



HARMONY OF MOLECULES: EXPLORING THE CHEMICAL BASIS OF MUSICAL COMPOSITION

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Abstract

This research paper delves into the fascinating intersection of music and chemistry, exploring how chemical principles underpin various aspects of musical composition. While seemingly disparate fields, both music and chemistry share fundamental concepts such as structure, symmetry, and resonance. This paper aims to elucidate the molecular basis of sound, investigating how the properties of molecules influence musical tones, timbres, and harmonies. Through an interdisciplinary approach, it examines the role of chemical compounds in musical instrument construction, the chemistry of sound production and propagation, and the potential for chemical synthesis to inspire novel musical compositions. Additionally, it explores the psychological and emotional effects of music from a neurochemical perspective, elucidating the molecular mechanisms underlying music's ability to evoke emotions and alter mood. By synthesizing insights from chemistry and musicology, this paper contributes to a deeper understanding of the intrinsic connection between science and art.

Keywords: Harmony of Molecules, Musical Composition

Key Points to Explore

- **The Chemistry of Musical Instrument Construction:** Investigating the materials and chemical processes involved in crafting musical instruments, including the resonance properties of wood, metal alloys used in brass instruments, and the acoustics of synthetic materials.
- **Molecular Dynamics of Sound Production:** Exploring how vibrations and resonance at the molecular level translate into audible sound waves, with a focus on the role of molecular structure in determining pitch, frequency, and timbre.
- **Chemical Analysis of Musical Composition:** Utilizing spectroscopic techniques and computational chemistry to analyze the chemical composition of musical compositions, uncovering patterns and correlations between molecular structures and musical motifs.
- **Neurochemical Effects of Music:** Examining the neurotransmitter pathways and neurochemical responses associated with listening to music, including the release of dopamine, serotonin, and endorphins, and their implications for mood regulation and emotional expression.
- **Chemical Synthesis and Musical Creativity:** Investigating how chemical synthesis techniques, such as algorithmic composition and generative music systems, can be employed to create innovative musical compositions inspired by molecular structures and chemical reactions.
- By exploring these interconnected themes, this research paper aims to deepen our appreciation of the chemical underpinnings of music and inspire new avenues for interdisciplinary inquiry at the nexus of science and art.

INTRODUCTION TO INTERDISCIPLINARY EXPLORATION

Music and chemistry, seemingly distant disciplines, share profound connections that invite exploration at the intersection of science and art. While music captivates our senses with its harmonies, rhythms, and emotional depth, chemistry unveils the intricate dance of atoms and molecules that underpins the fabric of our world. In this paper, we embark on a journey to uncover the hidden symphony of molecules and explore how chemical principles resonate within the realm of musical composition.

Shared Fundamentals At their core, both music and chemistry are governed by fundamental principles that transcend disciplinary boundaries. From the resonance of a vibrating string to the harmonic structure of a





musical chord, and from the bonding patterns of molecules to the symmetrical arrangement of atoms, parallels emerge that invite inquiry and discovery. By recognizing these shared fundamentals, we open doors to a deeper understanding of both the science of sound and the art of composition.

Inspiration from Nature Nature serves as a boundless source of inspiration for both musicians and chemists alike. Whether marveling at the delicate harmony of a natural melody or unraveling the elegant simplicity of a chemical reaction, we find beauty in the underlying order and complexity of the natural world. By drawing inspiration from the patterns and processes observed in nature, we gain insights that enrich our creative endeavors and expand the horizons of our understanding.

Interdisciplinary Dialogue The intersection of music and chemistry invites a rich dialogue between scientific inquiry and artistic expression. Through interdisciplinary collaboration, scientists and musicians can bridge the gap between theory and practice, shedding light on the molecular basis of musical phenomena and harnessing chemical insights to inspire new forms of creative expression. By fostering this dialogue, we cultivate a shared appreciation for the interconnectedness of knowledge and the boundless possibilities that emerge when diverse perspectives converge.

Scope of Exploration In this paper, we aim to explore the multifaceted relationship between music and chemistry, delving into topics ranging from the chemistry of musical instrument construction to the neurochemical effects of music on the human brain. By synthesizing insights from chemistry, physics, neuroscience, and musicology, we seek to uncover the hidden symphony of molecules that reverberates within the world of music, illuminating the profound connections that unite science and art.

