More than a feeling

Emotionally evocative, yes, but music goes much deeper

By Susan Gaidos ▪ Photograph by Cary Wolinsky

Anyone who has felt the sting of tears while listening to a bugler play "Taps," swooned to a love song or cringed with irritation as a neighbor cranked the heavy metal knows that music can exert a powerful emotive effect.

And you don't need a neuroscientist to tell you that manipulating a melody's pace, tone and intensity can stir the emotions. Composers of symphonies, pop tunes, movie sound tracks and TV ads all know how to tune an audience's mood along a dial ranging from sad and glum to cheerful and chipper.

But neuroscientists might have something to say about how music orchestrates such profound emotional effects on the brain. And understanding the how may offer a hint as to why music affects humans so powerfully.

Over the past decade or so, studies have shown that music stimulates numerous regions of the brain all at once, including those responsible for emotion, memory, motor control, timing and language. While the lyrics of a song activate language centers, such as Broca's area, other parts of the brain may connect the tune to a long-ago association — a first kiss or a road trip down the coast, perhaps.

"It's like the brain is on fire when you're listening to music," says Istvan Molnar-Szakacs, a neuroscientist at the University of California, Los Angeles. "In terms of brain imaging, studies have

shown listening to music lights up, or activates, more of the brain than any other stimulus we know."

That music can activate so many brain systems at once is the reason it packs such a mental wallop. It exerts its most profound effect in the brain's emotional core, the limbic system. There, music changes virtually all areas of the brain responsible for regulating emotion, as neuroscientist Stefan Koelsch of Freie Universität Berlin describes in the March *Trends in Cognitive Sciences*. Music automatically engages areas essential to pleasure and reward. So much so, in fact, that the same pleasure centers in the brain light up whether you're listening to a favorite tune, eating chocolate or having sex.

These dramatic effects make music a valuable instrument for probing the brain's emotional circuitry. Koelsch and others are now using music as a tool to see how the brain processes a wide range of feelings such as sorrow, joy, longing and wonder. Some of these emotions, so easily felt in response to music, are otherwise difficult to evoke in an experimental setup. Other researchers are using music to explore how children with autism spectrum disorders process emotion. While these kids often have difficulty recognizing how others feel, they readily respond to the sentiments of a song.

Using music to study and stimulate the brain's emotional circuits may lead to new therapies for treating a wide range of emotional disorders, including depression, anxiety and post-traumatic stress disorder, scientists say. By understanding how music activates and coordinates the various emotional mechanisms in the brain, scientists may find ways to rewire a brain affected by illness or injury, or provide a work-around for damaged or underperforming brain regions.

Despite the long list of potential benefits for health and happiness, Koelsch contends that the deep, complex experience that music delivers is primarily a social, rather than an individual, phenomenon (see "Not just a pleasant sound," Page 22). Ages before people walked around with little wires in their ears to listen to music anytime, anywhere, tunes piped on flutes and reeds were probably used in tribal rituals to unify hunters and warriors about to do battle. Today, music helps pull people together at weddings, funerals and countless social events.

Musician Moussa Traoré, far left, leads a djembe drum circle in a West African rhythm. New brain studies highlight the emotional and social aspects of music.

Moody tunes

To explore the effect that music has on the mind, *Science News* asked researchers to share a song they enjoy and the emotion it evokes.

Ethan Ross, physician
SONG: "Dark Star" by the Grateful Dead
EMOTION: "Elation, euphoria and wonder."

Virginia Naples, vertebrate paleontologist
SONG: "The Wreck of the Edmund Fitzgerald" by Gordon Lightfoot
EMOTION: "Sadness and nostalgia for knowing about past events."

Alan Boss, planetary scientist
SONG: Beethoven's Ninth
EMOTION: "... the joy of being alive, at least for a while, and in spite of the struggles we face in living."

Eugenie Scott, physical anthropologist
SONG: "The Green and the Blue" by the Battlefield Band
EMOTION: "Empathy and sympathy."

