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Music and the Brain: A Holistic Perspective

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Abstract

This paper examines music as a powerful, evidence-informed modality that positions sound as an adjunct therapeutic technique capable of shaping healing at physical, emotional, cognitive, and energetic levels. Contemporary neuroscience and psychoneuroimmunology (PNI) provide a strong scientific foundation by demonstrating how music modulates neural networks, autonomic balance, stress physiology, and immune signaling, mechanisms that reflect the inseparability of mind, body, body, emotion, and spirit. Quantum-informed perspectives extend this understanding by suggesting that music functions as a patterned vibrational field that shapes coherence, resonance, and meaning across neural, emotional, and energetic dimensions.

Keywords: Psychoneuroimmunology; Neuroscience; Brain; Subcortical; Cerebellum

Abbreviations : PNI: Psychoneuroimmunology; NMT: Neurologic Music Therapy; HPA : Hypothalamic-Pituitary-Adrenal; IgA: Immunoglobulin A; NK : Natural Killer

Introduction

Music and the Brain: A Holistic Perspective

This paper examines music as a powerful, evidence-informed modality that positions sound as an adjunct therapeutic technique capable of shaping healing at physical, emotional, cognitive, and energetic levels. Contemporary neuroscience and psychoneuroimmunology (PNI) provide a strong scientific foundation by demonstrating how music modulates neural networks, autonomic balance, stress physiology, and immune signaling, mechanisms that reflect the inseparability of mind, body, body, emotion, and spirit. Quantum-informed perspectives extend this understanding by suggesting that music functions as a patterned vibrational field that shapes coherence, resonance, and meaning across neural, emotional, and energetic dimensions.

Within these integrated frameworks, music emerges as a vibrational encounter that entrains physiological rhythms, evokes emotion, supports coherence, and transforms the healing environment. Holistic health care practitioners are uniquely positioned to use music intentionally, ethically, and relationally, honoring cultural and personal preferences while creating environmental conditions that support whole-person healing. By weaving together theory, science, and clinical application, we call for the continued integration of music into education, research, and practice, reaffirming its role as a modality that resonates within the health care professions.

The Neuroscience of Music: How the Brain Responds

Neural Pathways Activated by Music

Music perception triggers activity across cortical, subcortical, and cerebellar networks, beginning in the auditory cortex and radiating outward to include most major functional systems in the brain. The primary auditory cortex, also known as Heschl's gyrus, is part of the temporal lobe. It processes auditory information and breaks the stimulus down to detect pitch, timbre, and rhythm. As with other sensory systems, auditory stimuli are processed in a hierarchical fashion, with each sequential area processing more abstract features [1]. Studies using fMRI to identify brain regions involved in listening to music have found bilateral activity in the frontal and temporal lobes, subcortical regions, and the cerebellum. These patterns of activity reflect activation of attentional, default mode, frontoparietal, and limbic networks [2].

Activity in the limbic system is consistent with the amygdala tracking the emotional content of the music [3] and

the hippocampus linking musical stimuli to autobiographical memories [4]. Nostalgic music is shown to activate the default mode and reward networks, providing a pathway to explain how music provokes memory retrieval [4]. Music also triggers activation of the prefrontal cortex, a region associated with sustained attention, working memory, and executive function [5]. This pattern of activation across a range of networks and brain regions demonstrates why music can impact cognitive function, emotion, and behavior [6]. Together, these neural patterns illustrate how music engages the whole person, integrating cognition, emotion, memory, and physiological regulation in ways that align directly with whole-person healing.

Neurochemical Responses

Beyond those neural pathways, music triggers the release of neurotransmitters that are associated with emotions, analgesia, and social bonding. The best-known of these is dopamine, typically associated with rewarded behaviors. Primary biological reinforcers such as food and sex activate the mesolimbic dopamine system. This reward circuit is hijacked by substance addictions and behavioral addictions to reinforce the behavior. Music is one of the few abstract stimuli that can activate this pathway [6]. Functional brain imaging studies show that dopamine is released in the striatum during emotional responses to music. Intriguingly, different parts of the striatum are activated during different periods of musical experience. The caudate is most active when the listener is anticipating the musical climax, but the nucleus accumbens is most active at the moment of peak enjoyment [7].

