A mind for music

There are very few activities for which your birthday suit and a three-piece suit are equally appropriate attire. Music is one of them.

Belting an improvised ditty alone in the shower and performing Handel's "Messiah" on stage with a full choral ensemble and orchestra both qualify as "song." Simple or intricate, practiced or spontaneous, individual or collective, highbrow or honky-tonk — music covers the gamut. And though instruments aren't instrumental, they are welcome and multifarious. Bells, drums, strings, woodwinds, harps or horns can certainly spice up a tune. (Though a Stradivarius may not survive a shower.)

But music's broad scope doesn't stop with its production. More fascinating than how people make music (and greater mysteries, perhaps) are why people make it, why others listen and how a beat of any sort can have such a profound impact on the body and the brain.

Coos and ahs exchanged by moms and babies around the globe may form a musical conversation that lays the groundwork for language, some scientists now propose. That notion joins others — including the desire to impress mates and the drive to build social bonds — in suggesting an evolutionary source of chanteys, dirges and ballads. Others see music as a pleasing diversion, and research shows that emotionally charged music — whether moving a person to tears of joy or calling forth memories of a failed romance — appears to activate the brain's reward circuitry. And while listening to music brings on an emotional rush, playing music may provide a mental boost. It turns out that musical training has benefits to the tune of improved understanding of grammatical rules and sharper auditory perception.

Though music's tendency to get charged with cultural, religious and emotional meaning may complicate things for scientists seeking its roots and benefits, it's that same tendency that makes pursuing the "what," "why" and "how" of music worthwhile. — Elizabeth Quill

In this section

Web edition

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Birth of the beat

Music's roots may lie in melodic exchanges between mothers and babies

By Bruce Bower
Photograph by Cary Wolinsky

At scientific meetings, psychobiologist Colwyn Trevarthen often plays a video of a 5-month-old Swedish girl giving her mother a musical surprise. Blind from birth, the girl reaches for a bottle and laughs appreciatively as her mother launches into a familiar song about feeding blueberries to a bear. As in baby songs everywhere, Trevarthen says, each line of the Swedish tune runs about four seconds and each stanza lasts about 20.

In a flash, the girl raises her left arm — an arm she has never seen — and begins conducting her mother's performance. The baby, named Maria, moves her arm just before many of the song's lines begin, leading her mother by about one-third of a second. In some cases, Maria synchronizes her hand movements with the rise and fall of her mother's voice. Mom's face glows in response to Maria's playful directions.

"Babies are born with a musical readiness that includes a basic sense of timing and rhythm," declares Trevarthen, of the University of Edinburgh.

Scientists have been finding that these chubby-cheeked cherubs heed a musical sense that moves them and grooves them long before they utter a word. Within a day or two after birth, babies recognize the first beat in a sound sequence; neural signs of surprise appear when that initial "downbeat" goes missing. Classical music lights up specific hearing areas in newborns' right brains. Even more intriguingly, babies enter the world crying in melodic patterns that the little ones have heard in their mothers' conversations for at least two months while in the womb (*SN: 12/5/09, p. 14*).

But infants do much more than pick up beats and mimic melodies, says Trevarthen. An inborn musical knack gets parlayed by babies into emotional banter with attending adults, who possess their own musical feel for infant care. Adults around the world intuitively

"Itsy Bitsy Spider" and other sing-alongs may prepare babies to learn social rituals, scientists propose.

speak to infants using a singsong, vocally exaggerated mix of words and sounds known as motherese.

Trevarthen rejects the notion that babies passively absorb adults' googly-eyed gab. Instead, he holds, infants intentionally prompt musical exchanges with adults, and infants know when they're being invited by a grown-up to interact. Here, the currency of communication consists of coordinated exchanges of gestures, facial expressions, coos, squeals and other sounds. Trevarthen and like-minded researchers call this wordless conversation "communicative musicality." Babies' natural musical aptitude gets them in sync with mothers. Within weeks of birth, mom and baby compose brief musical vignettes that tune up a budding relationship.

