**Lumiwave$^{tm}$ Deep Tissue Infra-red Light Therapy**
**Technology Overview**

## A "New" Approach to Injury Management

Light Therapy for injury and pain has only recently been gaining attention in the U.S. However, the science behind it has a nearly 100 year history. The scientific literature on Light Therapy, also known as Photo-Biostimulation Therapy, encompasses over 2,500 titles substantiating the technology's ability to promote tissue repair and reduce pain.

BioCare's Lumiwave Deep Tissue Infra-Red Light Therapy is a non-invasive, non-drug approach to injury recovery built on this vast body of research.

## The Evolution of Sports Medicine[1]

Galen was a Greek physician of the second century AD who was one of the first to rigorously depict human anatomy. He worked with gladiators in Rome, and could be considered the first professional trainer. It was through treating the gladiators that Galen learned a lot of his anatomy and physiology. While Galen believed in the health benefits of "gooseblood and cobwebs and various anticoagulants," he was also a careful observer who used the gladiatorial athletes, just as succeeding generations of doctors have used athletes, to test their treatments and techniques.

Jack Berryman, PhD, professor of medical history in the Department of Medical History and Ethics at the University of Washington School of Medicine in Seattle, says athletes have always served as subjects for new sports medical procedures. Not that they have always done so from the lofty position of respect enjoyed by today's superstars. Athletics was beyond normalcy, and historically were looked at [unfavorably] by intellectuals. There was too much emphasis on victory to the detriment of the body. Until about 1900, the medical community frowned on athletic activity… For a long time there was a disease in the medical literature called 'athlete's heart.' They thought athletics put too much strain on the heart. As late as 1912 they were viewing a trained heart (with a low pulse rate) as a diseased heart.

Then in the 1930s researchers began to study athletes in "fatigue labs," and the whole picture changed. That was when we learned the human body was capable of a lot more than it had been given credit for. By the 1950s and 60s, star athletes had become valuable commodities like racehorses, and sports medicine techniques were developed primarily to keep these stars playing. The surgical techniques that were sports related—shoulders, elbows, knees—were developed by working on athletes. Now these procedures are standard at just about any hospital.

## Modern Western Medicine: Approach to Injury and Pain

Treatment of injury and pain has a long history. Ice, baths and massage all have long history in treatment of injuries. Acupuncture has been practiced in China for several thousand years. Societies around the world and throughout time have taken advantage of the medicinal properties of a variety of plants containing natural opiate substances. In the middle and late 19$^{th}$ century, western medicine made great strides forward in pain management with the chemical determination and synthesis of opiates for anesthesia and pain control, and the isolation of salicylates from the bark of the willow tree. The powerful effectiveness of opiate treatments led western medicine to focus on pharmaceutical treatment of pain, almost to the exclusion of non-pharmaceutical approaches through much of the 20$^{th}$ century.

## "New" Modalities for Treating Injury and Pain

However, drug therapy comes at a price. Non-Steroidal Anti-Inflammatory Drugs cause significant bleeding stomach ulcers in 2% of patients. Twenty percent of these die of the bleeding. Opiates have long been recognized for their addictive side effects. Newer COX-2 selective inhibitors obviate most of this risk, but bring in additional risks for those with concomitant cardiovascular disease. This has resulted in the withdrawl of several popular COX-2s including Vioxx and Bextra. According to the Drug Enforcement Administration, 6.2 million people abuse prescription drugs. Therefore, new approaches to injury and pain management have emerged in western medicine over the past twenty years. The side effects and addiction problems associated with pharmaceutical approaches have contributed to the search for complimentary and alternative medicine for pain.

Acupuncture, electrical stimulation, acupressure, relaxation, and biofeedback are all being explored as alternatives or adjuncts to drug therapy. Electrical stimulation and ultrasound have been used more recently for stimulation of fracture healing. Controlled studies measuring the effectiveness of these therapies have brought them into the mainstream of legitimate approaches to therapy.

**Light Therapies**

Photo-biostimulation is the process whereby tissue exhibits specific complex biochemical responses when exposed to light energy.

The technology is being used in the form of lasers by physiotherapists and sports medicine specialists to treat a wide variety of acute and chronic musculoskeletal injuries and pain. Dentists use it to treat inflamed oral tissues, and to heal diverse ulcerations. Dermatologists use light therapy to treat edema, indolent ulcers, burns, and dermatitis. Rheumatologists have used light therapy to relieve pain, treatment of chronic inflammation and autoimmune diseases. Other specialists are applying the therapy to effect nerve regeneration. Light therapy is also used in veterinary medicine, sports medicine and rehabilitation clinics.

