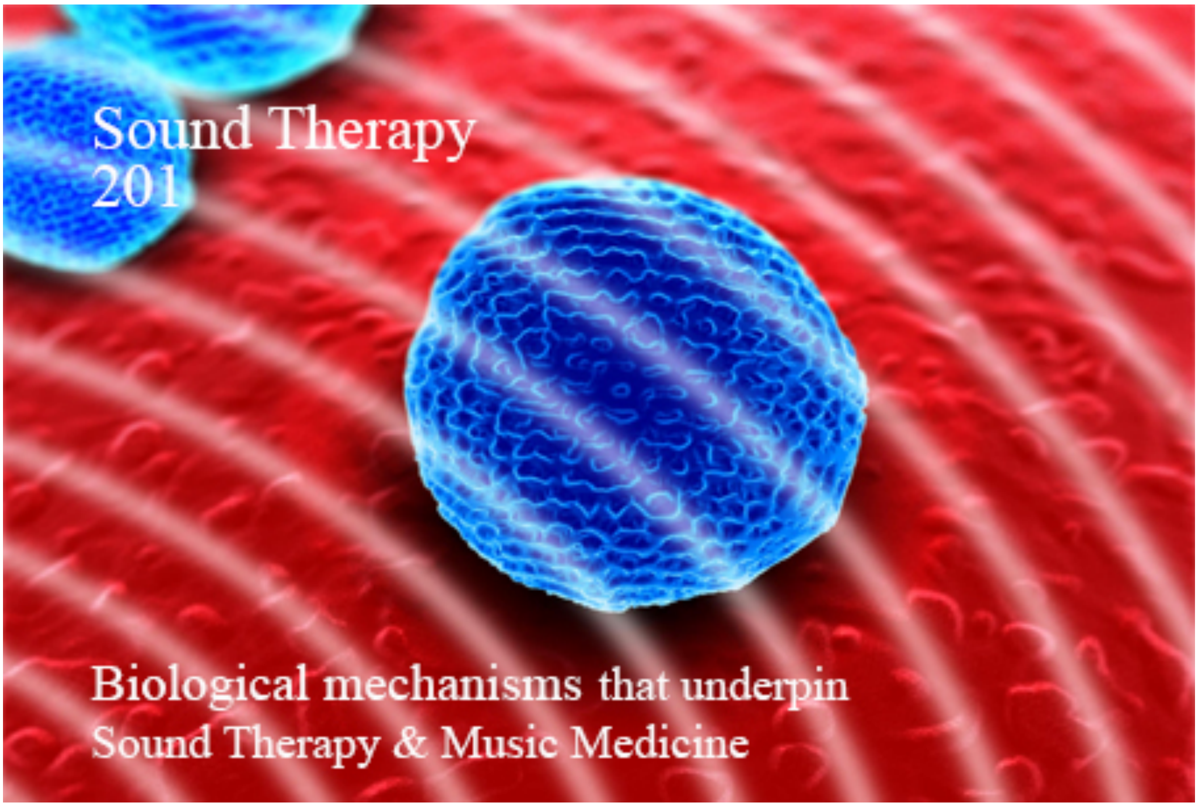


Sound Therapy 201

Biological Mechanisms

By John Stuart Reid

Introduction

The intent of this article is to provide an introduction to some of the many biological mechanisms advantageously activated by sound and music, collectively categorised as 'vibrational medicine'. Since the development of quantum physics in the twentieth century, discoveries made in medical physics reveal the body as a complex interplay of biofields[1] in which energy-information flows throughout the organism. At the level of the cell, information is exchanged through electromagnetic signals—primarily in the far infra-red spectrum—in addition to biochemical signals and sonic frequencies.[2] At the atomic level, biological complexities, and energy-information flow, can be viewed in terms of vibration. Nobel Laureate, Max Planck, said:

“As a man who has devoted his whole life to the most clear-headed science, to the study of matter, I can tell you as a result of my research about atoms this much: There is no matter as such. All matter originates only by virtue of a force *which brings the particle of an atom to vibration* and holds this minute solar system of the atom together”.[3]

It is in this context that vibrational medicine has its roots: considering the energetic (vibrational) interconnectedness of the mind-body system. Practitioners of holistic medicine, or functional medicine[4], as it is often referred to, review all aspects of the patient, including their emotions. In this expanded medical model, since the body is comprised of vibrational energy, a wide variety of vibrational and energetic modalities are available to support the patient’s physiology, including sound and music.

Some of the physiological mechanisms initiated by sound therapy and music medicine are achieved by whole-body immersion in specific sound frequencies, or in music, either recorded or live. Other mechanisms, initiated neurologically, can be achieved by listening to specific sounds or music by headphones.

An important yet little discussed aspect of physics, with significant implications for medical science, is that all sounds, whether single frequencies or a complex array of musical frequencies, create far infrared light (FIR), due to the atomic physics of inelastic sonic collisions. The infrared light created by sound and music is why sound intensity is measured in watts per metre squared [5] and such light is modulated in amplitude *by* the sound, thus, carrying the FIR component of the sonic energy-information almost 4cm into the body’s tissues.[6] As intercellular communication occurs mainly in the far infrared spectrum, the physics of sound-light interactions infers that sonic-modulated light is conveyed to cells in the medium of their own ‘language’.[2]

Before exploring the biological mechanisms that underpin Sound Therapy and Music Medicine it will be helpful to provide clear definitions of these modalities and of the related field of Music Therapy.

Music Therapy, Music Medicine, and Sound Therapy Definitions

Music Therapy is an accepted form of complimentary therapy in many hospitals and clinics, and may be defined as:

"The clinical and evidence-based use of music interventions to accomplish individualized goals within a therapeutic relationship by a credentialed professional who has completed an approved music therapy program".[7]

Music Therapy is a proven modality but is limiting in the sense that each patient requires a music therapist with whom to work. A plethora of books and scholarly articles are available on the subject of music therapy, and therefore is not the focus of this article.

Music Medicine may be defined as:

"Listening to music [for the purpose of healing] without the presence of a therapist."[8]

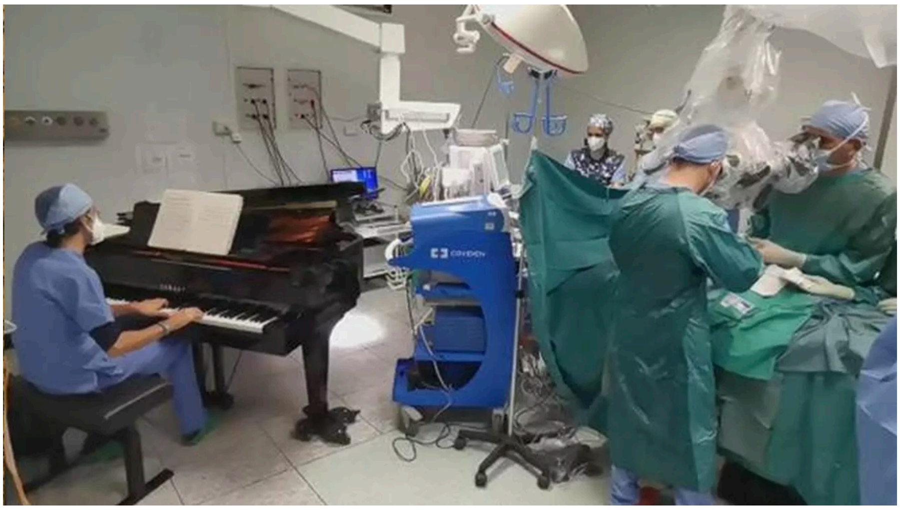
Music Medicine is a relatively new clinical modality that refers to the therapeutic utilisation of music, chosen by the patient in a clinical setting without the intervention of a therapist. As its title implies, music medicine focuses on the demonstrable benefits of music as treatment for specific health challenges. The mechanisms by which music affects the body's systems are complex and this article provides a short introduction into this subject.

Sound Therapy is defined by the International Sound Therapy Association as:

"The application of audible sound to the full body or to a specific part of the body, from electronically-generated sound sources, or from musical sources, as therapeutic support, by a credentialed Sound Therapy practitioner." [9]

This definition clarifies that therapeutic audible sound can be generated by electronic means, or provided by a musical source. The biological mechanisms triggered by such sonic support will be discussed later in the article.

At Riuniti hospital in Ancona, Italy, neurosurgeon, Dr. Roberto Trignani performed an operation to remove a double tumour in the spinal cord of a ten-year-old boy, while molecular biologist and pianist, Emiliano Toso, played a grand piano in the operating theatre.



Dr. Emiliano Toso playing piano in an Operating Room,
during live neurosurgery

Monitoring the boy’s brain activity via an encephalogram, suggested that the boy perceived the music. Dr. Toso said, "We tried stopping then restarting the music, noticing the patient's response. Despite the fact that the boy was under total anaesthesia, his brain appeared to perceive the music and this was very exciting." Dr. Trignani, head of the neurosurgery unit of Riuniti Hospital, commented, “Everything went well, there were no complications and there was a magical atmosphere of complete harmony in the Operating Room”. [10]

It is admirable and noble that musicians contribute their time and talent to playing in hospitals. The harp, in particular, has a long history of use in clinical settings and nursing homes and is likely to always form an important aspect of patient care. However, several commercial manufacturers have developed sound-based therapies that can support patients’ recovery from illness, which offer greater flexibility and convenience in clinical settings than live music.