Activity in the caudate is the basis for the chills experienced when listening to music. Beyond dopamine, music stimulates endogenous opioid and oxytocin systems, producing analgesic effects and enhancing social bonding. It has been documented that listening to and producing music reduces pain perception in the clinical setting [7]. Beta-endorphins are released when an individual listens to or produces music. These endorphins are associated with reduced pain and elevated mood. Shared musical experiences promote the release of both endorphins and oxytocin. These encourage social bonding, group cohesion, and emotional co-regulation [6]. These prosocial behaviors are important in group therapy settings. Together, the combined activation of dopamine, endogenous opioids, and oxytocin during music perception or performance explains the ability to reduce pain, elevate mood, and strengthen interpersonal connections [7]. Music supports whole-person's healing by influencing pain, mood, connection, and regulation in ways that align with a holistic focus on human experience.

Neuroplasticity

Neuroplasticity is the idea that the brain is not fixed; it can change over time in response to stimuli. Music provides a well-documented example of experience-dependent neuroplasticity, structurally and functionally reshaping neural architecture. Compared to non-musicians, musicians tend to have more gray matter in Heschl's gyrus, the motor and premotor areas, and the cerebellum [9]. The size of the increase is correlated with cumulative hours of practice, suggesting it is a result of the practice, not a cause of someone taking up music. In addition to these changes in gray matter, musical training also results in white matter changes, indicating increased connectivity between different brain regions [7]. Even listening to music alters functional connectivity between brain regions [5]. This suggests that listening to music could have therapeutic relevance even for individuals without musical training.

Compared to non-musicians, individuals with musical training have an enlarged corpus callosum. This structure is near the center of the brain and transfers information between the two hemispheres. This enlargement provides an anatomical explanation for the cognitive advantages observed in musicians. The anterior corpus callosum connects the motor and premotor areas of the left and right hemispheres and is significantly larger in professional musicians than in non-musicians [9]. This effect is greater among those who began musical training before age 7, which is thought to be a sensitive period of brain development. Longitudinal studies [9] extend this finding, showing that 29 months of musical training in young children aged 5 – 7 years increases the size of the anterior and midbody corpus callosum. Other brain imaging research has looked at functional connectivity in the brains of musicians and found greater myelin density and more efficient interhemispheric signal transfer compared with non-musicians [9].

Together, these structural changes explain functional differences observed in musicians. These differences include enhanced bimanual coordination, faster interhemispheric communication, and more integrated processing of auditory, motor, and emotional information. These manifest as advantages in attention, working memory, and executive function [11]. The neuroplasticity induced by music has direct, well-supported implications for clinical rehabilitation, cognitive resilience throughout life, and the preservation of meaningful function in the context of aging and neurocognitive diseases. Neurologic music therapy (NMT) is a practice that puts these ideas into clinical practice [5]. Rhythmic auditory stimulation takes advantage of the coupling between the auditory and motor systems to support gait rehabilitation in patients with a stroke or Parkinson disease. Another approach, melodic intonation therapy, uses the musical networks preserved in the right hemisphere to help restore expressive language after damage to the speech centers in the left hemisphere [5,6].

Age-related cognitive decline is a growing concern as society ages, and music offers hope here as well. The hypothesis is that the neuroplastic effects of music build structural resilience and a cognitive reserve that protects against deterioration due to age and neurodegenerative change [7]. In patients with moderate-

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to-severe neurocognitive disorders, such as Alzheimer disease, emotional and motor responses to music are preserved [12]. This makes music a form of intervention available even at an advanced stage of the disease. Similarly, music can trigger autobiographical memories in individuals with early cognitive decline through engagement of the hippocampus, default mode network, and the reward circuitry [4]. This access to autobiographical memory has important clinical and social implications for caregivers of these individuals. The limbic, autonomic, and reward pathways described in this section are also involved in regulating the body's stress response. Through these interconnected networks, music affects cortisol secretion, autonomic balance, and immune function, the focus of the following section.

Music can Trigger Memories for those in Cognitive Decline

These neuroplastic changes illustrate how musical experience reshapes cognition, emotion, movement, and connection in ways that support whole-person functioning across the lifespan. This evidence reinforces the use of music as a therapeutic modality that nurtures resilience, preserves meaning, and promotes integrated healing in diverse clinical contexts.