**Epidemiology of Acute Injury**

Sprains, strains, and tears accounted for 4 out of 10 nonfatal injuries and illnesses involving days away from work in 2001.[2] Sprains, strains, and tears constituted the leading injury and illness category for every major private industry division. Slightly more than a fourth of these cases (27.3%) resulted from overexposure to lifting, and 45.1% of the cases were back sprains, strains, or tears. Sprain, strain, and tear cases include avulsion, hemarthrosis, rupture, strain, sprain, or tear of joint capsule, ligament, muscle, or tendon. Sprain, strain, and tear cases are of moderate severity. In 2001, they involved a median of 6 days away from work—the same median reported for all nonfatal injuries and illnesses.

*Sports Related Injuries*

There are an estimate 40 million injury-related visits to hospital emergency rooms annually. Eight million (10%) of these visits are sports-related, and 8 times that number, or 32 million people, self-treat at home for sports related injuries.[3] Confirming these figures, the Centers for Disease Control analyzed data from the National Electronic Injury Surveillance System All Injury Program (NEISS-AIP) to characterize sports- and recreation-related injuries among the U.S. population. The results of that analysis indicate that during July 2000–June 2001 an estimated 4.3 million nonfatal sports- and recreation related injuries were treated in U.S. hospital emergency departments. Sports- and recreation related injuries treated in emergency departments represent only a portion of these types of injuries that receive medical attention; many more of these injuries are treated in other settings (e.g., health-care providers' offices and clinics).[4]

The most frequent injury diagnoses were

- Strains/Sprains 29.1%
- Fractures 20.5%
- Contusions/Abrasions 20.1%
- Lacerations 13.8%

The body parts injured most commonly were:

- Ankles 12.1%
- Fingers 9.5%
- Face 9.2%
- Head 8.2%
- Knees 8.1%

Overall, 2.3% of persons with sports- and recreation related injuries were hospitalized.

**Most Common Sports Injuries**

| | |
|---|---|
| Metatarsil Stress Fracture | $2^{nd}$, $3^{rd}$, and $4^{th}$ metatarsils of the foot are most at risk due to thin diaphysis. The $5^{th}$ metatarsil is most at risk of foot roll-overs. |
| Shin Splints | a strain in the anterior compartment muscle if the tibia, which hold up the foot. |
| Popliteus Tendinitis | The popliteus muscle, wraps from the lateral femur chondyle, inserting into the back of the tibia, limits the forward femoral displacement. Pronation and down hill running stresses the tendon. |
| Achilles Tendinitis | Strain or tear to tendon anchoring calf muscle to heel. |
| Patellofemoral Pain | Runner's Knee – most commonly relusting from excessive pronation and lateral pull on the patella. Congenitally high-riding patella may be a contributing factor. |
| Posterior Femoral Muscle Strain | Pulled hamstring resulting from imbalance of muscle strength vs quadriceps (<60%). Most often triggered by sudden bursts of movement – sprinting or jumping. |
| Piriformis Syndrome | Pain caused by compression of the sciatic nerve by the piriformus muscle running from the pelvic sacrum to the femur. |
| Lumbar Strain | Tearing of lower back muscles. |
| Lateral Epichondylitis | Overuse syndrome on grasping muscles and supination muscles of forearm which originate on the lateral epicondyle of the elbow. |
| Medial Epichondylitis | Resulting from forceful wrist flexion and pronation. |
| Rotator Cuff Tendinitis | Tearing or inflammation of rotator tendons. |

Source: Merck Manual, $17^{th}$ Edition, Ch 62.

**Etiology of Acute Injury**

*Sprains and Strains*

A sprain is defined as a stretch or tear of a ligament, the band of connective tissues that joins the end of one bone with another. Sprains are caused by trauma such as a fall or blow to the body that knocks a joint out of position and, in the worst case, ruptures the supporting ligaments. Sprains can range from first degree (minimally stretched ligament) to third degree (a complete tear). Areas of the body most vulnerable to sprains are ankles, knees, and wrists. Signs of a sprain include varying degrees of tenderness or pain; bruising; inflammation; swelling; inability to move a limb or joint; or joint looseness, laxity, or instability.

A strain is a twist, pull, or tear of a muscle or tendon, a cord of tissue connecting muscle to bone. It is an acute, noncontact injury that results from overstretching or overcontraction. Symptoms of a strain include pain, muscle spasm, and loss of strength. While it's hard to tell the difference between mild and moderate strains, severe strains not treated professionally can cause damage and loss of function.

*Common Knee Injuries*

Because of its complex structure and weight-bearing capacity, the knee is the most commonly injured joint. Each year, more than 5.5 million people visit orthopaedic surgeons for knee problems.

Knee injuries can range from mild to severe. Some of the less severe, yet still painful and functionally limiting, knee problems are runner's knee (pain or tenderness close to or under the knee cap at the front or side of the knee), iliotibial band syndrome (pain on the outer side of the knee), and tendonitis, also called tendinosis (marked by degeneration within a tendon, usually where it joins the bone).