"Our brains possess a storytelling sense that is an essential component of musicality from the beginning," says Trevarthen.

From his perspective, musical storytelling prepares infants to learn the rhythms and format of a native language. Adult forms of music, as well as dance and drama, spring from the intricately structured yarns spun by babies and mothers.

New research probing these early musical stories indicates that moms and tots vocally express and share emotions in finely calibrated ways that differ in some respects across cultures. Other findings suggest that mothers everywhere prod babies to sing and act out simple songs as a prelude to learning cultural practices.

And women who suffer from personality and mental disorders fail to connect musically with their babies, investigators find. Infants whose first relationship strikes a sour note may display social and emotional problems later in childhood.

But like healthy babies, Trevarthen notes, these unfortunate tykes try their darndest to relate musically with whoever is available.

Trevarthen's views draw criticism, though, from many cognitive psychologists and musicologists. They regard music as a universal practice, with still-mysterious evolutionary origins, that infants learn from their native cultures without the help of an innate timekeeper. From their first days, babies seamlessly learn to keep a beat and to prefer the same melodies that adults do, from this perspective. Some critics suspect that Trevarthen and his colleagues, not babies and mothers, are telling musical stories.

Story time

Stephen Malloch has no problem with Trevarthen's take on communicative musicality. Malloch, a musicologist at the University of Western Sydney in Australia, coined the term in 1996.

While listening to the chatter of a mother and her 6-week-old daughter, who Trevarthen had videotaped 17 years earlier, Malloch noticed he was tapping his foot. As a trained violinist whose stage fright pushed him into research, Malloch was accustomed to feeling the beat of musical sounds.

"I sensed a rhythmic, melodious give-and-take to the mother's gentle promptings and the baby's pitched vocal replies," he recalls. A few weeks later, communicative musicality came to mind as a shorthand term for emotional exchanges based on musical principles.

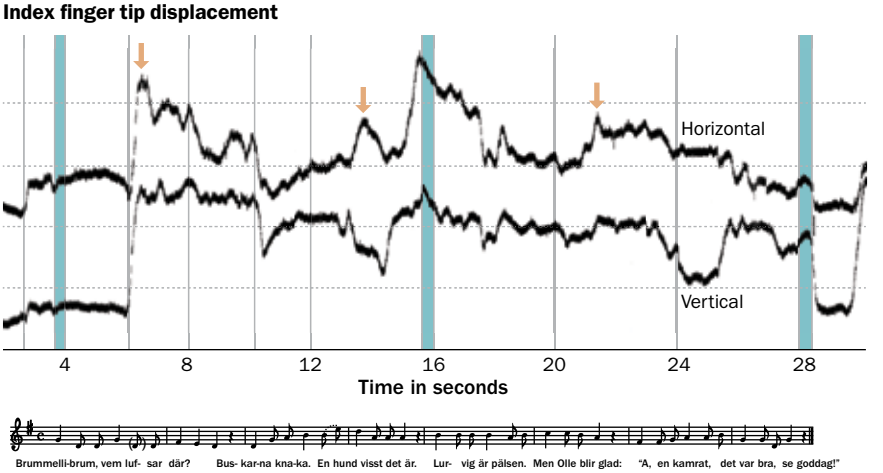
Malloch wasn't the first to have this idea. In 1981, European researchers Hanuš and Mechthild Papoušek asserted that mothers and babies intuitively communicate using melodies and other musical sounds. Malloch developed a way to identify the musical stories that he thinks are created during these intimate encounters.

He probed mom-baby conversations by measuring sound waves, pitch patterns and timbre, or tone attributes, starting with those in Trevarthen's video. An acoustic analysis revealed three features of communicative musicality — pulse, quality and narrative.