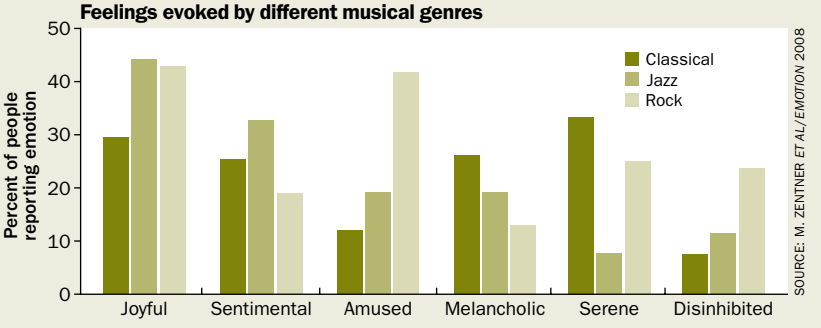
Chuck Steidel, astrophysicist
SONG: "Halah" by Mazzy Star
EMOTION: "We used to play this around 3:30 a.m. while observing on the Mauna Kea summit, so an exhilarated exhaustion, a partial dream state."

Holly Gibbs, conservation scientist
SONG: "Wagon Wheel" by Old Crow Medicine Show
EMOTION: "Anticipation and longing."

Kevin Padian, evolutionary biologist
SONG: "Won't Get Fooled Again" by The Who
EMOTION: "Rage and hope at the same time."

Margaret McFall-Ngai, microbiologist
SONG: "Girls Just Wanna Have Fun" by Cyndi Lauper
EMOTION: "Carefree life. It makes me smile big."

Feelings evoked by different musical genres



SOURCE: M. ZENTNER *ET AL./EMOTION* 2008

In my head

Music is universal. It occurs in all human cultures in some form, and extends deep into human history. Archaeologists have unearthed flutes made of bone that date back nearly 40,000 years. And scientists say that long before someone went to the trouble of carving a flute, humans banged out tunes using sticks and stones. Given that music gave early flutists and their fans no direct biological advantage over rival creatures — sweet melodies couldn't put food on the stone slab or guarantee grandchildren — researchers have long wondered why humans developed the capacity to perform and enjoy it.

Though music may not have evolved for survival purposes, modern-day imaging techniques reveal that it can have the same effects on the brain as many survival-related activities. In 2001, neuroscientists Anne Blood and Robert Zatorre of McGill University in Montreal asked people to listen to music deemed so moving by these participants that it "sent shivers down the spine." Blood, now at Harvard, and Zatorre showed that

music activates neural systems of reward and emotion similar to those stimulated by food, sex and addictive drugs.

Brain scans done using positron emission tomography, or PET, showed that increases in the "chill" intensity of the music correlated with changes in activity in the pleasure centers of the brain, including increases in blood flow to the brain's reward circuit — the midbrain, the ventral striatum and parts of the cortex.

At the same time, decreases in blood flow were seen in the brain's limbic system, a primitive region that governs the emotional response to a given situation. Structures in this region include the amygdala, known as the brain's fear center; the hippocampus, which is important for memory; and the nucleus accumbens, involved in pleasure.

In 2006, Koelsch and his group found that simply listening to joyful, pleasant music can lead to activity changes in all of these structures, even if people don't report having intense "chilling" experiences. Since then, studies carried out by him and others have elucidated additional areas of the brain specifically activated by music. Findings show that the brain areas stimulated depend on the type of music: Listening to a favorite tune will light up the brain's reward centers — and boost activity of the brain chemical dopamine, a molecule involved in desire and reward. The more you like a particular piece of music, the more jazzed you may get. Last fall, in a study in *PLoS One*, Zatorre and his group showed that the higher participants rated a song, the more emotionally aroused they got.

Other studies show that the amygdala kicks into action when volunteers listen to eerie-sounding or unpleasant music. (Consider waking at 2 a.m. to the sound of a partying neighbor's heavy metal.)