More severe injuries include bone bruises or damage to the cartilage or ligaments. There are two types of cartilage in the knee. One is the meniscus, a crescent-shaped disc that absorbs shock between the thigh (femur) and lower leg bones (tibia and fibula). The other is a surface-coating (or articular) cartilage. It covers the ends of the bones where they meet, allowing them to glide against one another. The four major ligaments that support the knee are the anterior cruciate ligament (ACL), the posterior cruciate ligament (PCL), the medial collateral ligament (MCL), and the lateral collateral ligament (LCL).

Knee injuries can result from a blow to or twist of the knee; from improper landing after a jump; or from running too hard, too much, or without proper warmup.

*Fractures*

A fracture is a break in the bone that can occur from either a quick, one-time injury to the bone (acute fracture) or from repeated stress to the bone over time (stress fracture).

Acute fractures: Acute fractures can be simple (a clean break with little damage to the surrounding tissue) or compound (a break in which the bone pierces the skin with little damage to the surrounding tissue). Most acute fractures are emergencies. One that breaks the skin is especially dangerous because there is a high risk of infection.

Stress fractures: Stress fractures occur largely in the feet and legs and are common in sports that require repetitive impact, primarily running/jumping sports such as gymnastics or track and field. Running creates forces two to three times a person's body weight on the lower limbs.

The most common symptom of a stress fracture is pain at the site that worsens with weight-bearing activity. Tenderness and swelling often accompany the pain.

*Dislocations*

When the two bones that come together to form a joint become separated, the joint is described as being dislocated. Contact sports such as football and basketball, as well as high-impact sports and sports that can result in excessive stretching or falling, cause the majority of dislocations. A dislocated joint is an emergency situation that requires medical treatment.

The joints most likely to be dislocated are some of the hand joints. Aside from these joints, the joint most frequently dislocated is the shoulder. Dislocations of the knees, hips, and elbows are uncommon.

**Etiology of Acute Injury: The Body's Healing Process**

From the moment a bone breaks or a ligament tears, the body goes to work to repair the damage. Here's what happens at each stage of the healing process:

1. At the moment of injury: Chemicals are released from damaged cells, triggering the inflammation proces. Blood vessels at the injury site become dilated; blood flow increases to carry nutrients to the site of tissue damage.

2. Within hours of injury: White blood cells (leukocytes) travel down the bloodstream to the injury site where they begin to tear down and remove damaged tissue (via lymphatic drainage), allowing other specialized cells to start developing scar tissue. Cell proliferation and modeling occurs at this point.

3. Within days of injury: Scar tissue is formed on the skin or inside the body as the proliferation and modeling continue. The amount of scarring may be proportional to the amount of

swelling, inflammation, or bleeding within. In the next few weeks, the damaged area will regain a great deal of strength as scar tissue continues to form.

4. Within a month of injury: Scar tissue may start to shrink, bringing damaged, torn, or separated tissues back together. However, it may be several months or more before the injury is completely healed.

**Pathology of Pain**

Pain is a universal experience. Nearly one-third of people will experience chronic pain at some point in their lives. Chronic pain affects 50 million Americans, according to the Joint Commission on Accreditation of Healthcare Organizations (JCAHO). This costs the country $125 billion or more each year in treatment, disability compensation and lost productivity.

Pain is the major reason for a patient to seek healthcare. For this reason JCAHO now lists pain as the "Fifth Vital Sign," along with pulse, blood pressure, temperature and respiration rate. Yet only an estimated one in four Americans with chronic pain receives proper treatment.

Clinical pain results from the stimulation of nerve endings, or nociceptors. This stimulation is most often caused by traumatic injury or disease affecting peripheral tissues. Pain signals are then sent along to the spinal cord and up to the brain where it is consciously recognized. Examples include skin cuts, bruises, arthritis and bone fractures. Pain can also arise from direct injury or disease of the nerves leading to the spinal cord, to the spinal cord itself or to the brain. This is called neuropathic disease. Examples include carpal-tunnel syndrome, migraines, and fibromyalgia.

**Current Practices for Injury Management**

1) Drugs

   Western medicine has focused on drug therapy for the past 150 years. Only in the last 20 years have non-drug therapies begun to rival pharmaceuticals for first line therapy. Many drugs operate by binding to specific receptor sites in the nerve endings, tying up the chemical reactions which communicate the pain response along nerve pathways. Most drugs interact with a wide variety receptors throughout the body in non-specific ways, resulting in side effects. Thus, the focus for drug development is to find ever more target-specific drugs.