Pulse refers to a timed series of sounds and words in an interaction. Each utterance by mother and daughter lasted about one and a half seconds, with little variation. Quality consists of emotional signals conveyed by voice and gestures. One example is the swoop of a mother's hand accompanying a dropping, then rising vocal pitch. In the recorded encounter, mother and daughter used the pulse and quality of the interaction to create musical narratives lasting no more than about 30 seconds.

One narrative begins with the mother uttering low-pitched phrases, such as "come on" and "that's clever," for five seconds. Her daughter's voice rises in response and the mother moves her vocal pitch an octave higher. Mom

Baby conductor Maria, a Swedish infant who has been blind since birth, showed scientists her sense of rhythm by lifting her arm and conducting her mother's singing. The figure below shows how Maria's left index finger moved (horizontally and vertically) throughout the familiar tune.



■ Maria moved her finger just before each phrase of the Swedish song began. In this way, she anticipated the movement in her mother's voice.

↓ Maria also synchronized finger movement when she heard sharp consonant sounds in words at the end of a line — "sar där," "visst det är" and "glad."

C. TREVARTHEN, ADAPTED BY T. DUBÉ

prompts responses from baby for about eight seconds. Their voices rise to a peak of intensity during a back-and-forth exchange that lasts another seven seconds. Mother and daughter then take six seconds to return to the mother's original, low voice pitch. So, Malloch says, each collaborative story contained an introduction, development, climax and resolution.

Feel the vowel

Musical storytelling of this kind largely depends on varying the pitch, timbre and rhythm of vowel sounds, which are more emotionally expressive than consonants, according to Trevarthen and University of Edinburgh psychologist Niki Powers. Mothers and infants in Scotland and Japan make these emotionally tinged sounds in culturally distinctive ways, the researchers say.

"Even with limited powers to produce learned sounds, infants in different countries express vocal emotions and parents intuitively respond to them," Powers says.

She and Trevarthen videotaped a dozen pairs of mothers and their 3- to 4-month-olds playing together at home, six in Scotland and six in Japan. The researchers' findings and those of several other teams appear in the 2009 book *Communicative Musicality*, edited by Malloch and Trevarthen.

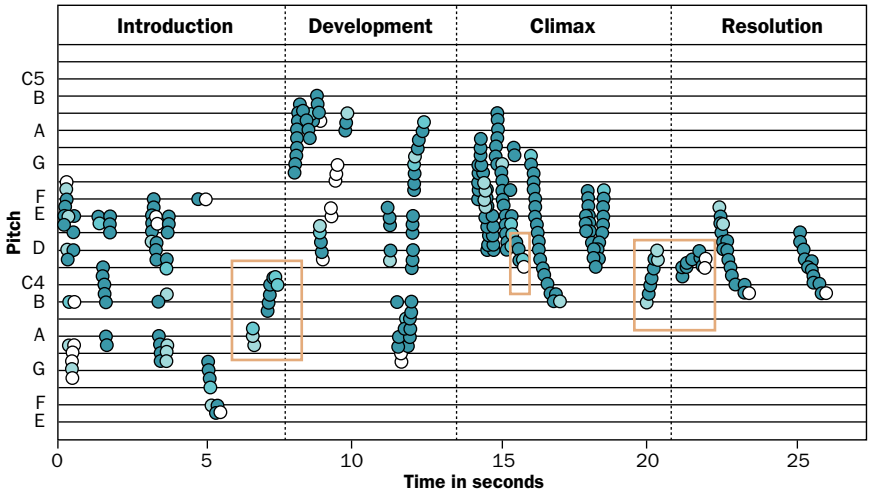
Language and cultural differences shape emotional communication, says Powers. Occasional high-pitched vowel sounds, interspersed among a stream of low vowel sounds of moderate intensity, denoted emotional responses by Scottish mothers to their babies, she suggests. Each low sound usually lasted no more than three-quarters of a second.

Japanese mothers consistently made high, intense vowel sounds. Swings from short to long vowels helped the moms convey emotion to the infants, in Powers' view. These women held many vowel sounds for less than one-quarter of a second but articulated others for a second or more.