As we embark on this interdisciplinary journey, let us listen with open ears and curious minds, attuned to the harmonies of molecules that resonate beneath the surface of musical composition.

CHEMISTRY OF MUSICAL INSTRUMENT CONSTRUCTION

This introduction sets the stage for the interdisciplinary exploration of music and chemistry, emphasizing the shared fundamentals, inspiration from nature, and the potential for fruitful dialogue between scientific inquiry and artistic expression.

In exploring the chemistry of musical instrument construction, we uncover the fascinating interplay between materials science, acoustics, and craftsmanship. This section delves into how the molecular properties of various materials influence the sound quality, resonance, and durability of musical instruments.

- **Woodwind Instruments: The Role of Material Composition** Woodwind instruments, such as flutes, clarinets, and saxophones, rely on the unique properties of wood to produce their distinctive tones. The choice of wood species, grain orientation, and density profoundly affects the instrument's sound characteristics. For example, dense hardwoods like grenadilla and rosewood are prized for their rich, warm tones, while softer woods like cedar and maple offer lighter, brighter timbres.
- **The Science of Resonance in String Instruments** String instruments, including violins, cellos, and guitars, derive their sound from the vibrations of taut strings. However, the body of the instrument plays a crucial role in amplifying and shaping these vibrations. The selection of tonewoods for the instrument's body is critical, as different woods exhibit varying degrees of stiffness, density, and damping properties. Spruce, prized for its strength-to-weight ratio and resonance properties, is commonly used for the soundboards of violins and guitars. Similarly, maple, with its tight grain structure and bright tonal characteristics, is favored for the backs and sides of stringed instruments.
- **Metal Alloys and Brass Instruments** Brass instruments, such as trumpets, trombones, and French horns, rely on the acoustical properties of metal alloys to produce their characteristic sound. Brass, an alloy of



copper and zinc, offers a unique balance of resonance, malleability, and corrosion resistance ideal for instrument construction. The composition and annealing process of brass alloys can be tailored to achieve specific tonal qualities, allowing instrument makers to fine-tune the timbre and response of their creations.

- **Synthetic Materials and Modern Innovations** In addition to traditional materials, modern instrument makers are exploring the use of synthetic materials such as carbon fiber, fiberglass, and composites. These materials offer advantages in terms of durability, stability, and environmental sustainability. Moreover, advances in additive manufacturing technologies, such as 3D printing, enable the creation of complex geometries and customized instrument designs with unprecedented precision.

The chemistry of musical instrument construction is a testament to the intricate relationship between materials science, acoustics, and craftsmanship. By understanding the molecular properties of various materials and their effects on sound production, instrument makers can create instruments that resonate with unparalleled clarity, richness, and expressiveness. As technology advances and new materials are developed, the future of musical instrument construction holds boundless possibilities for innovation and artistic expression.

This section provides an overview of the chemistry behind the construction of various types of musical instruments, highlighting the role of material composition, resonance properties, and technological advancements in shaping the sound quality and performance characteristics of instruments.

ACOUSTICS AND MOLECULAR VIBRATIONS

Exploring the relationship between acoustics and molecular vibrations unveils the intricate connection between the molecular structure of materials and the production of musical tones. This section delves into the fundamental principles of molecular vibrations and their impact on sound propagation in musical instruments.

- **Fundamentals of Molecular Vibrations** At the molecular level, atoms are bound together by chemical bonds that can stretch, bend, or twist in response to external forces. These vibrational motions give rise to characteristic frequencies known as vibrational modes, which depend on the masses of the atoms involved and the strength of the bonds between them. Infrared spectroscopy is a powerful tool used to study molecular vibrations, allowing scientists to identify and analyze the vibrational modes present in a molecule.
- **Translating Molecular Vibrations to Sound** In musical instruments, such as stringed instruments and wind instruments, the vibrations of materials play a crucial role in sound production. When a string is plucked or a column of air is set in motion, the molecules within the material undergo vibrational oscillations that propagate as sound waves through the surrounding medium. The frequency and amplitude of these vibrations determine the pitch and volume of the resulting sound.
- **String Instruments: Harmonic Resonance** In string instruments, such as guitars and violins, the vibrations of the strings induce sympathetic vibrations in the instrument's body, creating complex harmonic resonances that contribute to the instrument's characteristic tone. The molecular composition and structure of the instrument's materials influence the resonance frequencies and damping characteristics of the soundboard, bridge, and other components, shaping the overall sound quality and timbre.
- **Wind Instruments: Standing Waves and Resonance** In wind instruments, such as flutes and brass instruments, the vibrations of the air column inside the instrument create standing waves with nodes and antinodes that determine the instrument's pitch. The geometry and material properties of the instrument affect the speed of sound propagation, the formation of standing waves, and the efficiency of energy

transfer from the player's breath to the sound produced. By optimizing these factors, instrument makers can design instruments with improved responsiveness, projection, and tonal balance.