2) Acupuncture

   Acupuncture has been practiced for thousands of years. Interest in the treatment by western doctors was stimulated by the opening of China following Nixon's visit in 1972. The mechanism of action for acupuncture is not well understood. One theory is that it stimulates the nervous system to produce endorphins. Endorphins are peptides, or short protein segments, which fix themselves to the receptors of nerves, thus blocking transmission of pain signals. However, research has shown that this does not explain everything observed with acupuncture. Other mechanisms seem to be at work.

   A variation on acupuncture is acupressure, in which pressure is applied to specific points of the body without puncturing the skin with a needle.

3) Massage Therapies

   Hands-on manipulation for healing is probably older than any other healing tradition. The oldest written records of massage go back three thousand years to China. Massage therapies may be related to acupuncture and acupressure in the ways in which they work. Primary mechanisms and benefits include: improved circulation of blood, movement of lymphatic fluid, release of toxins, release of tension and reduction of stress.

4) Chiropractic Therapies

   Chiropractic therapies include therapeutic exercise, therapeutic stretches, traction-massage, soft tissue and massage therapy. The aim is to relieve pressure on the spine or peripheral nerves. It thus encompasses many of the alternative therapies described here.

5) Bioelectric Therapy

Bioelectric therapy relieves pain by blocking pain messages to the brain. The electrical impulses send signals to the brain that "scramble" normal pain signals, offering short-term pain relief. Bioelectric therapy also prompts the body to produce endorphins that decrease or eliminate painful sensations by blocking the message of pain from being delivered to the brain. It can be used to treat pain in many chronic and acute conditions such as back pain, muscle pain, headaches and migraines, arthritis, TMJ disorder, diabetic neuropathy, and scleroderma.

Transcutaneous electrical nerve stimulation therapy, more commonly referred to as TENS, is one example of bioelectric therapy. While effective in the short-term, long-term effectiveness of TENS remains questionable.

## LIGHT THERAPIES

The concept that light can be beneficial to human health is not new. Many effects of light are familiar. Exposure to sunlight stimulates vitamin D production. Seasonal Affective Disorder or SAD is also a well characterized phenomenon stemming from lack of sunlight, and is easily corrected by exposure to light of certain wavelengths.

Exposure to infrared light (light of longer wavelengths than visible light) stimulates biological processes affecting pain and tissue repair. Many of the original studies of the effects of light involved the use of lasers in order to tightly control wavelengths used. The application is sometimes referred to as “low level light therapy” to distinguish from high powered surgical lasers designed to cut or ablate tissue. Light emitting diodes – the familiar LEDs –offer a simpler alternative to lasers. LEDs provide a concentrated source of light energy in a narrow portion of the spectrum. This allows application of the beneficial portions of the spectrum in the near-infrared range, without the potentially harmful regions of the spectrum such as ultraviolet.

Visible and ultraviolet light is absorbed in the skin and therefore has minimal penetration to deeper tissues where the pain problem may reside. Infrared light, in contrast can penetrate much more deeply, delivering energy to the target tissues.

### Light Therapies and Tissue Healing

One of the beneficial characteristics of light therapy is that it has the ability to promote and enhance healing, not just treat symptoms. The irradiation by infrared light triggers the natural repair mechanisms carried out by the body. Several of the mechanisms of action for light therapy that work to alleviate pain and inflammation also play an important role in tissue healing.

Wound healing progresses through stages of inflammation, proliferation, remodeling and maturation. Light therapy has been demonstrated to impact each of these phases in beneficial ways. Light therapy can provide the following beneficial impacts in both open surface wounds and closed connective or soft tissue injuries:

1. Enhanced leukocyte infiltration. Light therapy stimulates activity involving neutrophils, monocytes and lymphocytes. These white blood cells play key roles in clearing out damaged cells.
2. Increased macrophage activity. Light therapy accelerates macrophage activity in phagocytosis, growth factor secretion and stimulation of collagen synthesis.
3. Increased neovascularization. The significant angiogenesis that occurs with laser therapy promotes revascularization with subsequent improvement in perfusion and oxygenation. Endothelial cell regeneration is accelerate[5]
4. Increased fibroblast proliferation. Light therapy stimulation increases fibroblast numbers and fibroblast-mediated collagen production.[8]
5. Keratinocyte proliferation. The beneficial synthesis activities and growth factor ability of keratinocytes are enhanced by proliferation secondary to light therapy.[9]
6. Early epithelialization. Laser-stimulated acceleration of epithelial cell regeneration speeds up wound healing, minimizes scarring, and reduces infection opportunities.