Infants in both countries tended to produce vowel sounds that lasted up to one second, much longer than vowels used in speech. Japanese babies emitted high-pitched, acoustically intense vowels, much as their mothers did.

In an upcoming issue of *Infant and Child Development*, Trevarthen marshals evidence suggesting that even newborns purposely coordinate vocalizations and movements with those of caretakers. An innate impulse to forge emotional ties with others drives such behavior, he posits. In the months after birth, babies build on this impulse by adopting a native culture's style of emoting vowel sounds.

A story in song Musical conversations between mom and baby can take the shape of stories, some scientists propose. The figure below shows the rise and fall of one such exchange. Mom's voice increases in pitch and intensity as the story reaches a climax. Baby often makes sounds (highlighted in boxes) as the story shifts from one stage to another.



Up the waterspout

At about the time that babies start to put emotional oomph into their voices, communicative musicality enters a ritualized arena dominated by simple tunes that must be performed, not just sung. Parents combine simple melodies and lyrics with activities that include knee bouncing, hand clapping and pantomime.

Physician Patricia Eckerdal of Sweden's Uppsala University Hospital and Björn Merker, an independent neuroscientist in Segeltorp, Sweden, have begun to chart the developmental trajectory of what they call action songs. Merker and Eckerdal videotaped 25 pairs of Swedish mothers and their infants playing together at home when the babies were 6, 9 and 12 months old.

The well-known sing-along "Itsy Bitsy Spider" is one example of an action song that babies learn as they grow. In its first incarnation, up to about age 3 months, the infant lies down as the adult does all the work. Mom forms a spider hand, makes it crawl it up the baby's body and tickles his or her chin at the "waterspout" ending of the first line. Mom spreads her fingers and runs them down the baby's body for "down comes the rain." At "out comes the sun," mom places her spread fingers in front of the baby's face. Gestures from the first line are then repeated with a final tickle.

By 6 months of age, adult and infant sit close together so that the child's hands and arms can be gently guided through the pantomime sequence while singing. By 9 months of age, infants perform "Itsy Bitsy Spider" on their own.

In this way, infants practice performing intricately structured acts and discover what those acts mean, an essential skill for learning a slew of cultural rituals. It's a short hop from getting the hang of "Itsy Bitsy Spider" to mastering dinner table etiquette and conversational rules, the scientists hypothesize.

"Action songs are the 'baby rituals' of human culture," Merker says.

Only people, not singing birds or other musical animals (*SN: 5/23/09, p. 8*), incorporate musical communication into social rites, he and Eckerdal assert.

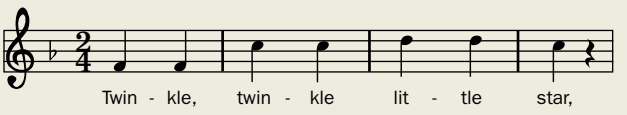
S. MALLOCH AND C. TREVARTHEN, EDS. *COMMUNICATIVE MUSICALITY*. BY PERMISSION OF OXFORD UNIV. PRESS. ADAPTED BY T. DUBÉ

Seeking a definition

Whether strummed by a guitarist who has gone platinum or sung by a mom who is playing with her child, music at its most basic level is a sequence of notes that can vary in a number of ways.

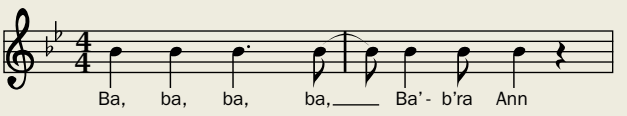
Pitch is determined by a sound's frequency. Notes that sit in different positions on a musical scale, called tones, have different pitches. Modern Western music, for example, combines 12 tones, with the A at the middle of a piano keyboard having a frequency of 440 hertz. Other cultures work with fewer tones. The first few notes of "Twinkle, Twinkle, Little Star" vary only in pitch.

