is at least partially responsible for binding the electrons which cumulatively represent the electrical charge and usable energy of the cell. Electrical energy of these areas must be below standard because the body's electrical flow cannot penetrate the resistance.

The first phase of a typical microcurrent treatment is typically designed to stimulate the tissue and affect the electrical resistance of the skin/electrode interface with 4 to 6 milliamps of current. The second phase is an introduction of a current between 25 and 900 uA. The increased activity of the mitochondria enhances the production of ATP in the cytoplasm. The ATP provides the fuel for the transmigration of metabolite and metabolic waste across the cell membranes as well as the re- establishment of cellular bioelectronic ionic concentration gradient. What this means is that cell membrane potential is re-established levels of intra-cellular metabolic waste (i.e. lactic acid) are reduced and fresh concentrations of usable cellular metabolites are introduced into the exhausted cell. At this point the cell can enter its regenerative phase.

FREQUENCY SPECIFIC MICROCURRENT

There seems to be a fairly narrow range of stimulation which falls within the biological waveband of the body's electromagnetic energies. Stimulation within this ideal range can have dramatically positive biological and clinical effects. Previous forms of electrotherapy, which simply bombard the tissues with high-intensity stimulation and produce hyperstimulatory analgesia due to neurological gate control, may be temporarily muting pain but are unable to recharge the cellular batteries, because the electrical current is far outside the body's natural biological waveband. The frequencies of stimulation and the electrical waveforms of treatment are also becoming more sophisticated and well defined as the science of electrotherapy approaches maturity. Much of the work establishing the frequencies that effectively stimulate the body was done in France by Paul Nogier MD. The most common frequencies used in Europe are multiples and fractions of 73 Hz, which they claim to be a primary resonant frequency of the body.

Each tissue in the body has individualized frequencies. The individualized and specific vibrational characteristic of each atom, of each tissue type, varies even more specifically for varying conditions, such as: trauma, inflammation, stress, environmental influences, etc. To put the theory of vibrations in a better overall perspective: different vibrations / frequencies of sound, light, radio waves, etc., are responsible for notes of music, colors of light, and radio stations. Vibrations are specific and unique for all matter, inorganic and organic. When an injury occurs to a tissue, the electrons in the affected tissue take on a different vibrational characteristic, unique to that injury or other abnormal condition. As the vibrations of the electrons change, it is believed the electrons concurrently may also change to a different "orbit" from what was normal for that tissue type. As a part of overall therapy it is useful to match the frequencies of the tissue disruptions with the

frequencies we choose for our therapy. The new vibrational characteristics that occur from damage to a tissue are countered with specific microcurrent frequencies that match the exact abnormal frequencies that are present in the damaged tissue. The desired effect is to neutralize those frequencies that are incorrect for the damaged / affected tissues. As the wrong electron frequencies are neutralized, and the electrons return to their normal orbital vibrations, the physiological condition of the tissues will begin to normalize. The speed at which these changes occur varies with each individual. Some patients may experience a notable change immediately after treatment, or in some cases the greatest changes will not be noticed for up to 24 hours. Changes occur in steps of progression. It is unreasonable to expect a tissue that was harshly affected by trauma or other outside /environmental influences, to change drastically in one day. Most chronic conditions of long standing will usually demonstrate significant changes after the first six treatments. However this is very individualized and can vary dramatically for any patient and / or condition. Some conditions may respond with rapid changes, while other conditions may take longer for notable changes to occur.

To better explain, if the electrons have been at the "wrong" frequencies for an extended period of time, after treatment the electrons may try to go back to those wrong frequencies (i.e. rebound) perhaps within four to seven days. Thus the net result is usually an average of six treatments for the notable changes to become long lasting. Microcurrent treatment should be repeated at appropriate intervals until the cause and effect principle becomes permanent.

The frequencies work on the principle of biologic resonance. Microcurrent frequencies seem to be able to resonate with biologic tissue and change the structure of the tissue when the frequency is correct. Once the tissue is changed and stable it seems to be able to stay in the new configuration.