A brief overview of some of the biological mechanisms activated by full body immersion in music or in specific sound frequencies

(Detailed explanations are provided later in the article).

Full body immersion in music or in specific sound frequencies (as distinct from listening with headphones), activates several beneficial biological mechanisms, four of which are briefly summarised as follows:

- Enhances nitric oxide (NO) production through active and passive acoustic stimulation of the sinus cavities and lungs by specific sound frequencies and music, resulting in a broad range of health benefits.

- Promotes pain mediation through stimulation of the body's large A-beta fibres or A-alpha fibres in the area experiencing pain, thus causing the pain 'gate' to close.

- Increases the availability of oxygen binding to haemoglobin molecules by low frequency sound pressure, thus breaking the pain-spasm-pain cycle or 'splinting cycle' by increasing the availability of oxygen to affected tissues.

- Activates the meridian system, via 'sonopuncture', with many health benefits, including pain mediation and anxiety mediation.

Headphone listening to music, or listening to specific sound frequencies, activates several biological mechanisms, four of which are briefly summarised as follows:

(Detailed explanations are provided later in the article).

- Mediates pain by the 'Descending Inhibition of Pain' system, also referred to as the 'top-down' modulation of pain. Such effects can be initiated by music (or white noise) as a result of activating endogenous opioids.

- Promotes stress reduction with consequent reduction in blood pressure and cortisol levels, and induces a state of joy with consequent increase in dopamine levels, leading to a proliferation of leukocytes, thus boosting immune system efficiency.

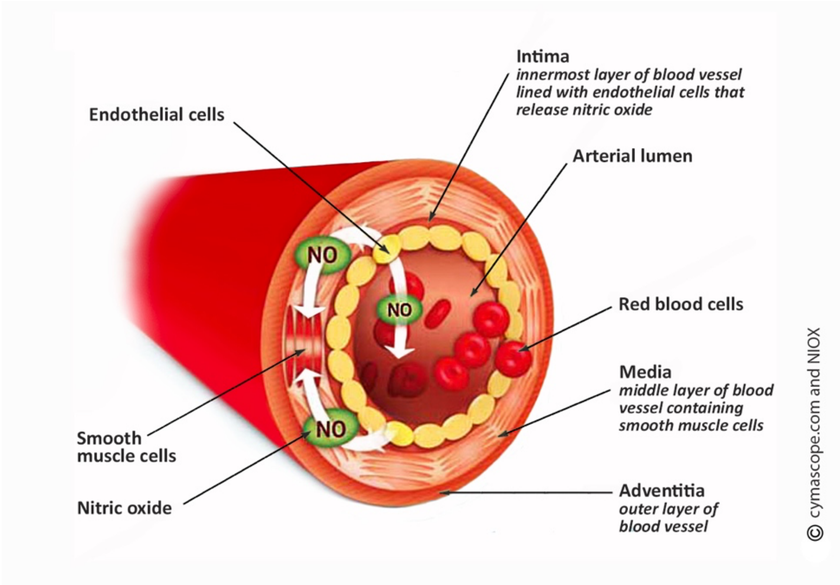
- Stimulates the brain binaurally—by binaural beats—to create changes in brain state, with physiological benefits.

- The vagus nerve is stimulated, thus regulating internal organ functions, including digestion, heart rate and respiratory rate, as well as promoting vasomotor activity and anti-inflammatory effects. Specific very low (sub audible) frequencies may also be applied by full ear headphones, combined with music.

Each of these biological mechanisms will be discussed separately.

Active and passive sonic stimulation of the sinus cavities and lungs

Before discussing the method of sonic stimulation of the sinus cavities and lungs, it is important to outline some of the natural health benefits of nitric oxide (NO), which is naturally produced in many areas of the body including the cilia in the sinus cavities and the alveoli in the lungs. NO reduces blood pressure by vasodilation[11] and many other health benefits are derived from this important molecule, for example: promotion of wound healing by cellular proliferation and angiogenesis,[12] mediation of cutaneous oedema and inflammation, cytotoxic action against pathogens,[13] increases cerebral blood flow and oxygenation to the brain,[14] inhibits the aggregation of platelets within blood vessels thus helping prevent thrombotic events,[15] supports reduction of pulmonary hypertension and chronic obstructive airway disease.[16]



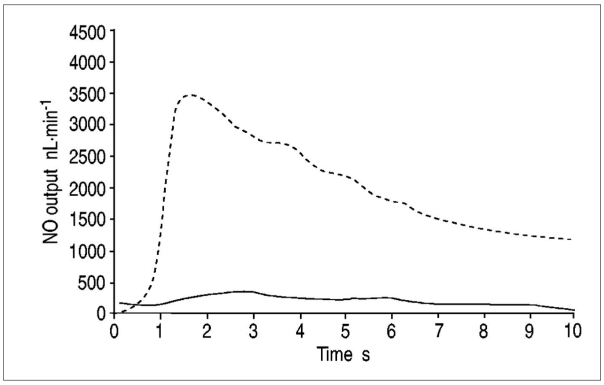
Nitric oxide relaxes smooth muscle cells in the walls of blood vessels, resulting in vasodilation

(Courtesy of NIOX)

NO can be produced in the body from the inorganic nitrates in green leafy vegetables and from fruits, particularly by the oral microbiome [17] and is also stimulated by exercise,[18] which can form part of a rehabilitation program, but the initial focus in this section is NO production in the sinus cavities brought about by both active and passive sonic stimulation. 'Active' stimulation refers to the practise of vocal humming, which has been shown to greatly elevate NO production.[19,20] The movement of air across the sinus cilia generates NO, from which the many health benefits are derived, although the exact mechanisms by which NO is produced by the cilia is not fully understood.[21]

The practise of nasal breathing is well known in the Yogic practise of pranayama, which means 'breath control' in Sanskrit, a practise that is mentioned in the Bhagavad Gita, written at some point between 400BCE and 200BCE.[22]

In a paper titled, *Assessment of nasal and sinus nitric oxide output using single-breath humming*,[23] the authors show that NO is significantly increased by a single breath exhalation while humming, as shown in the graph.



Original tracing of Nitric Oxide during a single-breath nasal exhalation with (dotted line) and without humming (solid line)

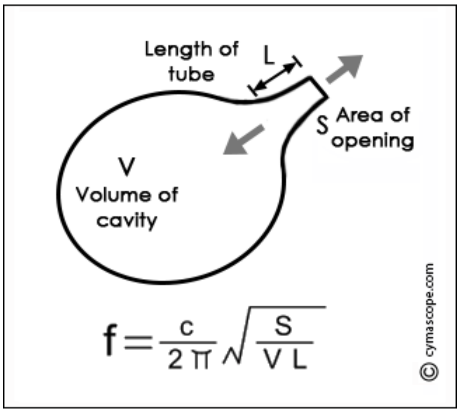
The authors of this study also carried out experiments to determine the optimum humming frequencies, and concluded that a measured frequency of 130Hz created the highest NO output of the sinus cavity in a human subject. The study does not specify whether the human subject was male or female but in either case the result is surprising when remembering that the sinuses consist of relatively small cavities, featuring Helmholtz resonant frequencies in the range 1kHz to 2kHz,[24] depending on gender and maturity.

An interesting fact concerning this range of resonant frequencies concerns the ancient Egyptian use of the sistra instrument, the rattle with metal discs, mentioned in the author's Sound Therapy 101 article. At the Festival of Opet the sistra was used to stimulate the nostrils: *'Receive the sistra presented to your nostril that he may give rejuvenating breath…"* [25] a statement suggesting that the ancient Egyptians were aware that sistra emitted a specific quality of sound that caused a rejuvenating effect on the sinus cavities.

Adult female skulls and sinus cavities are typically smaller than those of adult males; smaller sinus cavities support higher resonant frequencies. It should also be remembered that humming does not generate a single frequency but gives rise to an array of harmonics and that the prime resonant mode of the sinus cavities is automatically 'selected' during vocal humming as a natural aspect of Helmholtz resonance (the resonant property of a gas-filled cavity). Therefore, although the fundamental humming frequency of maximal excitation was found to be 130Hz, (in the study *Assessment of nasal and sinus nitric oxide output using* *single-breath humming*) the sinus cavities would almost certainly have been excited by a specific harmonic of this frequency.

Nitric Oxide is also generated by the alveoli in the lungs[26] and can be stimulated by both active and passive sonic stimulation; actively by humming or singing, and passively by externally applied sonic frequencies or music. Indicators regarding the optimum frequencies for passive stimulation can be obtained from studies in which the respiratory system has been modelled in terms of its resonant sonic characteristics.[27,28] In the study by University of Illinois[27], the Helmholtz resonant frequency of a healthy volunteer is shown to be in the order of 100Hz, increasing to around 250Hz for a person suffering from pulmonary fibrosis. These frequencies will vary between individuals due to gender and lung capacity as a function of the patient's genetic makeup. Similarly, the Helmholtz resonant frequencies of the sinus cavities will vary between individuals.