"Twinkle, Twinkle, Little Star"



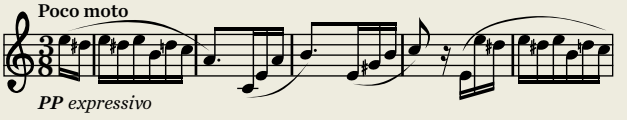
Rhythm emerges because different notes can last for varying amounts of time. Notes with different durations are represented differently in written music: Some have little flags, dots or open circles. A quarter note, for example, is drawn as a closed circle with a vertical line; it lasts for one beat. The first several notes of the Beach Boys' "Barbara Ann" vary only in note duration.

"Barbara Ann"

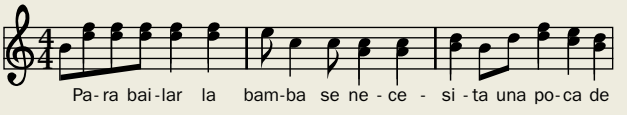


Combining different pitches and rhythms allows for the creation of **melodies**, the same way the combination of words makes a sentence. And when different notes are played at the same time to create chords, rather than just successively, they can lead to **harmony**. Other factors mix in to affect the character of the piece. **Dynamics**, how loud each note is and how that loudness changes over the course of several notes, opens even more room for variation. And **timbre**, or tonal quality, distinguishes one instrument from another—a piano sounds different from a tuba, and Celine Dion sounds different from Macy Gray. **Tempo** characterizes the overall speed of a piece. Changing multiple factors at a time leads to endless musical possibilities, from "Für Elise" to "La Bamba."

"Für Elise"



"La Bamba"



Considering beauty

While some would argue that any variation of sound with the above features makes music, others say music is more than the sum of its parts. Perhaps sound has to be pleasing to qualify? Pythagoras, an ancient Greek philosopher, recognized that when notes with pitches forming simple ratios are played together, they sound pleasant. Using a single string with a movable bridge—which allowed him to pluck two notes at once—he found that when one side of the string was half the length of the other, it created two notes that sound lovely together. (In Western music today, if a string producing the note A at 440 hertz is halved, it creates another A an octave higher.) A pleasing blend also occurred when one side was two-thirds or three-fourths the length of the other. Using these ratios, Pythagoras built a seven-note scale, and his ideas still help musicians understand why some music sings and other tunes fall flat. —*Elizabeth Quill*

FROM TOP: MUSIC NOTES - ALTAZAR/ISTOCKPHOTO ARRANGEMENT OF NOTES T DUBÉ; SPL/PHOTO RESEARCHERS, INC.

Unhinged melody

Some babies, though, face a form of ritualized rejection that would test even an itsy-bitsy spider's determination. Their mothers feel so alienated and alone that efforts to pull mom into melodic exchanges are like trying to grab fistfuls of water.

Psychologist Maya Gratier of Université Paris X–Nanterre and psychiatrist Gisèle Apter-Danon of Université Paris Diderot have examined communication breakdowns that afflict babies born to mothers diagnosed with borderline personality disorder. This condition revolves around a tendency to form intense, unstable relationships.

People with borderline personalities act impulsively, feel emotionally empty and constantly fear abandonment. Many have survived severe child abuse and neglect.

Gratier and Apter-Danon codirect a project that has tracked the interactions of about 150 pairs of French mothers and their babies from birth to about age 5. Many mothers qualify as having borderline personality disorder. Others have obsessive-compulsive personality disorder, paranoid personality disorder or no mental ailments.

In brief laboratory exchanges, these mothers awkwardly repeat one phrase over and over or produce strings of unusual sounds, such as tongue clicking and whistling. No rhythmic flow characteristic of typical baby talk emerges. It's almost as if a baby isn't there at all.

That leaves infants unable to get a

sound in edgewise. They withdraw from mothers with borderline personalities, vocalize little or get fussy and upset.