Together, the findings suggest that music has the capacity to both turn on and tone down neural activity in the brain.

Good vibrations

Knowing how music activates and coordinates the brain's emotional and reward circuits could help scientists develop new types of music therapies, Koelsch says. Information on how the amygdala responds to various types of music, for example, would allow researchers to target this area: tweaking it to calm fear-related activity in patients with anxiety disorders or boost pleasure-related activity in depressed patients. By listening to a specially designed music program for 30 minutes a day, five days a week, patients may tune the brain to improve mood (see "Take two stanzas and call me in the morning," Page 32).

Already, research confirms that most people are better off with a dose of music. Soothing music seems to lower heart rate and blood pressure, and studies show that music can be a valuable companion to traditional treatments for cancer, stroke and postoperative pain.

Recently, Koelsch's team showed that making music boosts mood, even if you're not musically inclined. In the study, 81 nonmusicians broke into small groups and played instruments while listening to excerpts of classical, jazz, Irish folk, salsa and reggae music. A control group of 73 listened to recorded music played on a computer, using sticks to keep in time with the beat. Before and after their jam sessions, participants completed a questionnaire designed to assess mood. Those in the instrument group reported lower levels of depression, anxiety and fatigue, and an increase in vigor after the session. Volunteers in the control group showed no such boost in mood.

Koelsch credits the change, at least in part, to music's ability to engage various social functions. He plans to test this idea by comparing people who make music in a group with those who play solo.

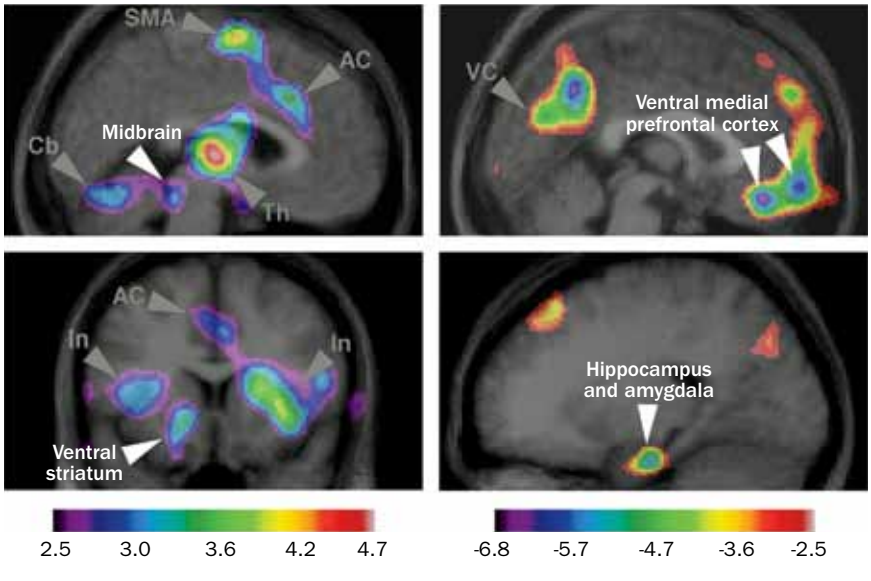
Emotional rescue

While music's power can easily be seen in ordinary people, its effects may be even more marked in those with autism. Music therapy has long been used to treat autism, but how and to what extent such therapy worked was not well understood. Four years ago, UCLA's Molnar-Szakacs began thinking of ways to study music and emotional processing in children with autism spectrum disorders.

In a recent study using functional MRI, he and his colleagues compared brain activity in autistic children with that in typically developing kids tasked to identify emotions in music. The findings, presented in Barcelona in June at the Organization for Human Brain Mapping's annual meeting, reveal that children with autism spectrum disorder are

Getting chills Listening to music you find moving can change activity in brain areas associated with emotion and reward. One study found that blood flow increased in the midbrain and ventral striatum (left) and decreased in the ventral medial prefrontal cortex, hippocampus and amygdala (right).