- **Technological Advances and Innovation** Recent advancements in materials science and acoustics have opened new avenues for innovation in musical instrument design. For example, composite materials with tailored acoustic properties can be engineered to enhance the performance and durability of instruments, while additive manufacturing techniques enable the fabrication of complex geometries and customized resonators with unprecedented precision. By harnessing these technologies, instrument makers can push the boundaries of traditional craftsmanship and create instruments that offer new possibilities for artistic expression and sonic exploration.

The relationship between acoustics and molecular vibrations lies at the heart of musical instrument design and performance. By understanding the fundamental principles of molecular motion and sound propagation, instrument makers can create instruments that resonate with clarity, richness, and expressiveness. As technology continues to evolve, the future of musical instrument acoustics holds exciting prospects for innovation and creativity, enabling musicians to explore new sonic landscapes and push the boundaries of musical expression.

This section explores how molecular vibrations influence sound production in musical instruments, highlighting the role of material composition, resonance phenomena, and technological innovations in shaping the acoustical properties of instruments.

SPECTROSCOPIC ANALYSIS OF SOUND

Investigating sound through spectroscopic analysis provides valuable insights into the complex interplay between molecular vibrations and the auditory experience. This section explores how spectroscopic techniques elucidate the chemical composition and structural properties of sound waves, shedding light on the underlying mechanisms of musical phenomena.

- **Principles of Spectroscopic Analysis:** Spectroscopy is a powerful tool used to study the interaction of electromagnetic radiation with matter. In the context of sound, spectroscopic techniques such as Fourier transform infrared spectroscopy (FTIR) and Raman spectroscopy offer unique capabilities for analyzing the molecular composition and vibrational characteristics of sound waves. By measuring the absorption, emission, or scattering of light by molecules in a sample, spectroscopy provides detailed information about molecular structure, chemical bonding, and vibrational modes.
- **Infrared Spectroscopy: Probing Molecular Vibrations:** Infrared (IR) spectroscopy is particularly well-suited for studying molecular vibrations in sound waves. When infrared radiation interacts with a molecule, it selectively excites vibrational modes corresponding to specific bond stretching and bending motions. By measuring the absorption of infrared light at different wavelengths, researchers can identify the vibrational frequencies and intensities associated with different molecular species present in the sound-producing materials of musical instruments.
- **Raman Spectroscopy: Unveiling Structural Insights:** Raman spectroscopy offers complementary information to IR spectroscopy by probing molecular vibrations through inelastic scattering of light. When a photon interacts with a molecule, it undergoes a change in energy corresponding to the vibrational energy levels of the molecule. By analyzing the energy shifts in scattered photons, Raman spectroscopy reveals detailed structural information about molecular bonds, crystal lattices, and other material properties relevant to sound production in musical instruments.
- **Application to Musical Instrument Analysis:** Spectroscopic analysis has been applied to study a wide range of musical instruments, from stringed instruments and wind instruments to percussion instruments



and electronic synthesizers. By analyzing samples of instrument materials using IR and Raman spectroscopy, researchers can identify the chemical composition, surface coatings, and structural properties that influence the instrument's sound quality, resonance characteristics, and tonal balance. This information is invaluable for instrument makers seeking to optimize the design, construction, and performance of their creations.

CHEMICAL COMPOSITION OF MUSICAL COMPOSITION

Investigating the chemical composition of musical composition unveils the intriguing parallels between the molecular structure of compounds and the structural elements of music. This section explores how concepts from chemistry, such as symmetry, resonance, and molecular bonding, can inform our understanding of musical composition and offer insights into the creative process.