One 3-month-old boy in the French study tried his best to spark an emotional dialog with his mother during a 27-second encounter, Gratier says. The woman drearily repeated the same line from a French nursery rhyme four times. Her son then blurted out "ahhh!" just as she launched into a fifth rendition. Caught off guard, the woman exclaimed "What?" before regaining composure and resuming her dry recitation.

Undaunted, the boy immediately belted out a louder sound. That stopped his mother long enough so that he could utter a cooing sound, with a few emotionally tinged pitch changes, for about as long as the nursery rhyme's initial phrase.

Gratier and Apter-Danon interpret the 3-month-old's behavior as an attempt to lure his mother into a musical exchange. It briefly worked, they say. The woman imitated his cooing sound once with her characteristic flat tone. Then she returned to her signature line. Once again, the boy became an observer, not a participant.

"The interactions of borderline mothers with their babies appear more like compilations of isolated moments that probably impede the creation of shared musical story lines," Gratier says.

Depressed mothers offer a more varied verbal diet to their babies than borderline mothers, but in an unusually low, unexpressive voice devoid of rhythmic timing, according to studies directed by psychologist Lynne Murray of the University of Reading in Eng-

Not just a pleasant sound

When people use music to share stories, comfort peers or worship gods, it takes on new meaning. Music's roles vary depending on time and place.

Bonding: Battle hymns, national anthems and alma maters unite people for a common cause and make them feel that they are a part of something larger. Marching bands (above), for example, can rile up crowds and promote pride at sporting events.

Relaxation: Mothers in almost all societies sing lullabies to put little ones to sleep. Called a *huluna* in the Philippines province of Batangas, the lullaby is so popular there that almost every mother has composed at least one for her child. And in Denmark, writing lullabies is an art form. A classic Danish lullaby, "The Sun is So Red, Mother," was written by a novelist, playwright and poet named Harald Bergstedt and arranged by famous composer and violinist Carl Nielsen.

Creative expression: The Chopi people of Mozambique are known for their timbila music, played on xylophones. The music and accompanying dance is developed like a symphony and also has room for individual players to improvise and show their creativity. Like music elsewhere, timbila helps the Chopi share who they are and where they come from.

Meditation/Trance: Music is believed to provide a way for shamans (one shown above in British Columbia) to enter a trance state and get in touch with the spiritual world. The Sami, indigenous people of northern Europe, have a traditional form of song called yoik said to open the door for communication with animal spirits. Drumming helps the shamans enter the spiritual world.

Learning: The "Alphabet Song," among other simple rhymes, helps children learn and remember facts. Some researchers believe that early songs, such as "Itsy Bitsy Spider," may also prepare infants to learn cultural rules and practices.

Revolt: Music can represent the emergence of a subculture that turns against traditional ways. All-night dance parties popular in the 1980s offered a way for people to let loose, experiment and declare their independence. In the early 1990s, municipalities across the United States and United Kingdom passed bylaws to limit the organization of these raves.

Worship: A wide range of religions employ music. In Indian tradition, bhajans express love for God (holy men shown above). Gospel music helps Christians praise God. And, though music is not a large part of Islamic tradition, five times a day Muslims are called to prayer as a muezzin chants in praise of Allah from the top of a mosque's minaret.

Social pressure: In rural Sudan, women known as hakamas (shown above) use chant-like songs to motivate men to fight in wartime and to call people to brotherhood during times of peace. In a society where men hold higher status than women, the songs empower women: Going against the songs is considered shameful.

Mourning: Dirges are an integral part of funerals for the Akpafu of southeastern Ghana. A ceremony begins when drums are beaten to announce the death to various clans. While clans are assembling, women begin to sing the first funeral dirge. Each activity of the burial ceremony has special dirges. And 30 to 40 different songs may be heard while family keeps watch over the body.