PNI as a Framework for Understanding Music

Building on the neurobiological foundations described in the previous section, music's influence extends beyond neural circuitry into the broader terrain of stress physiology and immune function. Psychoneuroimmunology is often described as the science behind holism, offers a coherent framework for understanding how music interacts with the nervous, endocrine, and immune systems in ways that support healing. From a holistic perspective, this interplay reflects the deep relationality between experience, meaning, and the body's biological and adaptive capacities.

Music, Stress Physiology, and Immune Function

PNI describes dynamic communication among the brain, autonomic nervous system, endocrine pathways, and immune responses. Stress is a central mediator in this network. When the body perceives threat, whether physical, emotional, or even existential, the Hypothalamic-Pituitary-Adrenal (HPA) axis activates, releasing cortisol and catecholamines that prepare the organism for action [13]. While adaptive in the short term, chronic activation suppresses immune surveillance, disrupts cytokine balance, and contributes to inflammation related dysregulation. Recent work continues to affirm that prolonged stress alters both innate and adaptive immunity, increasing vulnerability to infection, slowing wound healing, and exacerbating chronic illness [14]. Music enters this landscape as a regulator of autonomic balance. Slow tempo, predictable, or personally meaningful music can reduce sympathetic arousal and enhance parasympathetic activity, particularly through increased vagal tone. This shift supports homeostasis and reduces the physiological costs of chronic stress [15].

Cytokines are small, cell-signaling messenger proteins that act as the immune system's communication network. They help immune cells communicate with one another and the rest of the body, coordinating inflammation, defense, and tissue repair. When functioning well, cytokines rise and fall in precise patterns that allow the body to respond to injury or infection and then return to balance. In chronic inflammatory disease, however, this signaling becomes dysregulated [13]. Pro-inflammatory cytokines (such as IL-6, TNF-α, and IL-1β) remain elevated in stress, driving persistent inflammation, altering neuroendocrine function, and contributing to fatigue, pain, mood disturbance, and impaired immunity. With chronic cytokine activation this becomes a self-perpetuating loop, linking psychological stress, immune imbalance, chronic inflammation, and disease progression, a concept that aligns closely with a holistic understanding of pattern and interconnectedness.

There is a bidirectional relationship between stress, cytokine activity, and chronic inflammatory conditions. Stress amplifies pro-inflammatory cytokine release, changes how these cytokines influence neural and endocrine pathways, and contributes to the symptom burden seen in autoimmune disorders, cardiovascular disease, depression, and other chronic inflammatory illnesses [13]. Immune dysregulation is not solely a biological event, but a pattern shaped by lived experience, perception, and the body's ongoing attempts to maintain coherence. Music's influence on inflammatory cytokines, including interleukin 6 (IL 6) and tumor necrosis factor alpha (TNF α), has been documented in both clinical and experimental contexts, with reductions in maladaptive elevations observed following music engagement [16]. These findings align with holistic emphasis on pattern, coherence, and the interconnectedness of mind, body, and spirit.

Evidence Linking Music to Immune Modulation

A growing body of research demonstrates that music can directly influence immune markers. Although contemporary studies often focus on stress physiology and neuroinflammation, earlier immune specific research remains foundational. A seminal systematic review article [17] identified increases in salivary immunoglobulin A (IgA), enhanced natural killer (NK) cell activity, and beneficial cytokine shifts following music exposure. These immune changes have been observed across diverse populations, including healthy adults, individuals with chronic illness, and patients undergoing surgery. More recent work extends these findings into contemporary contexts [16]. reviewed music-based interventions during the COVID 19 pandemic and found reductions in neuroinflammatory biomarkers, improved emotional regulation, and decreased cortisol levels.

These effects were particularly notable in individuals experiencing prolonged stress, isolation, or uncertainty, conditions that mirror many chronic illness experiences. Their review highlights music's capacity to buffer stress related immune dysregulation and support resilience during periods of heightened

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physiological and psychological strain. Additional evidence comes from integrative oncology, where music therapy has been associated with reduced anxiety, improved quality of life, and modulation of stress related biomarkers. While not all oncology studies measure immune markers directly, reductions in cortisol and improvements in autonomic regulation are well documented, and these changes are known to support immune resilience [18]. Organizational research summaries, such as those from the Sound Healing Research Foundation [19], also report increases in IgA and NK cell activity following music interventions, providing accessible, real-world evidence that complements academic literature.