SOURCE: MODIFIED FROM A. BLOOD AND R. ZATORRE/*PNAS* 2001



Your brain on music

Music lights up almost every area of the brain, which shouldn't be a surprise since it makes people tap their feet, encourages the recollection of vivid memories and has the potential to lighten the mood.

Around the outside

1. **Prefrontal cortex:** This brain region plays a role in the creation, satisfaction and violation of expectations. It may react, for instance, when a beat goes missing. Recent work has shown that during improvisation a part of the prefrontal cortex involved in monitoring performance shuts down, while parts involved in self-initiated thoughts ramp up.

2. **Motor cortex:** Music is not independent of motion. Foot-tapping and dancing often accompany a good beat, meaning the motor cortex gets involved. And playing an instrument requires carefully timed physical movements. In some cases, this area of the brain is engaged when a person simply hears notes, suggesting a strong link to the auditory cortex.

3. **Sensory cortex:** Playing an instrument sends tactile messages to the sensory cortex, as keys are hit, for example.

4. **Auditory cortex:** Hearing any sound, including music, involves this region, which contains a map of pitches for the perception and analysis of tones.

5. **Visual cortex:** Reading music or watching a performer's movements activates the visual cortex.

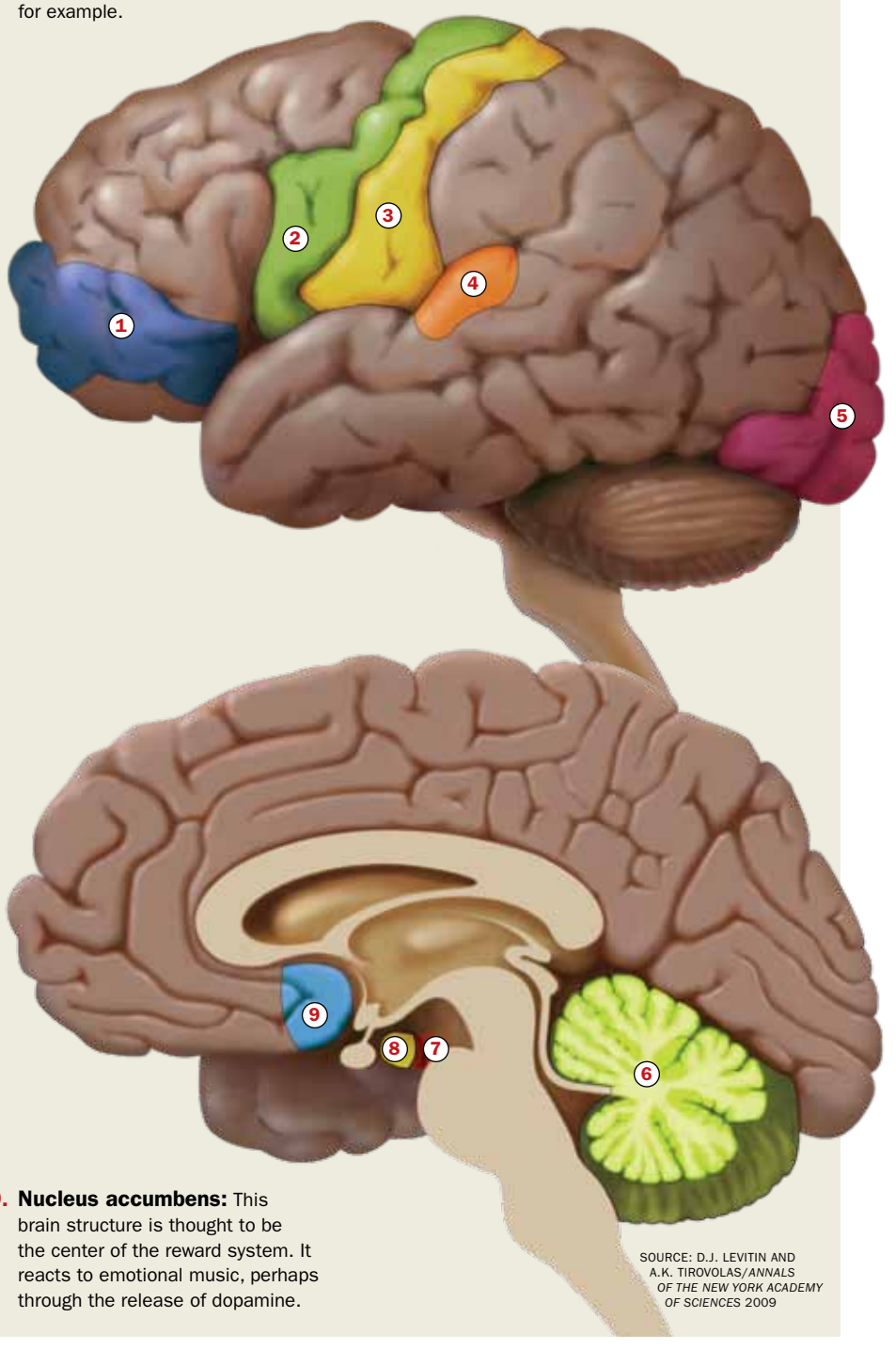
The inside track

6. **Cerebellum:** Movements such as foot-tapping and dancing activate this part of the brain. This could be because of the cerebellum's role in timing and synchrony; it helps people track the beat. The cerebellum is also involved in the emotional side of music, lighting up with likable or familiar music, and appears to sense the difference between major and minor chords.

7. **Hippocampus:** Known to play a role in long-term memory, the hippocampus (part of which is shown) may help the brain retrieve memories that give a sound meaning or context. It also helps people link music they have heard before to an experience and to a given context, possibly explaining why it is activated during pleasant or emotionally charged music.