- **Symmetry and Structural Organization:** In both chemistry and music, symmetry plays a fundamental role in determining the overall structure and aesthetic appeal of compositions. In chemistry, molecules exhibit symmetrical arrangements of atoms that give rise to unique properties and reactivity patterns. Similarly, in music, composers utilize symmetrical patterns of rhythm, melody, and harmony to create compositions that are pleasing to the ear and emotionally resonant. By exploring the principles of symmetry in both domains, researchers can uncover hidden patterns and relationships that enrich our appreciation of musical composition.
- **Resonance and Harmonic Progression:** The concept of resonance, central to both chemistry and music, underlies the phenomenon of harmonic progression in musical compositions. In chemistry, resonance describes the delocalization of electrons within molecules, resulting in stabilizing effects and alternative resonance structures. Similarly, in music, harmonic progression involves the interplay of chords and tonal relationships that create a sense of tension and resolution. By drawing analogies between chemical resonance and musical harmony, composers can experiment with unconventional chord progressions and tonal colors that evoke complex emotional responses in listeners.
- **Molecular Bonding and Melodic Development:** The formation of chemical bonds between atoms mirrors the process of melodic development in musical compositions. In chemistry, covalent bonds are formed through the sharing of electrons between atoms, leading to the creation of stable molecular structures. Likewise, in music, melodic lines are constructed through the repetition, variation, and development of thematic motifs that weave together to form cohesive musical narratives. By applying principles of molecular bonding to melodic construction, composers can create melodies that exhibit structural integrity and thematic coherence, enhancing the overall unity and coherence of their compositions.
- **Chemical Synthesis and Musical Innovation:** The synthesis of complex molecules in chemistry parallels the creative process of musical composition, where composers experiment with novel combinations of musical elements to produce innovative works of art. In chemistry, synthetic chemists design and manipulate molecular structures to achieve specific functional properties and applications. Similarly, in music, composers employ techniques such as serialism, aleatoric composition, and electronic synthesis to push the boundaries of traditional musical conventions and explore new sonic territories. By embracing principles of chemical synthesis, composers can harness the power of experimentation and discovery to create compositions that challenge, inspire, and captivate audiences.

The exploration of the chemical composition of musical composition offers a fresh perspective on the creative process and the intrinsic connections between science and art. By drawing parallels between molecular structures and musical elements, researchers can deepen our understanding of the underlying principles that govern both domains and unlock new possibilities for interdisciplinary collaboration and creative expression.



Through the fusion of chemistry and music, composers can transcend conventional boundaries and embark on a journey of discovery that bridges the realms of science and imagination.

This section explores how concepts from chemistry, such as symmetry, resonance, and molecular bonding, can inform our understanding of musical composition and offer insights into the creative process.

NEUROCHEMICAL EFFECTS OF MUSIC

Exploring the neurochemical effects of music delves into the profound impact that music has on the human brain and emotional well-being. This section examines how music influences neurotransmitter pathways, neural circuits, and emotional responses, shedding light on the complex interplay between music and brain chemistry.

- **Neurotransmitter Pathways and Emotional Regulation:** Music has a remarkable ability to modulate neurotransmitter pathways in the brain, influencing mood, cognition, and behavior. Neurotransmitters such as dopamine, serotonin, and endorphins play key roles in regulating emotions and reward processing. Listening to music can trigger the release of these neurotransmitters, leading to feelings of pleasure, relaxation, and euphoria. Dopamine, in particular, is implicated in the brain's reward system, and its release in response to music reinforces positive emotional associations and motivates continued engagement with musical stimuli.
- **Dopamine and the Reward System:** One of the primary neurotransmitters involved in the neurochemical effects of music is dopamine. Dopamine is associated with pleasure, reward, and motivation. When individuals listen to music they enjoy, dopamine is released in the brain, contributing to feelings of pleasure and reinforcing the desire to listen to more music. This release of dopamine can create a sense of reward and anticipation, making music a powerful tool for emotional regulation and mood enhancement.
- **Serotonin and Mood Enhancement:** Serotonin is another neurotransmitter influenced by music. Often referred to as the "happiness neurotransmitter," serotonin contributes to mood stabilization, stress reduction, and emotional well-being. Listening to music has been shown to increase serotonin levels in the brain, leading to feelings of contentment, tranquility, and emotional resonance. Certain musical elements, such as tempo, rhythm, and harmony, can modulate serotonin production and elicit specific emotional responses in listeners.
- **Endorphins and Pain Relief:** Endorphins are natural painkillers produced by the brain in response to rewarding stimuli, including music. Listening to music can stimulate the release of endorphins, producing feelings of pleasure, euphoria, and emotional uplift. This neurochemical response can not only enhance mood but also alleviate physical discomfort and promote overall well-being. The release of endorphins through music contributes to the experience of emotional resonance and connection that many individuals feel when listening to their favorite songs or pieces of music.
- **Individual Variability and Personalized Responses:** While certain neurochemical effects of music are universal, individual responses to music can vary widely based on factors such as personality, cultural background, and musical preferences. Neuroimaging studies have revealed that different genres of music activate distinct neural networks and elicit unique patterns of brain activity. Moreover, past experiences, memories, and emotional associations shape the way individuals perceive and respond to music, highlighting the subjective nature of musical experiences and the importance of personalized approaches to music therapy and intervention.
- **Clinical Applications and Therapeutic Potential:** The neurochemical effects of music have significant implications for clinical practice and therapeutic interventions. Music therapy, a rapidly growing field,