Identifying the precise resonant frequencies of the patient's lungs or sinus cavities is not necessary to offer therapeutic intervention if the practitioner plays live or recorded music to the patient at a moderate to high sound level, 70 to 85dBA, (it should be noted that live music contains far more high frequency harmonics, effective for sinus stimulation.) A patient's sinus cavities or lungs will automatically choose the specific frequency at which the cavity is naturally resonant, and this applies to (for example), to in-situ musical instruments, such as, pianos, harps, gongs, Tibetan bowls, crystal bowls and all recorded music via high fidelity sound equipment.



Helmholtz Resonance

f = resonant frequency of cavity, c = speed of sound in air, S = area of opening,

V = volume of air in the cavity, L = length of the tube

In addition to stimulation of nitric oxide production, acoustic stimulation of the sinus cavities and lungs can also help to clear mucus and improves symptoms of Chronic Obstructive Pulmonary Disease (COPD) and chronic bronchitis.[29]

Chronic pain mediation by audible sonic stimulation of nociceptors

Pain is a vital function of the body, providing early warning of damage or potential damage. It is both a sensory and emotional experience, affected by psychological factors such as past experiences, beliefs about pain, fear or anxiety.[30] Tissue injury, for example, initiates the liberation of various inflammatory mediators, including prostaglandins, cytokines and chemokines. Leukocyte migration to the injured area, a characteristic of the inflammatory response, is associated with pain and tenderness, and is involved in wound healing.[31] Acute pain is well understood and can be successfully mediated by analgesic medications; it is not within the scope of this article.

Chronic pain is a common, complex, and distressing problem, which has a significant impact on individuals and society.[32] Chronic pain, like most diseases, often arises from a series or combination of multiple events.[32] The biological processes that lead to the chronic pain state further increase sensitivity to painful stimuli and perceived levels of stress, which further modifies pain-related gene expression, creating a pathological pain cycle.[33] Even when there is a solitary precipitating event in the genesis of chronic pain (e.g. injury), there remain a series of factors that affect the duration, intensity, and effects (physical, psychological, social, and emotional) of chronic pain.[32]

The International Association for the Study of Pain, define pain as ‘An unpleasant sensory and emotional experience associated with, or resembling that associated with, actual or potential damage’ [34] and chronic pain is ‘pain which has persisted beyond normal tissue healing time’.[35] Pain is regarded as chronic when it has lasted for more than three to six months.[36]

Considering that pain is a universal experience, it is not understood why only a relatively small proportion of humans develop a chronic pain syndrome.[37] Prolonged use of analgesics, such as chronic opioid therapy, is associated with constipation, sleep-disordered breathing, hypothalamic-pituitary-adrenal dysregulation, fractures (as a result of osteoporosis) and significant declines in health-related quality of life and increased health care costs.[38] Therefore, it would be advantageous to mitigate chronic pain without long term use of analgesics.

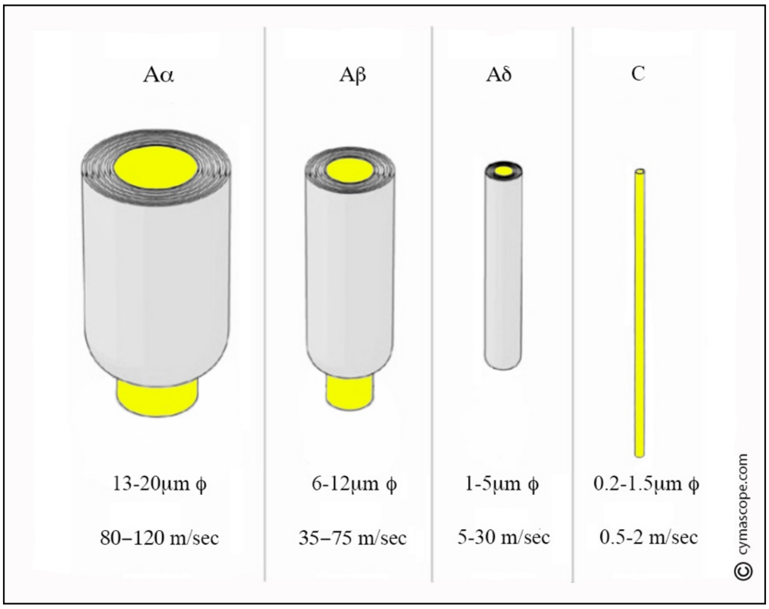
In this section we discuss audible sonic stimulation of the body's nociceptors, as an alternative therapeutic modality in the treatment of chronic pain. Unlike prolonged use of analgesics, audible sonic interventions have no known adverse side effects.

Nerve signal conduction by sound

To lay a foundation for discussion in the principles of pain mediation by sound, it is important to mention discoveries concerning nerve signal transmission by sound.

In 1952, Alan Hodgkin and Andrew Huxley, working with a squid's giant axons, described how action potentials (or nerve impulses) in neurons are initiated and propagated, known today as the Hodgkin–Huxley model.[39] It is regarded as one of the great achievements of twentieth century biophysics, for which they received the Nobel Prize in Medicine in 1963. Their theory, involving the flow of electric currents in nerves, became the standard teaching model in medical and biology textbooks. However, one aspect that puzzled researchers was the relatively slow conduction speeds in nerves, when compared with conduction speeds of electric currents in conductors. The speed of light in vacuum is 2.998×10^8 metres per second, which is approximately equal to a distance of 30cm per nano second. The speed of an electrical signal in a coaxial cable is about 2/3 of this, or 20cm per nano second, therefore, in one second the signal in a coaxial conductor will travel approximately 200,000,000 metres, which equates to a little over half the distance between the earth to the moon.

Nerve fibres, by comparison conduct signals several orders of magnitude slower than that of coaxial cables. The highest conduction speeds for nerve fibres are those of muscle axons, which can achieve speeds of over 100 metres per second.



The main classifications of afferent nerve fibres and their conduction speeds, which are very slow compared with electric currents in coaxial cables

However, in 2005 a new model of nerve conduction was proposed by researchers at the Niels Bohr Institute at the University of Copenhagen, whose experiments showed that nerves conduct sound (soliton impulses), which in turn generate electrical pulses, due to the piezo electric effect.[40] In their paper they note that "…measured propagation velocities, which are ~100 m/s in myelinated nerves, find a satisfying explanation". Put differently, propagation of nerve impulses by sound explains the slow conduction speeds, while such sonic impulses give rise to electrical impulses that travel to the brain for interpretation. This discovery has significant implications for sound therapy and music medicine, particularly for whole body immersion in music and specific sound frequencies.

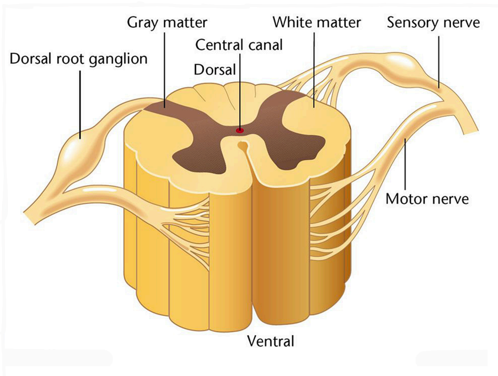
Principles of pain mediation by sound

Nociceptors are the specialised sensory receptors responsible for the detection of noxious (unpleasant) stimuli, transforming the stimuli into electrical signals, which are then conducted to the central nervous system.[30] They are the free nerve endings of primary afferent fibres and are distributed throughout the tissues of the body, including the skin, viscera, muscles, joints and the meninges of the brain, (though not in the grey matter of the brain).

The four main classifications of afferent fibre have specialised roles, for example, response to light touch, or to acute events, or response to chemical or thermal stimuli, but crucially all types of afferent nerve fibre respond to mechanical pressure. And since sound may be defined as:

“Mechanical radiant energy that is transmitted by longitudinal pressure waves in a material...”[41] it becomes clear that all types of afferent fibre respond to sound. This fact is reinforced by the Niels Bohr Institute discovery that nerves conduct sound as soliton pulses.

When nociceptors are stimulated, nerve impulses are transmitted to three spinal cord systems: the cells of the substantia gelatinosa in the dorsal horn; the dorsal-column fibers that project toward the brain; and the first central transmission (T) cells in the dorsal horn.[77]

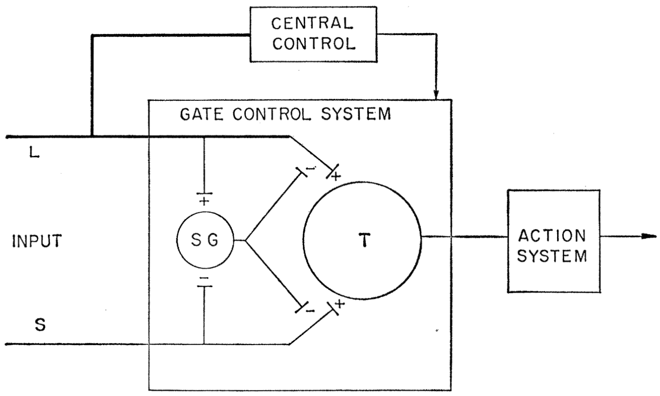


Cross section through spinal column showing the dorsal root ganglion

(Graphic: Emri Terim)

The theory by which sound frequencies can mediate pain are based on the ‘Gate Control Theory of Pain’, which was first proposed in 1965 by Ronald Melzack and Patrick Wall.[42] The theory was initially met with skepticism but despite having to undergo several modifications, its basic conception remains unchanged. Their theory provides a physiological-neural explanation for pain perception and ultimately revolutionized pain research. Gate Control Theory proposes that there are gates between the afferent nerves and the brain, located in the spinal column, which control how pain messages flow from the peripheral nervous system to the central nervous system.