8. **Amygdala:** The amygdala seems to be involved in musical memories. It reacts differently to major and minor chords, and music that leads to chills tends to affect it. Studies suggest the skillful repetition heard in music is emotionally satisfying.

9. **Nucleus accumbens:** This brain structure is thought to be the center of the reward system. It reacts to emotional music, perhaps through the release of dopamine.



SOURCE: D.J. LEVITIN AND A.K. TIROVOLAS/*ANNALS OF THE NEW YORK ACADEMY OF SCIENCES* 2009

CHARLES FLOYD

as accurate as "neurotypical" children at identifying emotion in music and show the same level of brain activation. Previous studies have shown less brain activity in kids with autism than in typical kids when looking at emotional faces.

"It seems like music acts as a sort of in, or doorway, to the [emotional] recognition system of children with autism," Molnar-Szakacs says. "telling us that at a biological level, emotional music has the same impact on children with ASD as it does on neurotypical children."

In the study, children with autism seemed adept at picking up on patterns in the music to identify the emotion, Molnar-Szakacs says. When asked how they made their decisions, the kids said that fast, loud, jumpy rhythms sounded happy, while slower, quiet music seemed sad.

His group is now looking to see how music activates certain neural systems that aren't active when these children look at faces. The studies may one day help scientists develop better interventions. Meanwhile, Molnar-Szakacs' group has developed a music-based program to help kids match and recognize various emotions — such as happiness, sadness and surprise — in social settings.

"It sounds a little like Pavlovian learning, but it's not," he says. "The goal is to not just have happy music playing with a happy face, but to have children learn to recognize different emotions so no matter what situation they find themselves in, they are able to reliably recognize an emotional face, and perhaps even the tone of an emotional reaction or voice."

Songs from the Stone Age

No one knows for sure whether music played a key role in human evolution or came about as a kind of ear candy. But there are several scientifically inspired proposals for the origins of music, some included below.

Da ya think I'm sexy?