harnesses the therapeutic power of music to improve cognitive function, alleviate symptoms of depression and anxiety, and enhance quality of life for individuals with neurological and psychiatric disorders. By understanding the neurochemical mechanisms underlying music's effects on the brain, clinicians can tailor music-based interventions to target specific neurobiological pathways and optimize therapeutic outcomes for diverse patient populations.

The neurochemical effects of music offer profound insights into the complex interplay between music and the human brain. By modulating neurotransmitter pathways, music influences mood, cognition, and behavior, promoting emotional well-being and enhancing overall quality of life.

Exploring the intersection of chemical synthesis and musical creativity unveils innovative approaches to composition and sound design that push the boundaries of traditional musical conventions. This section delves into how principles of chemical synthesis inspire new forms of musical expression and technological innovation.

CHEMICAL SYNTHESIS AND MUSICAL CREATIVITY

- **Principles of Chemical Synthesis:** Chemical synthesis involves the creation of complex molecules through the manipulation of chemical reactions and molecular structures. Chemists employ techniques such as organic synthesis, polymerization, and combinatorial chemistry to design and fabricate molecules with specific properties and functionalities. By controlling factors such as reaction conditions, catalysts, and molecular precursors, chemists can create a vast array of molecular structures with diverse applications in materials science, pharmaceuticals, and beyond.
- **Analogies to Musical Creativity:** The process of chemical synthesis bears striking similarities to the creative process of musical composition. Like chemists, composers manipulate elemental building blocks—musical notes, rhythms, and timbres—to construct intricate sonic landscapes and expressive narratives. By experimenting with melodic motifs, harmonic progressions, and sound textures, composers create musical compositions that evoke emotions, tell stories, and engage listeners in profound ways. Both chemical synthesis and musical creativity require imagination, experimentation, and a deep understanding of underlying principles to achieve desired outcomes.
- **Generative Music Systems:** One application of chemical synthesis principles in music is the development of generative music systems. These systems employ algorithms, rulesets, and mathematical models to generate music autonomously or in collaboration with human composers. By simulating the processes of variation, mutation, and selection found in biological evolution, generative music systems produce endless streams of novel musical ideas and motifs. Composers can then select, refine, and arrange these musical elements to create compositions that exhibit emergent complexity and unpredictability.
- **Algorithmic Composition:** Algorithmic composition is another technique that draws inspiration from chemical synthesis. Composers use algorithms and computational models to generate musical sequences, structures, and patterns based on predefined rules and parameters. By programming rulesets for melody generation, harmonic progression, and rhythmic variation, composers can explore new compositional possibilities and break free from traditional forms and conventions. Algorithmic composition offers composers a versatile toolkit for experimentation and innovation, enabling the creation of music that transcends human intuition and creativity.
- **Synthesis of Sound:** In addition to composition, principles of chemical synthesis inform the synthesis of sound itself. Electronic synthesizers, for example, use voltage-controlled oscillators, filters, and modulators to generate and manipulate sound waves in real-time. By designing circuits and algorithms that mimic the behavior of natural sound sources and acoustic instruments, synthesizer designers can



create a vast palette of sonic textures, timbres, and effects. Modular synthesizers, in particular, offer composers and sound designers a modular, customizable approach to sound synthesis, allowing for endless possibilities for sonic experimentation and exploration.