7. Growth factor increases. Two to five fold increases in growth-phase-specific DNA synthesis in normal fibroblasts, muscle cells, osteoblasts and mucosal epithelial cells irradiated with IR light are reported. Increases in vascular endothelial growth factor (VEGF) and fibroblast growth factor (FGF-2) secondary to infrared light irradiation have also been reported.
8. Enhanced cell proliferation and differentiation. Infrared-induced increases in Nitric Oxide, ATP and other compounds that stimulate higher activity in cell proliferation and differentiation into mature cells. Increased numbers of myofibroblasts, myofibrils, myotubules etc., as well as bone cell proliferation, have been clinically documented after light therapy. Satellite cells, the precursor cells in the process of muscle regeneration, show significant increase in proliferation when irradiated with light therapy.[10,11,12]
9. Greater healed wound tensile strength. In both soft tissue and connective tissue injuries, light therapy can increase the final tensile strength of the healed tissue. By increasing the amount of collagen production/synthesis and by increasing the intra and inter-molecular hydrogen bonding in the collagen molecules, laser therapy contributes to improved tensile strength.[13,14,15,16] The preceding effects combine to achieve an accelerated healing rate. The time from onset of injury to mature healed wound is reduced.[17]

**Light Therapies and Soft Tissue Healing**

Numerous studies have been conducted which demonstrate the effectiveness of infrared light on soft tissue healing. LED produced in vitro increases of cell growth of 140-200% in mouse-derived fibroblasts, rat-derived osteoblasts, and rat-derived skeletal muscle cells, and increases in growth of 155-171% of normal human epithelial cells. Wound size decreased up to 36% in conjunction with HBO in ischemic rat models.[18]

A clinical study was performed on 74 patients with injuries to the following anatomic locations: ankle and knee, bilaterally, Achilles tendon; epicondylus; shoulder; wrist; interphalangeal joints of hands, unilaterally. All patients had had surgical procedure prior to infrared light. Comparison of the healing process between two groups of patients obtained the following results: wound healing was significantly accelerated (25%-35%) in the group of patients treated with infrared light.[19] In another study, forty-seven soccer players with second degree ankle sprains were selected at random and divided into three groups: treatment with the conventional initial treatment (RICE, rest, ice, compression, and elevation), treatment with the RICE method plus placebo laser, and the third group treated with the RICE method plus an 820-nm GaA1As diode laser. The laser + RICE group showed statistically significantly edema reduction compared to controls at 24, 48 and72 hours.[20] Finally, a review of 9 separate placebo controlled trials measuring pain and range of motion scores in tendinopathies showed an average 32% improvement in treated over untreated.[21]

**Light Therapies and Bone Healing**

Studies of bone healing response to infrared light show acceleration of osteoblast formation as well as calcium salt deposition under the influence of infrared light.[22,23] Studies have demonstrated that bone growth factors are stimulated by IR light. Osteoglycin is a small leucine-rich proteoglycan (SLRP) of the extracellular matrix which was previously called the osteoinductive factor. SLRP are abundantly contained in the bone matrix, cartilage cells and connective tissues, and are thought to regulate cell proliferation, differentiation and adhesion in close association with collagen and many other growth factors. In osteoblastic cells the osteoglycin/mimecan gene was upregulated 2.3-fold at 2 h after exposure to infrared light.[24]

Nicolau and colleagues (2002) from Brazil demonstrated the positive effect of LLLT on the stimulation of bone in mice with latent promotion of bone remodulation at injury sites without changes in bone architecture, increased bone volume and increased osteoblast surface through increased resorption and formation of bone with higher apposition rates. A positive effect on bony implants has been demonstrated by Dörtbudak (2002) and Guzzardella (2003).[25]

An animal trial of 4 weeks' duration was conducted on osseous defects of 2.7 mm diameter made in each parietal bone of 20 rats (20 additional rats received placebo treatment). A GaAlAs diode laser was applied immediately after surgery and then daily for 6 consecutive days. Five rats from each group were killed on day 14 and the remainder on day 28 postoperatively. At both time points the tissue samples from the experimental animals contained significantly more calcium, phosphorus, and protein than the controls. Similarly, histological analyses disclosed more pronounced angiogenesis and connective tissue formation, and more advanced bone formation in the experimental group than in the controls.[26]

The effect of HeNe laser on the healing of tibial bone fractures in rats: 63 J (35mW) was given transcutaneously daily over the fracture area. After 4 weeks the tibia was removed and tested at tension up to failure. The maximal load at failure and the structural stiffness of the tibia were found to be elevated significantly in the irradiated group, whereas the extension maximal load was reduced. In addition, gross non-union was found in four fractures in the control group, compared to none in the irradiated group.[27]

**Pain Reduction from Light Therapy**
The pain reduction effects of light therapy have been extensively researched and documented in numerous clinical studies and medical papers. While much remains to learn with respect to the various mechanisms through which light therapy achieves pain reduction, there is a wealth of knowledge currently available to demonstrate the effectiveness of laser therapy in this regard. Because the pain amelioration capabilities of light therapy are accomplished via the combination of local and systemic actions —utilizing enzymatic, chemical and physical interventions — the process is very complex. However, there is a preponderance of medical evidence that justifies a conclusion that effective pain reductions and accelerated tissue healing can be achieved via light therapy. Following are processes and events that are promoted by light therapy.