Charles Darwin, an avid music fan, suggested in 1871 that humans' tunes evolved from courtship songs like those of birds, apes and other animals. In 2000, psychologist Geoffrey Miller of the University of New Mexico in Albuquerque elaborated on Darwin's idea, arguing that music-making abilities evolved along with intelligence and creativity as an advertisement of reproductive fitness to potential mates.

I feel good

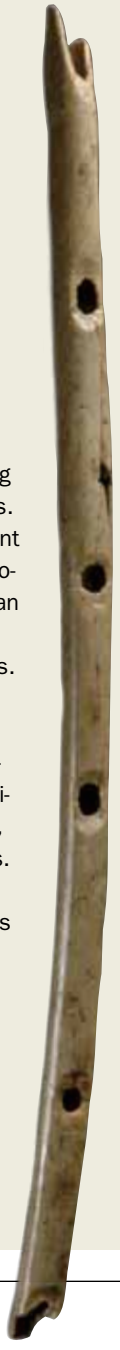
Harvard University psychologist Steven Pinker thinks of music as a gratifying diversion that offered no survival or mating advantages to human ancestors. In 1997, he dubbed music "auditory cheesecake," a pleasurable amusement that people concocted from evolved mental faculties such as language, emotions and motor control. Aniruddh Patel of the Neurosciences Institute in San Diego also views music as a human invention built on neural circuitry that serves other purposes, but he sees it as having biologically powerful effects.

Let's get together

One popular idea posits that music and dance evolved to bind groups of people together. Swedish neuroscientist Björn Merker suggests that musical abilities and activities originated in groups of ancestral males chorusing together, possibly to scare off males from rival groups and to attract migrating females. Anthropologist Robin Dunbar of the University of Oxford in England has suggested that music and language became increasingly vital social lubricants as hominid groups increased in size over the ages.

Mother and child reunion

With the emergence of the *Homo* genus roughly 2 million years ago, pairs of mothers and babies forged emotional ties by communicating musically, says Ellen Dissanayake of the University of Washington in Seattle. Prehistoric groups exploited mom-infant interactions and added music and dance to rituals, she proposes (see "Birth of the beat," Page 18). What people now think of as music emerged much later, in her view. — *Bruce Bower*



Evidence of ancient roots

Though early hominids may have made sweet sounds by banging sticks and stones together, the oldest distinguishable instrument dates to 40,000 years ago.

A flute made from vulture bone (shown) and others made from mammoth ivory have been found in Hohle Fels cave near Ulm, Germany, and date from 35,000 to 40,000 years ago. Holes in other bones dating to about 43,000 years ago were dismissed as bite marks from cave bears.

Gudi, literally "bone flutes," found in Jiahu in Henan Province, China, date to 9,000 years ago. Made from the wing bones of red-crowned cranes, the early instruments possess five to eight finger holes.

Pieces of several harps found in 1929 by Leonard Woolley in what was ancient Mesopotamia date back to almost 5,000 years ago. The most famous was the bull-headed lyre (replica shown), which had been preserved in a Baghdad museum until it was looted in 2003.

Two marble statues dating from 4,700 to 4,500 years ago depict a double flute player (shown) and a harpist. Found on the island of Keros, near Crete, the statues' purpose is unclear.

Six graded cylindrical wooden pipes discovered south of Dublin date to 4,000 years ago. The pipes, the largest of which is 50 centimeters long, lack holes and appear as if they were attached together as part of a larger instrument.

FROM LEFT: N. CONRAD, *ET AL./NATURE* 2009; SILVIO FIORE/GETTY IMAGES; GIANNI DAGLI ORTI/CORBIS; WOLFGANG SAUBER/WIKIMEDIA COMMONS

Happy together

Scientists say music's ability to touch emotion lies in its ability to forge social bonds and foster cooperative behavior. Koelsch and Nikolaus Steinbeis of the University of Zurich showed in 2009 that just listening to music creates a firestorm of activity in brain areas commonly used to understand another person's thoughts. "It was as if they were trying to figure out the intentions and desires of the composer," Koelsch says.