For example, pain-signals conduct freely along small A-delta afferent fibres (that sense sharp pain) and small type C afferent fibres (that sense dull pain) open the gate, resulting in the perception of pain in the brain. By stimulating the large A-beta fibres or A-alpha fibres in the area experiencing pain, a reaction is caused in nearby inhibitory neurons. Once activated, Inhibitory Neurons, which sit on the same path as the Projection Neurons, the gate closes, thus muting pain signals before they reach the brain. Stimulating A-beta fibres or A-alpha fibres can be achieved by specific sound frequencies, as mentioned below.



The Melzack-Wall Gate Control System (from Melzack and Wall)

L = large diameter nerve fibers, S = small diameter nerve fibers. The fibers project to the substantia gelatinosa (SG) and first central transmission (T) cells.

Activity in large fibers inhibits signals from small fibers.

(Drawing from Ronald Melzack & Patrick Wall: Pain Mechanisms: A New Theory.)

Some of the optimal frequencies found to be beneficial for pain mediation via nociceptor stimulation were discovered in Finland by clinical psychologist, Petri Lehikoinen, in the range 27Hz to 113Hz. Lehikoinen developed a therapeutic system: Physio Acoustic Sound (PAS) therapy, that was approved in the USA by the Federal Drug Administration (FDA) and in the UK by the British Standards Institute (BSI) for three claims: decreased pain, increased blood and lymphatic circulation and increased muscle relaxation and mobility.[43] In Norway, Olav

Skille placed particular emphasis on specific therapeutic frequencies at 40Hz, 52Hz, 68Hz and 86Hz.[43]

Neurogenic pain

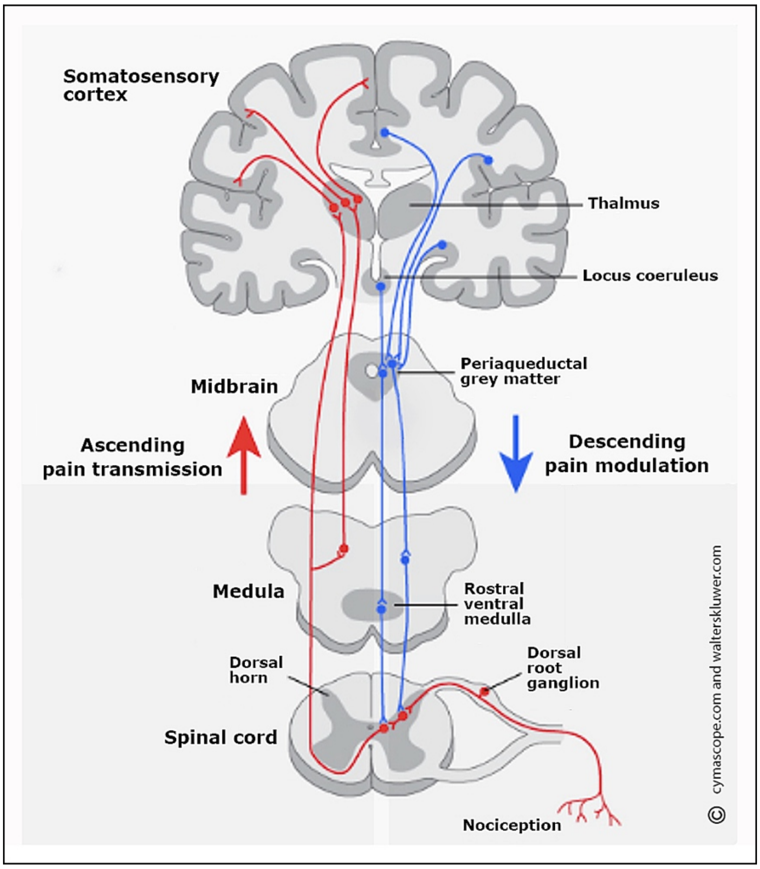
Pain can also be experienced that is not a consequence of nociception, categorized as 'neurogenic' pain, stemming from neural circuit dysrhythmias or disconnections. However, neurogenic pain has been found to be mediated by vibratory analgesia as a result of cortical dynamics.[44] For example, in a study with fibromyalgia patients, positive effects were obtained due to oscillatory coherence, with 40Hz vibro-tactile stimulation of the body.[45]

The descending inhibition of pain by music and white noise

A second mechanism of pain mediation, sometimes referred to as the "top down" modulation of pain [46] but more accurately described as the "Descending Inhibitory system"[47] or "Descending Analgesia System"[48] can be activated by music that creates a strong emotional response. Such music-invoked emotions can be described as "thrills".[49]

Music offers a wealth of benefits with no negative side effects and is, therefore, a favorable option for those who are looking for alternative pain management therapies.[47]

The origin of this second pain mediation mechanism arose from an early study by Dr. Henry K. Beecher, titled *Pain in men wounded in battle* in which he notes, "Three-quarters of badly wounded men, although they have received no morphine for a matter of hours have so little pain that they do not want pain relief medication… Strong emotion can block pain."[50]



Ascending and Descending Pain Pathways

(Courtesy of walterskluwer.com)

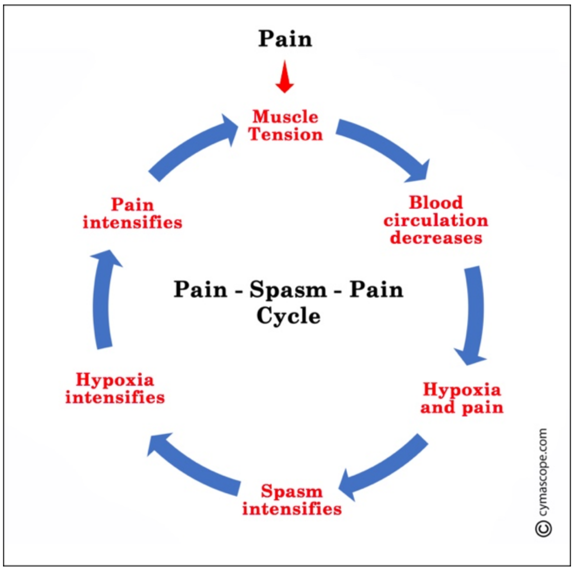
Descending Inhibition concerns tracts arising from the brainstem that terminate on the spinal cord to suppress sensory transmission and consequently produce analgesia.[47] Music - induced analgesia is hypothesized to occur as a result of the release of opioids during music listening,[48,49] thereby engaging the descending analgesia system that creates anti-nociceptive responses in the spinal cord. Descending inhibitory pathways use endogenous opioids, hydroxytryptamine (5-HT) and noradrenaline and their effects are mediated through supraspinal, midbrain-spinal and brainstem-spinal circuits.[51] A large number of brainstem structures suppress pain through descending projections to the spinal dorsal horn, and in most cases their descending pain suppressive effect is relayed through the periaqueductal gray matter (PAG) and the rostral ventromedial medulla (RVM).[47] The RVM in the brainstem is a particularly important relay site for integrating descending influences to the spinal cord.[47]

Breaking the "pain-spasm-pain" cycle in spinal injury, by sound

The first suggestion of a pain-spasm-pain cycle is generally credited to Janet Travell who wrote in 1942, "If muscle spasm causes pain, and pain reflexly produces muscle spasm, a self-perpetuating cycle might be established…"[52] Today, it is well known that spinal injuries typically create muscle spasm to "splint" the site of injury, providing protection while the healing process takes place.

In a round table discussion between four physicians, titled, *Diagnosis and Treatment of Low-Back Pain because of Paraspinous Muscle Spasm: A Physician Roundtable*, published in the journal Pain Medicine, Dr. McCarberg states:

"From an initial injury the patient develops pain. Motor neurons are activated as a reflex to splint that area causing muscle spasm. Muscle spasm clearly causes pain, but the exact cause of pain is poorly understood. Regardless, this pain will cause more muscle spasm…Hopefully, if this cycle is interrupted, a chronic problem will not occur."[53] The trauma caused by a spinal injury, or other injury, causes pain, which leads to muscle tension. A cascade of effects then results in which the muscle tension decreases the blood circulation, which (hypothetically) causes hypoxia and further pain in the affected muscles. The spasm then intensifies, which causes the hypoxia to intensify and the pain to intensify, therefore causing far more pain than the injury.



Pain > Muscle tension > Blood circulation decreases > Hypoxia and pain > Spasm intensifies > Hypoxia intensifies > Pain intensifies

The decrease in blood circulation is hypothesised to be a direct result of compression of intramuscular blood vessels, a concept that is supported by the fact that it is known that blood supply to a muscle is decreased during voluntary contraction and that pain following muscular exercise is very similar to pain induced by experimental reduction in the blood supply to a muscle.[54]

Pain relief and anxiety relief by acupressure and sonopuncture

Acupressure is an alternative medicine methodology that originated in ancient China; embodying treatment effects by stimulating acupuncture points using acute pressure.[55] The World Health Authority, in their 1991 international acupuncture nomenclature report, lists 14 main meridians and 361 classical acupuncture points, in addition to 8 extra meridians and 48 extra points.[56] These same classical acupuncture points, which can be activated by acute local pressure, can also be activated by sound, since sound (as mentioned earlier) may be defined as: "Mechanical radiant energy that is transmitted by longitudinal pressure waves in a material..."[41] This is the basis of 'sonopuncture', a therapeutic modality that is a type of acupressure.