**Mechanisms of Action for Light Therapies**

*Mechanisms of Action: Nitric Oxide*
One of the most important mechanisms of action for light therapy is release of nitric oxide. A naturally occurring chemical in the body, nitric oxide is a key signaling molecule which can set off a number of beneficial effects. Most notably, it has a critical role in promoting blood flow to tissues. It also indirectly inhibits inflammation processes, thus reducing inflammation. In acute inflammatory responses, such as sudden injury, large increases in nitric oxide levels can play a role in increased pain. However, within the nervous tissues smaller levels of nitric oxide release, as stimulated by light therapies, can paradoxically have pain reducing effects. This was demonstrated in an animal model by Mrowiec et al in which they showed that an inhibitor of nitric oxide signaling blocks the analgesic effect of low power laser on intact rats.

The benefits of light therapy are that they reduce the discomfort of pain and inflammation while promoting blood flow and the body’s tissue repair mechanisms.

*Mechanisms of Action in Healing:*
*Mobilization of endogenous chemical or protein signals for adult stem cell engraftment*
Recent work has shed light on the underlying mechanisms of tissue repair within the body. Conboy[28] et al, investigated the influence of systemic factors on aged progenitor cells of peripheral tissues such as muscle and liver. They conducted an experiment wherein they established parabiotic pairings (that is, a shared circulatory system) between young and old mice (heterochronic parabioses), exposing old mice to factors present in young serum. Notably, heterochronic parabiosis restored the activation of Notch signaling as well as the proliferation and regenerative capacity of aged satellite cells. The exposure of satellite cells from old mice to young serum enhanced the expression of the Notch ligand (Delta), increased Notch activation, and enhanced proliferation in vitro.

In another line of research, Gold[29] et al elucidated the role of a protein signaling molecule, calreticulin (CRT), an intracellular protein with functional significance in the transport of protein through the endoplasmic reticulum. It has more recently been recognized as a critical regulator of extracellular functions, particularly, in mediating cellular migration and as a requirement for the uptake and clearance of dead cells. Dr. Leslie Gold and her team discovered that CRT has remarkable effects on the acceleration of the rate and quality of tissue repair in experiments that involved both the application of CRT to different animal models of skin injury and in vitro assays commonly used to assess wound repair.

Minimized scarring is observed with infrared light treatment. Some of these signaling mechanisms may underlie the efficacy of infrared light in accelerating wound healing, as seen in clinical trials.

*Mechanisms of Action: Lymphatic Drainage*
There is also a hypothetical potential that the presence of IR by increasing lymphatic circulation does so by virtue of an increase in the diameter of the lymphatic vessels, not just by increased flow rates within the vessel at an unchanged diameter. This diameter increase, if definitively present, would also explain the presence of large diameter protein cells within the normal bone circulation that cannot be attributed to the vascular circulation and would additionally explain a facilitated process for removal of debris and larger protein cells passing out of traumatized areas that is additionally stimulated by the use of IR.[30]

*Mechanisms of Action: Effects on Nerves*
Studies of the effectiveness of light therapy on a number of chronic pain conditions suggest that it may have activity on specific nerve fibers involved in "slow conduction" of pain signals. Human and animal studies have found elevated levels of endorphins (small proteins which block pain signals in nerves) in response to light therapy.

*Mechanisms of Action: ATP – The energy source for cells in the body*
Light affects the mitochondrial respiratory chain by changing the electric potential of cell membranes and, consequently, their selective permeability for sodium, potassium and calcium ions, or by increasing the activity of certain enzymes such as cytochrome oxidase or adenosine triphosphatase.[31]

Clinical results have been attributed to the general effects of infrared light therapy and its ability to increase the rates of healing through mitochondrial ATP production and alteration in the cellular lipid bi-layer. Additional hypothesis includes the subsequent capacity of irradiated cells to alter their ion exchange rate and thus influence the catalytic effects of the specific enzymes and substrates. These in turn initiate and promote the healing process completing the cascading cycle of events.[32]

Studies of cultured cells show that levels of Adenosine Triphosphate (ATP) are raised upon exposure to specific wavelengths of infrared light. ATP is the final fuel into which all food is ultimately transformed. It is the energy currency for the body's cells. The body's self repair of injured tissues requires enhanced amounts of ATP. Studies of rats exposed to infrared light show increased ATP levels in their brains. In addition to serving as the energy currency for cells, ATP can serve as a neurotransmitter. After being broken down to adenosine, it binds to adenosine receptors that block pain signals in the nervous system.