Declarations of love: The ncas, a brass mouth harp, is played by Hmong men outside the wall of a lover's house. Though the men may also whisper softly during courting,

CLOCKWISE, TOP LEFT: TED SPIEGEL/CORBIS; ROBERT HARDING IMAGES/MASTERFILE; WORLDPICTURENETWORK/STOCKPHOTOFINDER.COM; FRÉDÉRIC NOY/COSMOS/AURORA PHOTOS

land. Infants interact hesitantly with depressed mothers, mimicking their low, flat vocal delivery.

Borderline personality disorder and depression alike deprive women of the flexibility and expressiveness needed for communicating musically with babies, Gratier holds. When there's no room for playful musical exchanges, interactive sync is sunk. In their long-term study, Gratier and Apter-Danon find that disrupted musical communication between mothers and babies heralds social difficulties for these children in preschool.

they will inevitably switch to the ncas to woo a chosen gal. Lloyd (John Cusack) may have had the same idea in *Say Anything* when he lifted a boom box playing Peter Gabriel's "In Your Eyes" above his head.

Work: Sea chanteys are onboard working songs, the rhythm of which helps synchronize the repetitive movements of sailors. There are different songs that provide the right tempo for hoisting sails, hauling nets and pulling up anchors.

Social interaction: Much of African music takes the form of call and response, meaning the activity is participatory. A leader will sing or play an instrument and the rest of the group will respond with hoots, hollers, clapping or a traditional refrain. In this way, much of the music becomes cyclical, with no clear end.

Mythology: Among Aboriginal Australians, each clan may share songs that tell stories about the journeys that mythical ancestors took as they carved valleys and built mountains to create the Earth's landscape. The songs trace ancestral history, tie the people to the land and lay down rules of conduct.

Entertainment: Music is a whole-body phenomenon. In some cases, it lightens the mood or passes the time. From noh, a traditional form of Japanese musical theater that dates to the 14th century, to the pop concerts of today, watching others make music makes people feel good. *—Elizabeth Quill*

Musical divide

Under better circumstances, mom and baby embark on a maiden voyage of improvisation, says Ellen Dissanayake, a professor of art and music at the University of Washington in Seattle. Musical ad-libbing of this type relies on timing techniques similar to those used by jazz musicians, Dissanayake proposes. A regular beat and timed melodic passages provide a structure for jazz instrumentalists to synchronize their playing and take turns soloing. Like jazz musicians, mothers and babies negotiate novel twists and turns in the flow of communication, building up emotional tension that they resolve together.

Scientists already knew, she notes, that 4-month-olds who coordinate pauses, turn taking and other conversational rhythms with mothers — without becoming rigidly synchronized and unable to adjust — interact well with others at age 1 (*SN: 6/23/01, p. 390*). That's consistent with the idea that mothers and babies employ just enough musical structure in their encounters to enable creative storytelling, thus grooming the child to deal flexibly with others.

Dissanayake theorizes that musical communication between mothers and babies emerged roughly 2 million years ago in the *Homo* genus, well before the emergence of language. With the evolution of physically helpless babies needing years to grow big brains, nonverbal exchanges that bonded infants to their mothers became essential.

In her view, Stone Age foragers transformed two-way musical communication into the temporal arts — singing, playing instruments, dancing, making expressive gestures, reciting poetic stories, clapping hands and beating out rhythms. In small-scale societies, she says, the temporal arts convey messages in ritual ceremonies, such as the need to appease gods believed to control vital resources. Such practices lessen worries about life's uncertainties and fuel group cohesion.

By creating stories out of precisely timed sounds and movements, Stone Age mothers and babies laid the groundwork for spoken language, says Dissanayake.

Today's music, from Ludwig van Beethoven to Lady Gaga, has transformed the temporal arts into a commercial enterprise that can still draw people from around the world into tribes bound by shared feelings and rituals (*SN: 4/11/09, p. 14*), Dissanayake asserts. Consider the pilgrimages that far-flung opera lovers take to hear famed vocalists and the popularity of all-night raves.

Her evolutionary scenario, like communicative musicality itself, stands defiantly outside mainstream music research. "This mother-infant stuff seems a little squishy to many scientists," Dissanayake says.