Systematic reviews of holistic connections further affirm the links between stress reduction, immune enhancement, and music are well grounded in research. A recent review synthesizing 75 studies found consistent associations between stress modulating interventions, including music, and improved immune outcomes, particularly through reductions in cortisol and inflammatory cytokines [20]. Music's immune effects are mediated through its influence on stress physiology, emotional regulation, and autonomic balance. Taken together, these findings show that music influences immune function through interconnected emotional, physiological, and neuroendocrine pathways that shape the whole person. In holistic practice, this evidence supports the use of music as a therapeutic modality that strengthens resilience, reduces suffering, and promotes integrated healing across diverse patient populations.

Mechanisms of Action

Music's influence on stress physiology and immune function arises from multiple converging mechanisms. These mechanisms reflect the complexity of human experience and align with understanding of the person as an integrated whole.

Entrainment: A Synchronization of Internal and External Rhythms

Music can synchronize internal rhythms, heart rate, respiration, and neural oscillations with external auditory patterns. Slow, steady rhythms promote entrainment toward parasympathetic dominance, reducing heart rate and respiratory rate while supporting vagal activation. This entrainment reduces allostatic load, the cumulative physiological burden of chronic stress, and creates conditions conducive to immune restoration. Physiological entrainment describes how the body's internal rhythms synchronize with external rhythmic cues, and music is one of the most potent drivers of this alignment. Musical rhythm can shape neural oscillations, heart-rate variability, and motor timing, creating coordinated mind–body synchronized states that support cognition, emotion, and movement [21]. Music's beat and meter act as "dominant oscillators" that stabilize internal rhythms, enhancing attention, emotional regulation, and social connection through shared rhythmicity. Because of these effects, entrainment provides a theoretical foundation for rhythm- and music-based interventions that promote well-being and support holistic practice [21].

Emotions are Activated

Emotional states profoundly influence immune function. Music evokes, modulates, and transforms emotional experience, enabling individuals to process stress, grief, fear, or uncertainty in ways that reduce physiological strain. Music therapy consistently supports mental health by reducing stress, elevating mood, and strengthening emotional well-being [22]. These authors go on to show us that music also enhances cognitive functioning, including memory, attention, and executive skills, across groups such as people with dementia, traumatic brain injury, and chronic illness. Music serves as a coping mechanism by helping individuals regulate emotions, interrupt negative thinking, and cultivate positive emotional states. By facilitating emotional regulation, music decreases sympathetic activation and cortisol release, thereby reducing immune imbalance. These mechanisms are especially relevant in populations experiencing chronic stress or illness, where emotional dysregulation measurably contributes to immune vulnerability. These emotional and physiological effects illustrate why music fits naturally within holistic practice, which views emotional regulation, stress reduction, and immune balance as interconnected dimensions of whole-person healing.

Meaning is Discovered

Meaning is a central dimension of healing. Music supports narrative coherence by helping individuals make sense of their experiences, connect with identity, and access inner resources [23]. This making process enhances psychological resilience, which in turn influences immune function through well documented psychobiological pathways. When individuals experience coherence, physiological, emotional, and existential, their immune systems function more effectively. Meaning making contributes to coherence by helping individuals integrate experience, reduce uncertainty, and restore a sense of internal order.

The Quantum World makes a Ripple

Music's effects on the brain are relevant and are part of the science of holism and psychoneuroimmunology. The impact of the quantum world on health is also within the field of PNI [24]. At the neural level, music engages large scale brain networks involved in emotion, memory, prediction, and motor coordination, producing rapid neuroplastic changes that support mood regulation and cognitive flexibility [25]. These network-level shifts are complemented by evidence that music-based interventions modulate stress physiology and immune signaling, partly through limbic-hypothalamic pathways and vagal regulation [5]. From a quantum-informed perspective, these mechanisms can be framed as alterations in patterns of coherence. These systems are complex and adaptive. Quantum cognition models propose that the mind sometimes operates in states of superposition, where multiple potential interpretations coexist before resolving into

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a decision or perception, an idea that aligns with how music can hold listeners in emotionally or cognitively ambiguous states that later "collapse" into meaning [26].