*Mechanisms of Action: Acetylcholine, Bradykinin and Ions*
Two more neurotransmitter chemicals involved in pain are acetylcholine and bradykinin. These two are affected by light therapy. Nerve tissue membranes are threaded through with ion channels. It is now conventional wisdom that acetylcholine and nicotine act at these receptors to alter electrochemical properties at a variety of synapses, which can in turn affect the release of several other neurotransmitters. When activated by acetylcholine they allow selected ions to flow across the cell membrane, suppressing pain responses. Infrared light exposure increases acetylcholine levels. In contrast, bradykinin levels are suppressed by infrared light, reducing signaling of pain in the central nervous system. It is likely that several or all of these mechanisms contribute to the analgesic activity of light therapy.

**Summary of Light Therapy Clinical Studies**
While a detailed summary of clinical studies on light therapy and pain is beyond the scope of this paper, a brief synopsis will highlight some of the work in this area focusing on some of the more recent studies.

*Carpal Tunnel Syndrome*: Many of the conditions for which the application of light therapy has been investigated include some of the most chronic, intractable clinical situations, circumstances in which standard therapy is generally of poor to moderate utility. One of the most studied is carpal tunnel syndrome. Carpal tunnel syndrome is a neuropathy arising from the compression of the median nerve as it passes from the forearm to the palm beneath the transverse carpal ligament. Multiple, controlled studies of light therapy or light therapy combined with electrical nerve stimulation have indicated response rates of up to more than 90% [33,34,35]. These results were significantly better than placebo effects obtained in the same studies. Relief of pain for carpal tunnel syndrome is an FDA-approved protocol for light therapy.

*Head and Neck Pain*: The application of light therapy to head and neck pain has received significant attention, in part because of the use of lasers in the field of dentistry. Indeed, light therapy is effective at reducing dental hypersensitivity[36] and, in a randomized double blind trial, at reducing pain following endodontic surgery.[37] More broadly, the effective use of light therapy in temporomandibular disorder, myofascial pain, and other circumstances where pain is a significant part of the clinical presentation has been reported[38,39, 40, 41, 42]. The last of these references implicates serotonin in light-mediated analgesia.

*Musculoskeletal Injuries*: Another significant group of studies has addressed the role of light therapy in musculoskeletal injuries sports/activity injuries, tendonitis, and muscle soreness[43,44,45,46,47,48,49,50]. Prominent in these studies are those of a Swiss group has reported positive results obtained in multiple clinical studies for pain reduction and/or increased healing for a variety of injuries at various anatomical locations. The clinical results are buttressed by animal data from independent investigators demonstrating improved healing of experimental tenectomies in rabbits, rats, and chickens. However, another group, while reporting favorable trends of light therapy, indicated that the effect fell short of statistical significance. Additional studies suggest the efficacy of IR in the treatment of lower back pain and in osteroarthritis[51,52]. NASA—led studies on musculoskeletal injuries showed improvement of greater than 40% in musculoskeletal training injuries in Navy SEAL team members, and decreased wound healing time in crew members aboard a U.S. Naval submarine.

*Wound Healing:* A number of clinical studies have demonstrated efficacy of infrared light on acute and recalcitrant wounds. In a Swiss study of 74 patients suffering from a variety of joint-related injuries, the group treated with infrared light showed from 25% - 35% improvement over untreated controls in terms of redness, heat, pain, swelling and loss of function.[53] In a double-blind study of recalcitrant venous stasis ulcers in non-diabetic patients, all subjects who received an active infrared treatment either healed completely or demonstrated significant reductions in wound area during the next two to six months in contrast to untreated patients[54].

*Clinical Summary*

In summary, the use of light therapy has been explored in a variety of clinical situations and promising results have been obtained. The most substantial data indicate the efficacy of light therapy in conditions such as acute and chronic musculoskeletal pain where the biostimulatory healing properties of the light add to the direct action of light on the nociceptive system. Nonetheless, light therapy has also been shown to benefit in a variety of clinical situations in which pain relief is not readily obtained by conventional therapeutic approaches, intractable anorectal pain and diabetic sensorimotor polyneuropathy and, for example[55,56].