OVERALL POTENTIAL BENEFITS OF MICROCURRENT

Microcurrent electrical stimulation has been used or studied for many different therapeutic applications. Studies have been conducted which demonstrate the efficacy of microcurrent electrical stimulation for: (see appendix for references)

♦ Reduction in pain improvement scores with accompanying substantial reduction in serum levels of the inflammatory cytokines IL-1, IL-6, and TNF-X, and neuropeptide substance P. Beta- endorphin release and increases in serum cortisol.

♦ Significant pain reduction and increased range of motion in chronic back pain, fibromyalgia, cervical pain, Carpal Tunnel Syndrome, and arthritis patients

♦ Reduction of pain in degenerative joint disease of the temporomandibular joint

♦ Lasting reduction in myofascial pain of the head, neck and face

♦ Reduction in pain and increased mobility in peritendinitis calcarea of the shoulder

♦ Reduction in post-operative pain and edema,

♦ Reduction in healing time in soft tissue injury

♦ Reduce in treatment and rehabilitation time and reduction in worker down time

♦ Increasing range of motion in ankle dorsiflexion in CP,

♦ Increase the rate of healing in injured athletes, control pain, increase the rate of fracture repair, and treat myofascial pain and dysfunction

♦ Reduction in pain at power-grip and lifting a weight load with pronated forearm, improvement in grip-strength in chronic lateral epicondylitis patients,

♦ Superiority to conventional physical therapy in number of treatments required to relieve pain, severity of side effects, total cost of treatment and patient satisfaction,

♦ Reduce severity of muscle damage signs and symptoms.

APPENDIX

MICROCURRENT ELECTRICAL THERAPY PRECLINICAL STUDY PROOF OF CONCEPT

Preclinical studies have shown that externally applied electrical stimulation can:

♦ Cause migration of epithelial and fibroblasts into a wound site[1,3,6,10]

♦ Increase ATP (adenosine triphosphate) concentrations in tissues[11]

♦ Increase protein and DNA synthesis[3,6,8]

♦ Promote healing of soft tissues or ulcers[4,10,12]

♦ Accelerate the recovery of damaged neural tissue[9]

♦ Reduce edema[7], and

♦ Inhibit the growth of various pathogens.[2,5]

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MICROCURRENT ELECTRICAL THERAPY
CLINICAL PROOF OF CONC EPT

Microcurrent electrical stimulation has been used or studied for many different therapeutic applications. Studies have been conducted which demonstrate the efficacy of microcurrent electrical stimulation for:

♦ Reduction in pain improvement scores with accompanying substantial reduction in serum levels of the inflammatory cytokines IL-1, IL-6, and TNF-X, and neuropeptide substance P. Beta- endorphin release and increases in serum cortisol.[1]

♦ Significant pain reduction and increased range of motion in chronic back pain, fibromyalgia, cervical pain, Carpal Tunnel Syndrome, and arthritis patients [1,4,6,8,20,21,23]

♦ Reduction of pain in degenerative joint disease of the temporomandibular joint[12]

♦ Lasting reduction in myofascial pain of the head, neck and face [13]

♦ Reduction in pain and increased mobility in peritendinitis calcarea of the shoulder [5, 28]

♦ Reduction in post-operative pain and edema, [3,10]

♦ Reduction in healing time in soft tissue injury [9,11,14,15,19,22]

♦ Reduce in treatment and rehabilitation time and reduction in worker down time [14,27]

♦ Increasing range of motion in ankle dorsiflexion in CP, [2]

♦ Increase the rate of healing in injured athletes, control pain, increase the rate of fracture repair, and treat myofascial pain and dysfunction [16, 24,25,26]

♦ Reduction in pain at power-grip and lifting a weight load with pronated forearm, improvement in grip-strength in chronic lateral epicondylitis patients, [17]

♦ Superiority to conventional physical therapy in number of treatments required to relieve pain, severity of side effects, total cost of treatment and patient satisfaction, [27]

♦ Reduce severity of muscle damage signs and symptoms, [7]

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I'd like to personally think Dr. Lathrop for his fine work in assembling what I think is the finest explanation of why microcurrent can have such a marvelous effect on an injured body. There is so much here to digest. The bottom line is this: Clinical microcurrent works, and we have the physiology to understand why and how, and what can cause failures.