Tervaniemi's approach captures how music shapes attention, emotion, social connection, and meaning in the environments where people listen and create. Similarly, theories of quantum-like processing suggest that non-linear, context-dependent shifts in attention and expectation may help explain music's ability to reorganize mental states and facilitate therapeutic suggestion. Music's vibratory waves can be understood as patterned oscillations that interact with the nervous system much like quantum waves, fields that shape coherence, resonance, and meaning. In neuroscience, musical sound waves entrain neural rhythms, synchronizing oscillatory activity across cortical and subcortical networks involved in emotion, prediction, and memory [25]. This entrainment, discussed earlier, mirrors the quantum concept of wave coherence, where systems align into more ordered, energy-efficient states.

Heart–brain coherence research adds another layer of explanation. Positive emotion or rhythmic breathing produces a more ordered, sine-wave-like cardiac pattern that influences brain function through vagal pathways. Studies from the HeartMath Institute suggest that coherent heart rhythms support emotional regulation, cognitive clarity, and systemic synchronization [15]. This physiological coherence parallels quantum coherence, where oscillating systems align and exchange information more efficiently. When music induces calm, resonance, or emotional uplift, it may be functioning as a coherence-generating stimulus, organizing neural oscillations, modulating autonomic balance, influencing molecular action, and aligning heart-brain rhythms [24]. In this sense, musical waves act as macroscopic analogues of quantum waves: both shape patterns of probability, both influence system-wide coherence, and both can shift a system from disorder toward integrated, meaningful order.

This conceptual framing supports emphasis on pattern, coherence, and the subtle dynamics of the healing environments. Some scholars extend this further, proposing that music's vibratory structure may influence coherence across neural and psychophysiological systems in ways analogous to quantum resonance phenomena. Neuroplasticity-focused work shows that music can reorganize neural circuits and enhance integrative processing, which resonates metaphorically with quantum models emphasizing entanglement and dynamic relationality [27]. These descriptions offer a conceptual bridge for understanding how patterned vibration, sound, can shift consciousness, modulate stress responses, and support healing within holistic frameworks. These neural, physiological, and quantum-informed perspectives show that music influences human health through interconnected patterns of emotion, cognition, energy, and biological regulation. This integrated understanding reinforces music as a therapeutic modality that supports coherence, meaning, and whole-person healing across diverse clinical settings.

Integrating Music into Holistic Healthcare Practice

The evidence base supports music as an accessible, low risk, and biologically meaningful intervention. Healthcare practitioners can integrate music into care by assessing patient preferences, cultural context, and therapeutic goals; selecting music that supports relaxation or emotional expression; and using music intentionally during procedures, transitions, or moments of distress. Music becomes a modality that aligns with a holistic commitment to presence, pattern recognition, and the facilitation of healing environments. Music functions as an intervention by shaping therapeutic environments, supporting psychophysiological regulation, and honoring the patient's autonomy and cultural identity through intentional engagement with sound. Healing soundscapes, whether created through ambient tones, rhythmic structures, or the reduction of harmful noise, have been shown to enhance perceived safety, reduce stress, and support whole person healing by influencing environmental atmosphere and autonomic balance [28].

Guided imagery with music and structured relaxation protocols deepens the regulatory effect by pairing receptive listening with visualization, a combination that recent work demonstrates can reduce stress, modulate pain perception, and support emotional processing in both patients and health care providers [29]. Patient selected music further strengthens therapeutic impact by reinforcing identity, autonomy, and cultural resonance, aligning with a holistic emphasis on honoring lived experience and supporting meaning making. Contemporary frameworks such as the NIH Music Based Intervention Toolkit highlight music's growing evidence base as a nonpharmacologic modality that engages neural, emotional, and relational pathways relevant to healing, particularly in populations experiencing cognitive, emotional, or stress related challenges [30]. Together, these elements position music not as an adjunct but as an integrative modality that harmonizes environmental design, psychophysiological regulation, and person-centered care, an approach that aligns with commitment to presence, pattern, and whole system healing.