A comprehensive review paper of fifteen acupressure studies concluded that acupressure is shown to reduce dysmenorrhea pain, labor pain, low back pain, chronic headache, and other traumatic pains. The clinical trials showed that acupressure can be efficiently conducted by health care professionals as an adjuvant therapy in general practice for pain relief.[57] The authors also concluded that their systematic review paper begins to establish a credible evidence base for the use of acupressure in relieving pain and that an evidence-base of reliable and valid evaluation is crucial for clinicians. In terms of the implication for nursing education, practice, and research, the review provides important evidence that acupressure uses a noninvasive, timely, and effective way to support its effectiveness in relieving a variety of pains.[57]

D. Carey, a licensed acupuncturist, developed a therapeutic method using tuning forks of specific frequency to activate acupuncture points while she was Clinical Dean at the Northwest Institute of Acupuncture and Oriental Medicine, in 1995. The intent was to seek a non-invasive therapy that could be taught to students and used in clinics with patient populations who were critically ill, including those suffering from HIV/AIDS, chronic pain, and trauma.[58] Today, this method of sonopuncture training is available in a certified course, providing an integrative medicine model that dovetails with many clinical specialities and can provide support for patients pursuing traditional Western medicine therapies.[59]

Sonopuncture, self-applied or practitioner-applied, by tuning forks, courtesy of

(Courtesy of Dr. E. Franklin)

Licensed acupuncturist, M.E. Wakefield, L.Ac., awarded 'Educator of the Year' by the American Association of Oriental Medicine in 2005, is co-author of V*ibrational Acupuncture: Integrating Tuning Forks with Needles*,[60] with MichelAngelo, M.F.A., vibrational medicine advisor. Their book uniquely explores the synergy of tuning forks and acupuncture. For pain mediation, via sonopuncture, the authors recommend applying a tuning fork of 136.1Hz to specific acupuncture points. Although sonically activating acupressure points typically supports several interconnected bodily systems, the following examples focus mainly on pain mediation:

Lu-7 Lieque, 'Broken Sequence' alleviates headaches, sore throat, migraines, toothache, pain in the wrist.

SI-3 Houxi, 'Back Stream' alleviates neck pain, acute lumbar sprain, pain in the shoulder and elbow.

UB-62 Shenmai, 'Extending Vessel' alleviates headache, backache, leg ache, insomnia.

TH-5 Waiguan, 'Outer Pass' alleviates headache, facial pain, finger pain, hand tremors.
Bl-58 Feiyang 'Taking Flight' mediates sciatic pain, alleviates headache, back pain.

Another important therapeutic use of tuning forks was discovered by E.D. McKusick, M.A., author of the book, *Tuning the Human Biofield*.[61] Energy-information is constantly radiated from the body in the form of biofields, as mentioned in part one of this article. (See winter edition of HTJ). The biofields include bio-photonic energy, for example, modulated infrared electromagnetism that is a natural consequence of cellular metabolic processes, in addition to modulations in the electromagnetic fields emitted by the heart, brain and other organs. Quoting from the book's foreword by Dr. Karl H. Maret, who practices Complementary and Alternative Medicine, "when a holographic sound field such as that produced by a tuning fork, which contains complex data structures of pure frequencies with changing phase relationships interacts with the biofield of a person, the cellular memories of various tissues can be reawakened, potentially leading to a healing response. Quantum physical field theory predicts the occurrence of a number of coherent dynamic phenomena in liquid water inside cells and tissues that may be stimulated by sound. This process affects the free electron clouds existing within these coherent water domains, [thus modifying] cellular processes through their interaction with the hydration shells surrounding cell membrane receptors." The biofield tuning method has been shown to consistently reduce anxiety, as well as relieve pain.[62]

A biofield therapeutic tuning session in progress
(Courtesy of E.D. McKusick]

Pain relief by sonopuncture administered by electronic devices

Although sonopuncture is typically applied by tuning forks, devices that emit low frequency vibration can also achieve sonic activation of acupressure points [63] in addition to devices that emit ultrasound.[64] The acupressure points on the soles of the feet can also stimulate the meridian system by applying audible sound frequencies.[65] Dr. M. Cromwell developed a therapeutic device that uses a vibro-tactile transducer, emitting a range of audible sound frequencies into acoustic gel-filled pads on which the soles of the feet rest, thus stimulating the meridian system. Together with her assistant, Kate Holland, CCP, they conducted a six-week investigative pain study in 2016, with three individuals, a female of 30-years, a male of 38-years and a male of 68-years.[66]

Sonopuncture applied via vibro-tactile transducer and acoustic gel-filled pads

(Courtesy of Dr. M. Cromwell)

In summary for this section on Acupressure/Sonopuncture, there exists a significant potential for pain reduction, in addition to support for a range of other chronic conditions, including depression, PTSD, insomnia and others.

Musical stimulation of the immune system (via headphones or full body immersion)

Illness in any form can cause emotional distress and emotions can play a significant role in a patient's recovery from illness or from an operating procedure. Stress and fear cause the release of cortisol from the adrenal glands [67] helping prepare the body for 'fight or flight' by providing extra glucose, tapping into protein stores via gluconeogenesis in the liver.[68] However, cortisol also suppresses the immune system[69] and other bodily systems considered by Nature to be 'non-essential' in the short term, making the patient more vulnerable to contracting pathogens. While pharmaceutical sedatives are routinely prescribed to mediate a patient's stress and fear, music can produce a similar outcome without medication. The harp, in particular, when played live to patients, provides full body immersion in a myriad of sonic frequencies that have both physiological and psychological benefits. Listening to recorded harp music via headphones has a direct effect on the vagus nerve, as described later.

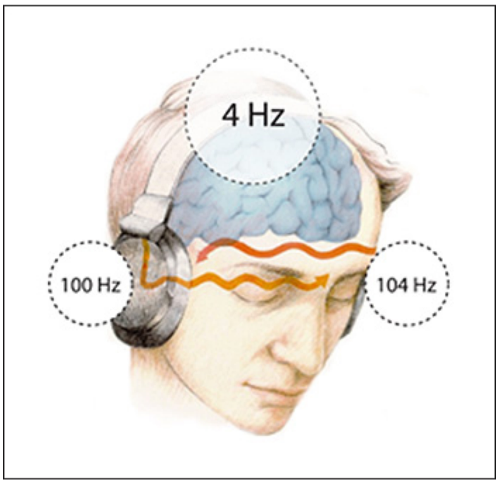
Music can evoke happy memories of times, places, or life events that can quickly transform a patient's mood into a sense of joy, in which state the brain and enteric nervous system in the digestive tract produces dopamine, which boosts the immune system.[70,71] In parallel with the increase in dopamine, a patient's favourite music causes a reduction in cortisol levels.[72] Joy also triggers the pituitary gland in the brain to release beta-endorphins into the bloodstream, which produce analgesia by binding to mu-opioid receptors that are present throughout peripheral nerves. Mu-opioid receptors have been identified in the central terminals of primary afferent neurons, peripheral sensory nerve fibres and dorsal root ganglia.[73]

The pituitary gland also stores of the neuropeptide, oxytocin, colloquially known as the 'love hormone'. Oxytocin is made in the hypothalmus and transported to large, dense-core vesicles of the posterior lobe of the pituitary gland[74] where it is released into the blood stream in response during sexual activity and orgasm in addition to childbirth. In a broader context there appears to be a general consensus among studies that music listening enhances oxytocin synthesis[75] and postoperative patients listening to music through headphones demonstrated an increase in serum oxytocin and reported higher levels of relaxation, compared to a control group with no music.[76] Oxytocin and its receptors appear to hold the leading position among the candidates for the substance of 'happiness',[77] and in a study focussed on autistic children, significantly lower levels of oxytocin was found in their blood plasma, suggesting a ray of hope in finding a role for oxytocin in treatment of autism,[77] that is, in both of these cases, (evoking happiness and supporting the treatment of autism) there is an obvious link in the form of music, whether applied via headphones or full body immersion.

A further important connection between music and the immune system was reported in a 2019 study by Augusta University, USA. The researchers found that when mice were subjected to low frequency sound vibrations, macrophages in their bloodstream proliferated significantly.[78] This effect has not yet been demonstrated in humans, however, it seems likely that human blood will respond in a similar way to that of murine blood. The possible mechanism that powers the proliferation of macrophages in blood that is immersed in low frequency sound, is an increase in the pO_2 level. It is important to mention that this aspect of the connection between music and the immune system would occur only during full body immersion, since the full circulatory system would require stimulation by low sonic frequencies.