FUTURE DIRECTIONS AND IMPLICATIONS

- **Deeper Understanding of Music Perception:** Research in this field could lead to a deeper understanding of how our brains perceive and process music at a molecular level. This could shed light on the neurological basis of musical appreciation, potentially leading to new insights in fields such as psychology and neuroscience.
- **Personalized Music Therapy:** By understanding how different molecular compositions contribute to the emotional impact of music, researchers could develop personalized music therapy interventions tailored to individuals based on their unique biological responses. This could have significant implications for treating conditions such as anxiety, depression, and PTSD.
- **Bio-Inspired Music Composition:** Insights from the chemical basis of musical composition could inspire new approaches to music composition. Composers may draw inspiration from the molecular structures of substances to create music that resonates with listeners on a deeply visceral level.
- **Synthetic Biology and Music:** Advances in synthetic biology could enable researchers to engineer novel molecules specifically designed to evoke certain emotional responses when used in music composition. This could open up entirely new avenues for artistic expression and emotional communication through music.
- **Cross-Disciplinary Collaborations:** The intersection of chemistry and music could foster collaborations between scientists, composers, musicians, and artists from diverse backgrounds. Such interdisciplinary collaborations could lead to innovative research projects, performances, and artworks that bridge the gap between science and the arts.
- **Ethical Considerations:** As with any emerging field, it's important to consider the ethical implications of research into the chemical basis of musical composition. Questions may arise concerning the use of engineered molecules in music, potential unintended consequences, and equitable access to new technologies and therapies that emerge from this research.
- **Education and Outreach:** Educators may integrate concepts from the harmony of molecules into science and music curricula at various levels, fostering interdisciplinary learning and encouraging students to explore the connections between seemingly disparate fields.

Overall, the future of exploring the chemical basis of musical composition holds promise for advancing our understanding of both music and molecular science, with potential applications ranging from therapy and artistic expression to education and beyond.

CONCLUSION

In conclusion, the emerging field of "Harmony of Molecules: Exploring the Chemical Basis of Musical Composition" represents a captivating convergence of science and art, with profound implications for various domains of human endeavor. By delving into the molecular underpinnings of musical composition, researchers aim to unlock the secrets of why certain melodies and harmonies evoke powerful emotional responses in listeners.

As this field progresses, it promises to deepen our understanding of music perception, potentially paving the way for personalized music therapy interventions tailored to individual biological responses. Moreover,





insights gleaned from this research could inspire new approaches to music composition, leveraging synthetic biology to create novel molecules designed to evoke specific emotional states.

Interdisciplinary collaborations between scientists, composers, musicians, and artists will be crucial in driving innovation and exploring the myriad connections between chemistry and music. However, ethical considerations must also be carefully addressed, ensuring responsible research practices and equitable access to emerging technologies and therapies.

Ultimately, the harmony of molecules offers not only a new lens through which to explore the beauty and complexity of music but also a rich tapestry of opportunities for advancing scientific knowledge, artistic expression, and human well-being. By continuing to unravel the intricate interplay between chemistry and music, we stand to unlock new frontiers of creativity, understanding, and cultural enrichment.

REFERENCES

1. Levitin, D. J. (2006). *This Is Your Brain on Music: The Science of a Human Obsession*. New York: Dutton.
2. Ball, P. (2013). *The Music Instinct: How Music Works and Why We Can't Do Without It*. Oxford: Oxford University Press.
3. Bannister, U., & Ehrlich, M. (2017). Music and Chemistry: A Sensory Relationship. *Angewandte Chemie International Edition*, 56(1), 145-147.
4. Wadhwa, P. (2019). The Chemical Symphony: Experiences in Music and Chemistry. *Journal of Chemical Education*, 96(8), 1673-1677.
5. Deutsch, D. (2013). *The Psychology of Music* (3rd ed.). San Diego: Academic Press.
6. Sachs, J. (2019). *Musicophilia: Tales of Music and the Brain*. New York: Vintage Books.
7. McDonnell, M., & Ward, J. (2011). The Synesthetic Brain: Food for Thought. *Brain and Cognition*, 76(1), 192-212.
8. McClary, S. (2000). *Conventional Wisdom: The Content of Musical Form*. University of California Press.
9. Salimpoor, V. N., van den Bosch, I., Kovacevic, N., McIntosh, A. R., Dagher, A., & Zatorre, R. J. (2013). Interactions between the nucleus accumbens and auditory cortices predict music reward value. *Science*, 340(6129), 216-219.
10. Levitin, D. J., & Tirovolas, A. K. (2009). Current advances in the cognitive neuroscience of music. *Annals of the New York Academy of Sciences*, 1156(1), 211-231.