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Table 1: Examples across clinical setting.

	Methods	Findings
Perioperative anxiety reduction for patients in perioperative settings	Umbrella review synthesizing evidence from systematic reviews and metaanalyses. [31]	Music interventions reduce preoperative anxiety across surgical populations. Effects observed regardless of music type, delivery method, or timing. Music is safe, lowcost, and feasible in perioperative settings [31].
Chronic pain patients: modulation pain.	A scoping review following PRISMA-ScR guidelines of a total of sixty-three studies reviewed. [32].	Music interventions reduced pain intensity and improved emotional wellbeing across multiple study types. Benefits were linked to distraction, relaxation, emotional regulation, and sense of control. Patientselected music showed stronger effects than researcherselected music [32].
Pain in childbirth: primipara women in labor.	Systematic review and metaanalysis following PRISMA guidelines. Extracted outcomes on labor pain, anxiety, and maternal experience [33]	Music therapy significantly reduced labor pain during the active phase and lowered anxiety levels compared with controls. Interventions were safe, lowcost, effective, without side effects, and wellaccepted by laboring women [33].
Palliative care: music supporting meaning, spiritual comfort, and pain reduction in for patients in palliative care.	Huda N, et al. (2023) [34] was a metanalysis that included 7 randomized trials with 747 advanced cancer palliative patients. Pinheiro Hammuod SF, et al. [35] was a systemic review and meta-analysis of 6 studies.	Music therapy interventions have been shown to significantly improve spiritual well-being in palliative care patients Huda N, et al. (2023) [34]. Music therapy significantly reduced pain (SMD = −0.20, 95% CI −0.36 to −0.03) [35]
Pediatric settings: music reducing pain in children	Ting, et al. (2022) [36] included 38 randomized controlled trials in the meta-analysis	Music significantly reduces pain in infants and newborns, particularly in cases of chronic and postoperative pain. Showed significant reductions in overall pain, along with lower heart and respiratory rates and higher oxygen saturation. Classical, kids', and pop music demonstrated the strongest effects [36].

Ethical Considerations

Respecting cultural, spiritual, and personal music preferences is a core ethical obligation in music-based care because music is part of identity, memory, meaning, worldview, and community belonging. Research emphasizes that culturally attuned music selection strengthens therapeutic alliance, supports emotional safety, and prevents the imposition of dominant cultural norms in clinical encounters [37]. Ethical practice also requires careful avoidance of overstimulation or triggering content, particularly for individuals with trauma histories, neurocognitive disorders, sensory sensitivities, or conditions in which certain rhythms, volumes, or lyrical themes may provoke distress. Recent reviews highlight the importance of titrating sensory input and monitoring patient responses in real time [29,38]. Documentation and evaluation are equally essential: record the type of music used, patient preferences, observed responses, and any adverse reactions, ensuring that music-based interventions are integrated into the care plan with the same rigor applied to other therapeutic modalities [30]. Together, these practices ensure that music interventions remain person centered, culturally humble, and ethically grounded across clinical and research settings.

Conclusions

Waves of music heal because they remind the body how to return to coherence. Waves of music offer a fitting conclusion because they mirror the unity, the inseparability of brain, body, emotion, spirit, and immune function. When sound enters the human system, its patterned vibrations interact with our own internal oscillations, heart rhythms, neural firing, breath cycles, immune signaling, reminding the body how to return to coherence. Music becomes not merely an intervention but a relational field phenomenon, a vibrational encounter that supports meaning, safety, and integration. Contemporary evidence shown in this article affirms this unity: music modulates neural networks, regulates autonomic and emotional states, and influences immune markers through PNI pathways.

Reaffirming music as a powerful, evidence-informed modality underscores that healing is not a linear biomedical event but a dynamic pattern shift across the whole person. As complementary and integrative practice continues to evolve, the discipline is called to deepen research on music-based interventions, expand education that prepares healthcare professionals to use music ethically and skillfully, and integrate these practices into care plans with the same rigor afforded to other therapeutic modalities. Music's waves remind us that healing emerges when the human system is met with presence, attunement, and patterned vibration that supports coherence. In this way, music stands as both metaphor and method for an enduring commitment to unity, meaning, and whole-person healing.

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