Binaural Beats (via headphones) to create changes in brain state, with physiological benefits

Binaural beats were discovered accidentally in 1839 by the Prussian scientist, Heinrich Wilhelm Dove, during experiments with two tuning forks of dissimilar frequency. He has been referred to as 'The Father of meteorology'[79] for his work in that field, however, as late as 1915 his discovery of binaural beats was considered a trivial special case of monaural beats.[80] Monaural beats occur when two sounds of slightly different frequency sound simultaneously, resulting in a pulsating effect caused by the mixing of the two sounds, which are reinforced during moments when their phases align, and diminished when their phases oppose each other. But during headphone listening, when two slightly different frequencies are experienced, the composite difference frequency is known as a binaural beat and it provides a mechanism for stimulating the auditory system at very low frequencies, below the frequency range of hearing.[81] Listening to binaural beats produces the illusion that the sounds are located somewhere within the head. The lower auditory centres of the brain are in the medulla oblongata, and impulses from the right and the left ears first meet in the left or right superior olivary nucleus. These structures are part of the olive, an organ that in this view lies behind the brain stem. It is probable that binaural beats are detected here.[80] The difference frequency between sounds presented to the left and right ears entrains the brain rhythms to that frequency.



Depiction of binaural beats

(Courtesy of Hemi-Sync® hemi-sync.com)

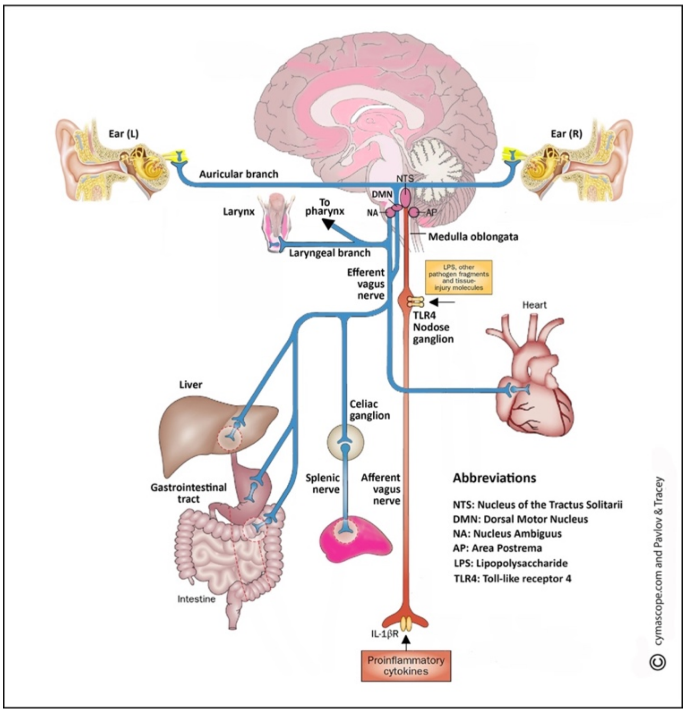
In a carefully designed, double-blind, binaural beats crossover study, titled: *Binaural Auditory Beats Affect Vigilance, Performance and Mood. Physiology and Behavior*, 29 volunteers were tested. The recordings used in the study contained a background sound of pink noise and a carrier tone, within which was embedded an entraining difference frequency between left and right channels. (The purpose of the pink noise was to mask the sound of the carrier tone.) The participants were kept blind to the true purpose of the study and were unaware of the presence of binaural beats in the headphones. The results of the study provided evidence that presentation of simple binaural auditory beat stimuli during a 30-minute vigilance task can affect both the task performance and changes in mood associated with the task. The effects on behaviour and mood were observed in the absence of participant expectations, and experimental control ruled out placebo effects. The authors concluded that simple binaural-beat auditory stimulation can influence psychomotor and affective processes, even when people are unaware that such signals are being presented, and that this technology may have applications for the control of attention and arousal and the enhancement of human performance.[81]

In another double-blind crossover study, titled: *Reduced pain and analgesic use after acoustic binaural beats therapy in chronic pain - A double-blind randomized control cross-over trial*, the authors concluded that theta rhythm binaural beats reduced pain intensity, stress and analgesic use, compared to sham stimulation, in chronic pain patients. A further conclusion was that the subsequent significant reduction in analgesic medication consumption in chronic pain patients' daily living could offer a valuable tool, augmenting the effect of existing pain therapies.[82]

Robert Monroe of The Monroe Institute, created a system of binaural beats in which individuals listen to a combination of audio binaural beats mixed with music, pink noise and/or the natural sound of the ocean waves that has been named the 'Hemi-Sync' process. Studies with this system have shown improvements in sensory integration[83] relaxation, meditation, stress reduction, sleep and pain management[84] enriched learning environments and enhanced memory.[85]

Sonic stimulation of the vagus nerve (via headphones) and by vocalisations

The vagus nerve represents the main component of the parasympathetic nervous system, which oversees a vast array of crucial bodily functions, including control of mood, immune response, digestion and heart rate and carries an extensive range of signals from the digestive system and organs and vice versa.[86] Upon exiting the jugular foramen, an auricular branch is given off, giving innervation to the auditory canal and external ear. This is the only branch of the vagus nerve given to the head. As the vagus nerve descends the neck via the medulla oblongata, branches leave to the pharynx and larynx before continuing into the thorax where it connects with the heart and other major organs. The laryngeal and auricular connections are of special interest in the context of sound therapy and music medicine, discussed later in this section, following an overview of the vagus nerve and methods of its therapeutic stimulation.



Vagus nerve branches and functional anatomy of the inflammatory reflex

(Adapted with permission, Pavlov and Tracey [87])

Schematic description:

Inflammatory mediators, such as cytokines, are released by activated macrophages and other immune cells upon immune challenge. These mediators are detected by sensory components of the afferent arm of the inflammatory reflex. Neural interconnections between the NTS, AP, DMN, NA and higher forebrain regions integrate afferent (red) and efferent (blue) vagus output, thus, regulating immune activation, supressing pro-inflammatory cytokines,[86] and reducing inflammation. Vagus efferent output can be supported by auricular and laryngeal input.

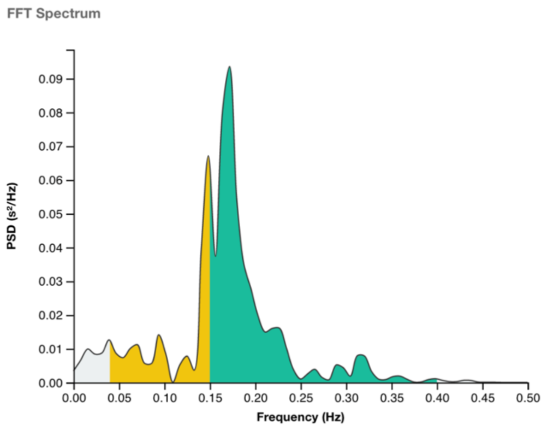
The bi-directional communication between the brain and the gastrointestinal tract, sometimes called the 'brain-gut axis', is a complex system that includes the vagus nerve, and is becoming increasingly important as a therapeutic target for gastrointestinal and psychiatric disorders, such as inflammatory bowel disease, depression and posttraumatic stress disorder.[86] The gut is an important control centre of the immune system and the vagus nerve has immunomodulatory properties. As a result, this nerve plays important roles in the relationship between the gut, the brain, and inflammation.[86]

There is a 'hard-wired' connection between the nervous system and immune system as an anti-inflammatory mechanism. Counterregulatory mechanisms, such as immunologically competent cells and anti-inflammatory cytokines normally limit the acute inflammatory response and prevent the spread of inflammatory mediators into the bloodstream. The dorsal vagal complex, responds to increased circulating amounts of tumour necrosis factor (TNF-α) by altering motor activity in the vagus nerve,[86] therefore, stimulation of the vagus nerve can help restore cytokine balance, leading to a reduction in chronic inflammation. The vagus nerve is a major component of the neuroendocrine-immune axis which is involved in coordinated neural, behavioural, and endocrine responses that provide an important first-line innate defence against infection and inflammation and helps restore homeostasis in the body.[88] Inflammatory diseases in which tumour necrosis factor (TNFα) is a key cytokine are good candidates for treatment targeting cholinergic anti-inflammatory pathway (CAP).[88]

In essence, the inflammatory reflex is a physiological mechanism through which the vagus nerve regulates immune function and inhibits pro-inflammatory cytokine production,[87] thus, preventing excessive inflammation by alerting the brain to the presence of cytokines, which triggers the release of anti-inflammatory molecules that reduce the inflammation and maintain a healthy balance.[89]

One of the most important potentials for vagus nerve stimulation concerns its role in cancer prognosis. In a review paper titled, *The Role of the Vagus Nerve in Cancer Prognosis: A Systematic and Comprehensive Review,* the authors highlight the fact that cancer remains the second leading cause of mortality worldwide, with prostate cancer being the most prevalent cancer type in men and breast cancer in women. Cancer is a complex condition since it includes several hundreds of different types and because it involves and is affected by multiple body systems. Studies have shown that three basic biological factors contribute to the onset and progression of tumorigenesis: (1) oxidative stress, leading to DNA damage, (2) inflammation that contributes to escape from apoptosis, angiogenesis and metastasis, and (3) excessive sympathetic activity, which affects where cancer cells will metastasize. One factor common to these three factors, which inhibits all three and influences cancer prognosis, is vagus nerve stimulation because it reduces oxidative stress, informs the brain about inflammation and profoundly inhibits inflammation, and inhibits sympathetic activity since it is a major branch of the parasympathetic nervous system.[90] An interesting and potentially crucial aspect of vagus nerve activity concerns the link to Heart Rate Variability

(HRV), the variability of interbeat cardiac intervals that is strongly correlated with vagal nerve activity and cardiac autonomic regulation.