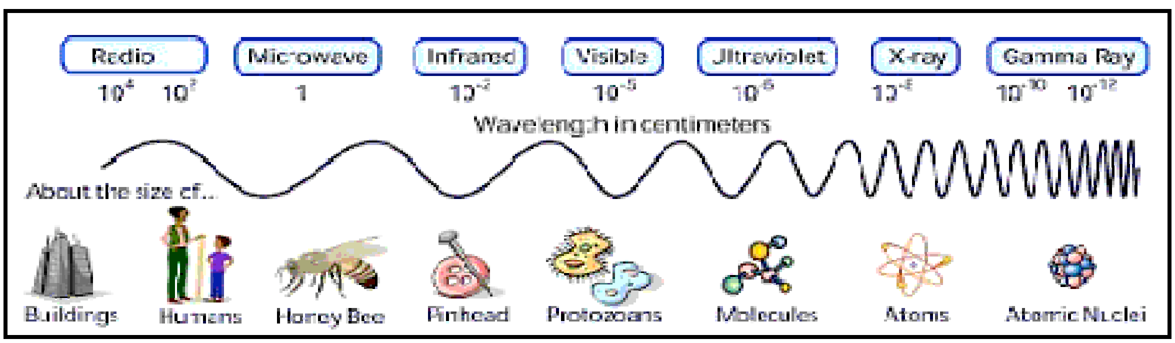
## BioCare Lumiwave Deep Tissue Infra-red Light Therapy

The Lumiwave Deep Tissue Infra-Red Light Therapy is a non-invasive device that administers photo-biostimulation of body cells using a narrow wavelength of infrared light. The infrared therapy treatment penetrates damaged tissue with very specific light energy providing a therapeutic exposure that results is a complex cellular response. Clinical research has shown infrared induced photo-biostimulation treatments increase in adenosine triphosphate (ATP) and release of nitric oxide (NO) in the body. ATP stores energy in the body and NO improves blood flow. This interaction promotes the body's own natural healing and immune capability responses of tissue.

BioCare's patented emitter technology maximizes photo-biostimulation with optimal dosage and wavelength parameters. Unique features of this technology control the output wavelength by regulating the temperature of the light emitting diodes, allowing the energy to be absorbed by the body in a highly effective manner. Under- or over- dosage is not harmful within the established parameters. Research has shown that improper exposures may render the treatment ineffective.

**Dosing of Lumiwave IR Light Treatments**
Dosing of light therapy is dependent on the type of problem that is being addressed. For deep tissue pain and healing both a higher dosage and deeper penetration is required. For surface wounds the dose should be lower. Light dose is measured in Joules/cm2 of photon energy delivered. In general, there is a "therapeutic dosing window" which defines the optimal range of doses by indication. For open wounds this range is between 0.1 and 8 Joules/cm2 with the optimal dose occurring around 1 Joules/cm2. For deeper tissue the optimal dose occurs at about 5 Joules/cm2. BioCare devices are engineered to adjust to deliver optimal dosing for all indications in 3 to 6 minutes.

Much research has been done to determine effective wavelengths for light therapy. It is generally accepted that wavelengths between 660nm – 1100nm constitute a range of effective treatment. It has also been demonstrated that infrared light nearing a wavelength of 900nm has as much a 2X factor of depth penetration when compared with a 660 nm red light. The absorptive characteristic of water peaks at wavelengths of 900nm, which supports deeper tissue penetration for therapeutic wavelengths around 900nm. BioCare uses 895 - 900 nm because it provides optimal photon energy dispersion for both deep tissue and surface healing.




**LED Versus Laser Light Sources**
*Low Level Light Therapy*
Low Level Light Therapy (light therapy) simply means the use of portions of the electromagnetic spectrum, from the far red to near infrared, to elicit beneficial biological responses. Since many of the studies originally involved the use of lasers as a source of well-controlled, narrow-spectrum light, the term 'low level' is used to distinguish it from the high power applications of surgical lasers designed to produce cutting or ablation of tissue. Light therapy works instead by stimulating natural biological processes in the area where the light is applied.

*Light Emitting Diodes*
Light emitting diodes (LEDs) offer a concentrated source of light energy in a narrow portion of the spectrum. LEDs are a cheaper, easier alternative to lasers as an output source for controlled, narrow-spectrum light. In this way we can tap the beneficial portion of the spectrum, such as near infrared, without the potentially harmful regions of the spectrum of sunlight such as ultraviolet.

**Conclusion**

The FDA has recently cleared multiple laser and LED devices for treatment of a variety of medical conditions including carpal tunnel syndrome, cervical neck pain, low back pain, joint pain, generalized muscle pain and acceleration of wound healing. Governmental agencies such as NASA are currently using technical light therapy for medical conditions in space applications. The U.S. Olympic training facilities have just released statements of endorsement for laser therapy for athletes. All of these events validate the growing acceptance in mainstream medicine for the medical efficacy of laser therapy as a viable, often superior therapeutic treatment modality. With over 200 clinical studies — many of which are double- blind, placebo-controlled — and in excess of 2000 published articles on Light Therapy, this innovative new technology has a well-documented research and application history. Having grown far beyond its distant Institutional Review Board (IRB) and experimental treatment status, light therapy is now being considered a therapy of choice for many difficult pain management challenges such as fibromyalgia and myofascial pain. New and ongoing clinical investigations offer growing potential for even more widespread applications of this truly unique light therapy.

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