Studies show that listening to music stimulates brain areas specialized for imitation and empathy that contain what researchers call mirror neurons. These brain circuits, first described in monkeys, act like mirrors in the mind, reflecting others' actions and intentions as if they were one's own. The neurons allow you to feel loved ones' pain or simulate their actions, even if only in your mind.

But mirror neurons are active not only when a monkey sees or performs an action, but also when it hears the sound associated with an action. Molnar-Szakacs says that this sound-related function may have developed for survival reasons, enabling the understanding of actions that couldn't be seen, such as detecting footsteps in the dark.

Because music has historically brought people together to sing, dance and celebrate rituals, it can make people feel like they are in a social interaction, he says. Until recently, whenever people heard music, they would also see feet tapping, hands drumming or instruments being strummed, plucked or hit.

"If you think about music in terms of human evolution, rather than in terms of the iPod, music has for the majority of human history been made in the physical presence of others," Molnar-Szakacs says.

Last year, writing in *Social Cognitive & Affective Neuroscience*, he and Katie Overy of the University of Edinburgh added new details to their theory, first described in 2006, that ties together the mirror neuron system and the limbic system to explain why music has such a profound emotional impact in humans.

I will survive

Probing music's effects on emotion may also help answer a long-standing puzzle: why music, a pleasurable but seemingly unnecessary part of life, is universal across cultures. Some experts believe that the ability to perceive and enjoy music is an inborn human trait. Others see it as human invention, born from the brain's ability to coordinate various functions.

In the March *Physics of Life Reviews*, Harvard physicist Leonid Perlovsky suggests that the development of language itself may have set the stage for the human brain to appreciate music. Before spoken language emerged, early people might have used simple hand gestures and vocal signals to communicate. Such signals were probably closely tied to emotion, says Perlovsky.

As the rational, language-based part of the brain began to dominate, humans were able to differentiate among ideas, concepts and feelings. But the emergence of language, and the "thinking mind," created a disconnect from the emotional mind, he contends.

Music, though, helps humans maintain the ability to tap into these more ancient, emotive systems, and is an instinct rooted in the human evolutionary past, Perlovsky says.

In contrast, Aniruddh Patel of the Neurosciences Institute in San Diego sees music as a human invention — not an evolutionary adaptation — built on neural circuitry that ordinarily serves other functions. He compares humans' desire to create and enjoy music to their ability to control fire.

"Nobody argues that our brains have been specifically shaped by evolution to make fire, yet it's universal in human culture because it's so valuable to us," he says.

Music serves a similar purpose, Patel says, providing things people value deeply, such as the ability to remember information over time and a way to conduct rituals with power and efficiency. "Therefore it stuck," he says.

Koelsch offers yet another reason why music appears across human culture: It provides a crucial social glue. Humans are social animals, and music automatically engages systems for social cognition, communication and cooperation, he says.

Music "is particularly effective in establishing a sense of unity, belongingness and trust among individuals," says Koelsch. "I don't say that music always does this — apparently it doesn't. But it can be very powerful in doing so." ■

Explore more

- Oliver Sacks. *Musicophilia: Tales of Music and the Brain*. Vintage, 2008.

A cuneiform tablet dating to 4,000 years ago from Nippur, an ancient Sumerian city, includes instructions for performing music on string instruments and suggests people had a sophisticated idea of octaves more than 4,000 years ago.

The tomb of Ramses III, who ruled Egypt more than 3,000 years ago, contains a bas-relief including two blind musicians playing before the gods. Discovered in 1768 by James Bruce, the tomb was dubbed "The Tomb of the Harpists" and is sometimes called "Bruce's tomb."

Bronze carnyces found buried beneath a temple in Corrèze, France, date to more than 2,000 years ago. The carnyx was a Celtic battle horn (two replicas shown), sometimes with a boar's head at its top. —*Elizabeth Quill*