Power Spectral Density of HRV is typically expressed in milliseconds squared (ms^2), plotted against frequency
(Courtesy of EliteHRV.com)

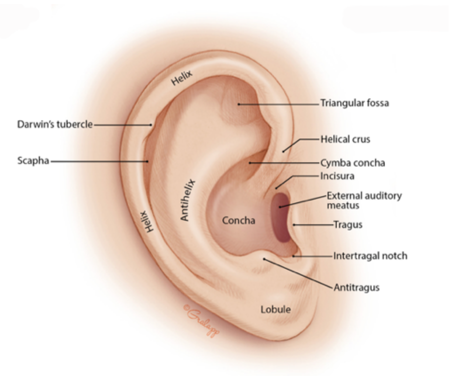
The Power Spectral Density (PSD) of high frequency heart rate variability, (HF-HRV is cardiac frequency activity in the range, 0.15 to 0.40 Hz) is strongly associated with cardiovagal activity.[91] (By comparison, low frequency cardiac activity (LF) is in the range 0.04 to 0.15Hz). LF and HF frequency bands are widely used to quantify parasympathetic and sympathetic regulation.[91]

The vagus nerve plays a major homeostatic role, indicated by people with high HRV who have shown improved recovery rates to physiological stress in cardiac, hormonal and immune systems, compared to those with lower HRV. In twelve studies that investigated the association between vagal tone activity and prediction of prognosis in cancer, which included 1822 patients, the emerging evidence was consistent in demonstrating a prognostic role of vagal activity and a significant correlation between survival time and high frequency heart rate variability. Using the vagal nerve index of HF-HRV, when data was analyzed from a cohort of women with metastatic and recurrent breast cancer it was found that in a sample of 87 women, higher HF-HRV significantly predicted long term survival. It was also found that the predictive validity of HF-HRV improved when dividing it by the patients' heart rate, thus reflecting a more vagal/sympathetic ratio. The authors of the review study call for seriously considering adding HRV to the clinical estimation of prognosis in oncology.[90]

In the next section, methods of vagus nerve stimulation are discussed including electrical, sonic, auricular and laryngeal, all of which improve vagal tone with many potential health benefits. The vagus nerve can also be stimulated by acupuncture, by experienced and licensed acupuncturists.

Electrical stimulation of the vagus nerve (VNS) was first studied in the 1930s and 1940s with animals, which laid the groundwork for studies in humans. Following successful clinical trials, the FDA approved the use of an implanted electrical vagus nerve stimulator for the treatment of certain types of epilepsy in 1997. The procedure involves implanting electrodes near the vagus nerve in the neck, along with a control device and battery implanted into the chest. The same mode of treatment was later also approved by the FDA for use in chronic, drug resistant depression.[89]

Transcutaneous (through the skin) vagus nerve (tVNS) is currently emerging as an alternative and seeks to administer electrical stimulation to the vagus nerve without the need for implant surgery, thus avoiding the associated risks. Stimulation is typically applied via the auricular branch of the vagus nerve via the tragus of the pinna. The European Union certified tVNS as an alternative treatment for epilepsy and pain in 2010 and 2012 respectively.[89]



The pinna, showing the location of the tragus, where the vagus nerve terminates

(Courtesy of Tori Lewis Fibonacci Web Studio)

As early as 2001, researchers showed that electrical stimulation of the vagus nerve via the tragus, using a form of electroacupuncture reduced the dependence of patients with coronary arterial disease on vasodilator medication.[92] In their study, titled, *Vagal neurostimulation in patients with coronary artery disease*, the authors stimulated the area of the ear near the auditory passage that contains endings of the auricularis nerve, by means of electrodes attached to short acupuncture needles, inserted to a depth of 0.1 to 0.3 mm. The authors concluded that electrical stimulation of the auricularis nerve results in tonic activation of the central vagus nerve structures and that an increase in vagal tone improves cardiac blood supply in patients with severe angina via dilation of spastic cardiac micro vessels.[92] Referred pain to the ear from myocardial infarction has also been reported, due to the connectivity of ear and the heart, via the vagus nerve.[93]

In the study titled, *Anti-inflammatory properties of the vagus nerve: potential therapeutic implications of vagus nerve stimulation*,[88] electrical tVNS frequencies used to activate vagal afferents to mediate depression and epilepsy are quoted as 20-30Hz and activation of the cholinergic anti-inflammatory pathway (CAP) as 1-10Hz. The authors mention anti-inflammatory properties of the vagus nerve both through its afferent (activation of the HPA axis) and efferent (activation of the CAP) fibres and that it is a good therapeutic target in inflammatory conditions of the digestive tract, for example, irritable bowel syndrome, and rheumatoid arthritis.

Sonopuncture tVNS

Several commercial manufacturers are now producing devices that provide electrical transcutaneous vagus nerve stimulation,[94,95,96] and others that utilise infrasonic sound.[97] Returning to the subject of sonopuncture and to the research by the Niels Bohr Institute, discussed earlier in this article, it was shown that nerves conduct sound (soliton impulses), which in turn generate electrical pulses, due to the piezo- electric effect.[40] Therefore, although a corpus of research shows that the vagus nerve can be electrically stimulated via the tragus and other acupressure points of the ears, it is clear that this can also be achieved sonically, and that such sonic stimulation will, automatically, lead to electrical stimulation of the auricular branch of the vagus nerve, due to the piezo-electric effect. In this scenario full ear headphones should be worn, enabling the full pinna of the ear to receive sound frequencies.

Very low frequencies for tVNS can be delivered sonically, via headphones

The very low frequencies commonly deployed in tVNS therapies can be created sonically via high specification headphones, and several manufacturers now produce headphones that can deliver sounds as low as 5Hz.[98,99,100] Although no studies of this type have yet been conducted, this form of sonopuncture may hold great therapeutic potential in support of a wide variety of illnesses, some of which have been mentioned in this section, including chronic inflammation. Sonic stimulation of the vagus nerve would be achieved by sinusoidal tones, generated by an audio signal generator and fed to headphones via a suitable audio amplifier with the ability to handle very low frequencies. However, specially prepared music could also be deployed therapeutically, that is, music to which the very low frequencies identified in tVNS studies could be added to the music, either embedded in the recording or added separately to the amplifier input feed from an electronic signal generator. In such a scenario the patient would be able to enjoy the many health marker benefits of listening to music, mentioned earlier in this article, while the vagus nerve would be vibrationally stimulated by sonopuncture frequencies below the range of hearing, adding further health benefits, for example, reducing chronic inflammation.

Before discussing vocal stimulation of the vagus nerve we make a special mention of the work of French otolaryngologist, Alfred A. Tomatis (b.1920, d. 2001). Dr. Tomatis received his Doctorate in Medicine from the Paris School of Medicine and formulated a theory that many vocal problems are actually hearing problems, based on the concept that *the voice cannot produce what the ear cannot not hear,* today referred to as 'The Tomatis Effect'.

Tomatis developed the 'Electronic Ear', a device that utilizes bone conduction and sound filters to improve the tone of the muscles in the middle ear, to sensitize the listener to the missing frequencies, particularly in the high registers. The ear starts forming a few days after conception and is fully developed by the fourth month of pregnancy. Tomatis theorized that information coming from the fetal ear stimulates and guides the development of the brain. He believed that a number of auditory communication problems begin in pregnancy, with the fetus not properly responding to the voice of the mother. In children with ASD, he believed that his electronic ear device simulated the sound of the mother's voice as heard in the uterus, leading the child to gradually accept and respond to her real unfiltered voice. He reported that this method often brought startling results, with children crying with joy as they recognized their mother's voice for the first time. He wrote: "It is this [vagus] nerve that helps the singer to consciously rediscover the correct respiration rhythm as well as cardiac and visceral rhythms so that a synergy is created between this internal network and the larynx…It is equally important in mastering a fluid and correct verbal flow of speech…Without doubt singing is one of the best ways to free ourselves from the burden of parasympathetic or neurological imbalances."[101]

Vocal stimulation of the vagus nerve

Last, in this section of the article, the laryngeal connection to the vagus nerve expresses and directly influences internal visceral states through the voice. In the article, *Stalking the calm buzz: how the polyvagal theory links stage presence, mammalian evolution, and the root of the vocal nerve*,[102] Joanna Cazden discusses Stephen W. Porges 'polyvagal theory' which emphasises phonation, respiration and hearing. Porge's research proposes that the voice is strongly influenced by neuro-regulation that underlies our ability to communicate, and because the vagus nerve mediates both our emotional state and our laryngeal muscle activity, our visceral states directly influence and are expressed through the voice.

Full appreciation of the autonomic vagus nerve, its influence on behaviour and its implications for vocal performance, requires a distinction between the neurophysiologic aspects of the autonomic system's two main sub-branches, the sympathetic and parasympathetic.[102] These two aspects of the autonomic nervous system can be thought of as a sympathetic accelerator and a parasympathetic break, providing bidirectional neural communication between our organs and brainstem.[103] Several nerve tracts in the brain can send sympathetic signals to stimulate a faster heart beat but *only the vagus nerve sends a slowing signal*, achieved during exhalation: the heart beats slightly faster as we inhale and slower as we exhale.[104] This effect is termed, Respiratory Sinus Arrhythmia (RSA), which is a measure of vagal tone. The auditory nerve (CN VIII) that carries sound signals from the ears to the brain receives close crosstalk from the myelinated vagus nerve. Porge mentions that the voice is a potent trigger of the physiological states of others and that emotional prosody is an audible sign of autonomic status, recognised in the brain of the listener. Because the laryngeal nerves branch directly from the vagus, the voice transmits our inner resilience and expressive visceral state to others through sound.[102]

In the study, *Music Structure Determines Heart Rate Variability of Singers*,[105] it is suggested that singing can be viewed as initiating the work of a vagal pump: Singing produces slow, regular and deep respiration which in turn triggers RSA, causing a pulsating vagal activity. In addition, as discussed in the section *Active and passive sonic stimulation of the nasal cavities and lungs,* singing, chanting and humming stimulates nitric oxide production in the nasal cavities and lungs, with many associated health benefits.

Playwright, John Guare, said, "the purpose of art is to exercise the muscles of the soul, so that when the challenges of life come, we are prepared". Porge's polyvagal theory suggests that these "muscles of the soul" may be found in the tiny area of the brainstem where a single myelinated pathway influences the remarkable vagus nerve.[102]

Vibrational medicine: the future

The depiction of a therapeutic bed of the future, as fictionalised in the television series

'Star Trek', inspired the imagination of millions of viewers into what may be possible in the twenty-third century. Yet even now, medical physics of the twenty-first century is beginning to develop a non-invasive diagnostic bed capable of indicating asthma, sepsis, and even several types of cancer by monitoring exhaled gases and compounds from patients. The technology that makes this possible is a mass spectrometer, the same type of instrument on board NASA's Perseverance rover on Mars, searching for signs of life. Other instruments that can be integrated into this future bed include **thermal and hyper-spectral imagers** that will track temperature and skin colour to monitor a patient's metabolism, while ultrasound sensors will non-invasively measure **blood flow and oxygenation** to analyze the heart's activity and blood circulation in real-time.[106]

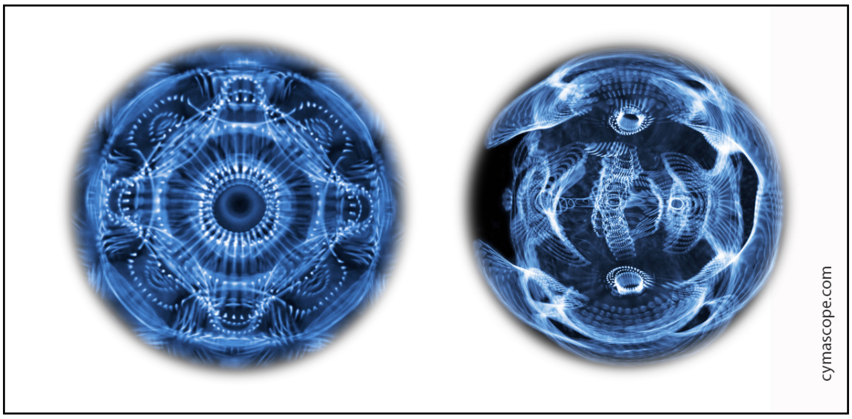
Brain activity can also now be measured without attaching electrodes to a patient's scalp, by superconducting quantum interference device (SQUID) magnetometer, making it possible to monitor neurological conditions remotely. The distance between the skull and the magnetometer is typically 2cm at present but future improvements in sensitivity may make it possible to build the magnetometer into the structure of the bed, providing EEG readouts in bed-head displays. Such powerful diagnostic aids seem like science fiction, yet are becoming a reality.

Also mirroring Star Trek, active healing technology could be built into hospital beds of the future. For example, as this article has highlighted, chronic pain mediation without use of analgesics is already possible by means of sound vibrations applied to specific body parts, which can be achieved while a patient is supine. Commercial vibro-acoustic beds have been developed by several manufacturers [107,108,109] and their use in clinical environments is likely to play an increasingly important role in hospitals of the future.

In addition to pain mediation, whole body vibration to supine patients could greatly enhance a patient's blood oxygen levels, as the author's preliminary studies have shown, thereby supporting the healing of many illnesses. Sonic stimulation of a patient's lungs and nasal cavities would also increase their nitric oxide levels, thereby encouraging vasodilation, lowering blood pressure and providing many other health benefits.

Music delivered to every patient, via ultrasonic speakers, would help elevate their mood and therefore, dopamine levels, providing a helpful boost to their immune system, crucial to healing processes.

One of the greatest challenges facing medicine in the twenty-first century is in eradication of cancer, yet a discovery made by Professor James Gimzewski of UCLA, in 2002, offers an intriguing potential for eradicating not only cancer cells but perhaps any pathogen. Using an Atomic Force Microscope, he and his colleague, Dr. Andrew Pelling and team, were able to listen to the sounds of cells for the first time. Surprisingly, they found that the respiration sounds of cells lie in the audible range when amplified, naming their new approach to cell biology, 'sonocytology', referring to the 'songs' of cells.[110,111] Raman spectroscopy offers an accessible alternative method of recording the songs of cancer cells, which differ significantly from that of healthy cells. In a study by the author, in collaboration with Professor Sungchul Ji of Rutgers University, sounds from cancer cells and healthy cells, derived by Raman spectroscopy, were made visible with the aid of a cymascope instrument, imprinting the sound vibrations onto medical grade water, rather like a fingerprint on glass, thus leaving a visual signature of the cell sounds. A typical cymaglyph (sound image) of a healthy cell sound is symmetrical, while that of a cancer cell is skewed by comparison. The study, titled, *Imaging Cancer and Healthy Cell Sounds in Water by Cymascope, Followed by Quantitative Analysis by Planck-Shannon Classifier* was published in the Water Journal (waterjournal.org), as the revealing medium of sonic vibrations in the cymascope instrument is water.[112]



Healthy cell cymaglyph (left), cancer cell cymaglyph (right)

This collaborative study was a first step toward creating visual imagery for a surgeon who would wear specially adapted eyewear, to see, in real time, changing sound patterns as the Raman laser probe is scanned across the tissues during an operating procedure. However, the most exciting aspect of this new technology lies in its potential for early cancer detection and ultimately to destroy cancer cells. By taking a biopsy of a cancer, its sonic signature could be detected and amplified, then used to modulate an ultrasound beam directed at a tumour. In such a scenario the tumour cells would absorb sufficient acoustic energy (of the cancer cell's own sonic signature) to be destroyed. Such a therapeutic procedure would likely be given during a series of outpatient visits, in which a percentage of the tumour's mass would undergo a controlled shrink on each visit, to minimise the toxic waste of dead cancer cell material. For leukemia sufferers, this principle holds the potential for sonic irradiation the patient's blood via a specially adapted intraoperative recirculating system.

Another area of future sound-based medical physics concerns the G0 phase of the cell cycle in which a system of cells becomes quiescent due to environmental changes, for example, glucose depletion, heat shock, free radicals, pathogen invasion, or toxicity. When a system of cells is in the G0 phase this creates imbalance in the body, resulting in physiological symptoms, yet, hypothetically, cells in this 'sleeping' state can be stimulated to return to the normal cell cycle by immersion in specific sound frequencies or in music. (Recall that Professor James Gimzewski's research [110,111] indicated that the sounds emitted by cells are in audible frequency ranges, typically centred around 1kHz.) The quasi-holographic nature of sound, and the spherical space-form of audible sounds, mentioned in the introduction to this article, is why Faraday Wave patterns manifest on the surface membranes of cells, organs, visceral fascia and in visceral fluids. Although not within the scope of this article, it is also why all of the energy information within a specific sound frequency, or within music, is conveyed to the cell's interior. Also popularly known as 'cymatic patterns' after Dr. Hans Jenny, who coined the term to mean 'visible sound', the importance of this natural phenomenon is vital in relation to the future of vibrational medicine. The integral membrane proteins and primary cilia of cells are, in a very real sense, massaged by the anti-nodal pressure points of such microscopic sound patterns, stimulating cells in ways that have yet to be discovered.

Sound organises matter, a fact that can be seen in simple Chladni Plate experiments with particulate matter, and in more sophisticated experiments with the CymaScope instrument, in which liquid water is used as the imprinting medium to transpose sonic periodicities to water wavelet periodicities.[7] Life as we know it cannot exist without liquid water; 'structured water', or 'exclusion zone' (EZ) water, is discussed in depth by Professor Gerald H. Pollack, in his ground-breaking book, *The Fourth Phase of Water.* [113] He proposes that EZ water (H_3O_2), literally generates the electricity that helps power all living creatures. Here then is a connection waiting to be explored between sound frequencies that organise water molecules, and EZ water that powers life. Professor Pollack has discovered that EZ water is built by light, particularly infrared light, yielding a potentially fascinating connection between sound and our physiology: *inelastic sonic collisions create sonically-modulated infrared light that powers the EZ water-building mechanism in cells, which in turn powers our biology*. The organisational aspect of sound and its EZ water-building mechanism is already beginning to provide insights into what might come to be termed 'sono-biology', a field in which the role of structured water and sound is likely to become increasingly important in medicine.

These are just some of the many advances in medical science that hold the potential to support humankind in the quest to reverse disease, extend life and improve quality of life. The role of sound in medical modalities is growing each year for drug-free therapies and for diagnostic applications, and is finding welcome support among many physicians, and in hospitals worldwide. I predict that Sound Therapy and Music Medicine will have an important role in the future of medicine, one that deserves to be developed and nurtured.

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