Trevarthen and colleagues weave a fanciful story around a threadbare body of data, asserts psychologist Sandra Trehub of the University of Toronto at Mississauga, a pioneer in studying infants' music perception. Music's evolutionary origins remain unknown, she emphasizes (see "Songs from the Stone Age," Page 28).

"According to its proponents, communicative musicality has boundless scope, so it's an idea than can neither be proven nor falsified," Trehub says.

Babies notice rhythmic downbeats and react to melodies with wondrous expressions even when by themselves, "so social communication is unlikely to provide a complete answer to early musicality," adds psychologist Marcel Zentner of the University of York in England.

Trevarthen remains undeterred. The next scientific step, he says, is to devise a measure of musical interactions that combines facial expressions and gestures with vocalizations.

Eventually, Trevarthen insists, researchers everywhere will tap their feet to the sounds of music reverberating in mother-baby chatter. ■

Explore more

- S. Malloch and C. Trevarthen, eds. *Communicative Musicality: Exploring the Basis of Human Companionship*. Oxford University Press, 2009.

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."

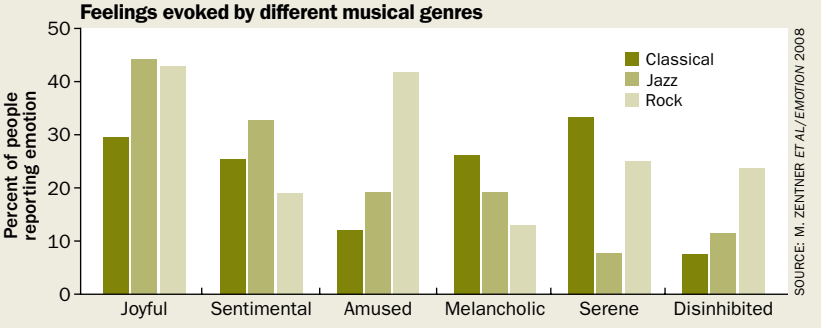
Chuck Steidel, astrophysicist
SONG: "Halah" by Mazzy Star
EMOTION: "We used to play this around 3:30 a.m. while observing on the Mauna Kea summit, so an exhilarated exhaustion, a partial dream state."

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.

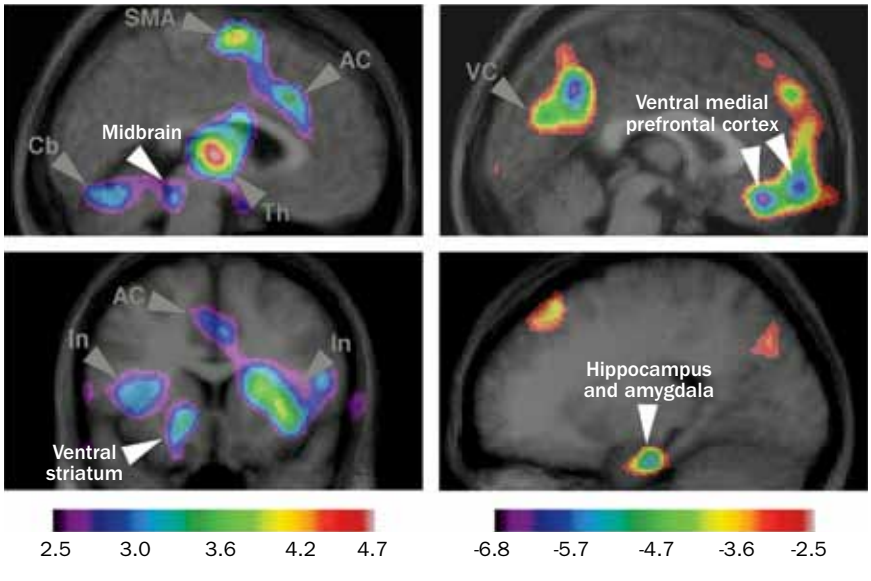
Emotional rescue

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.

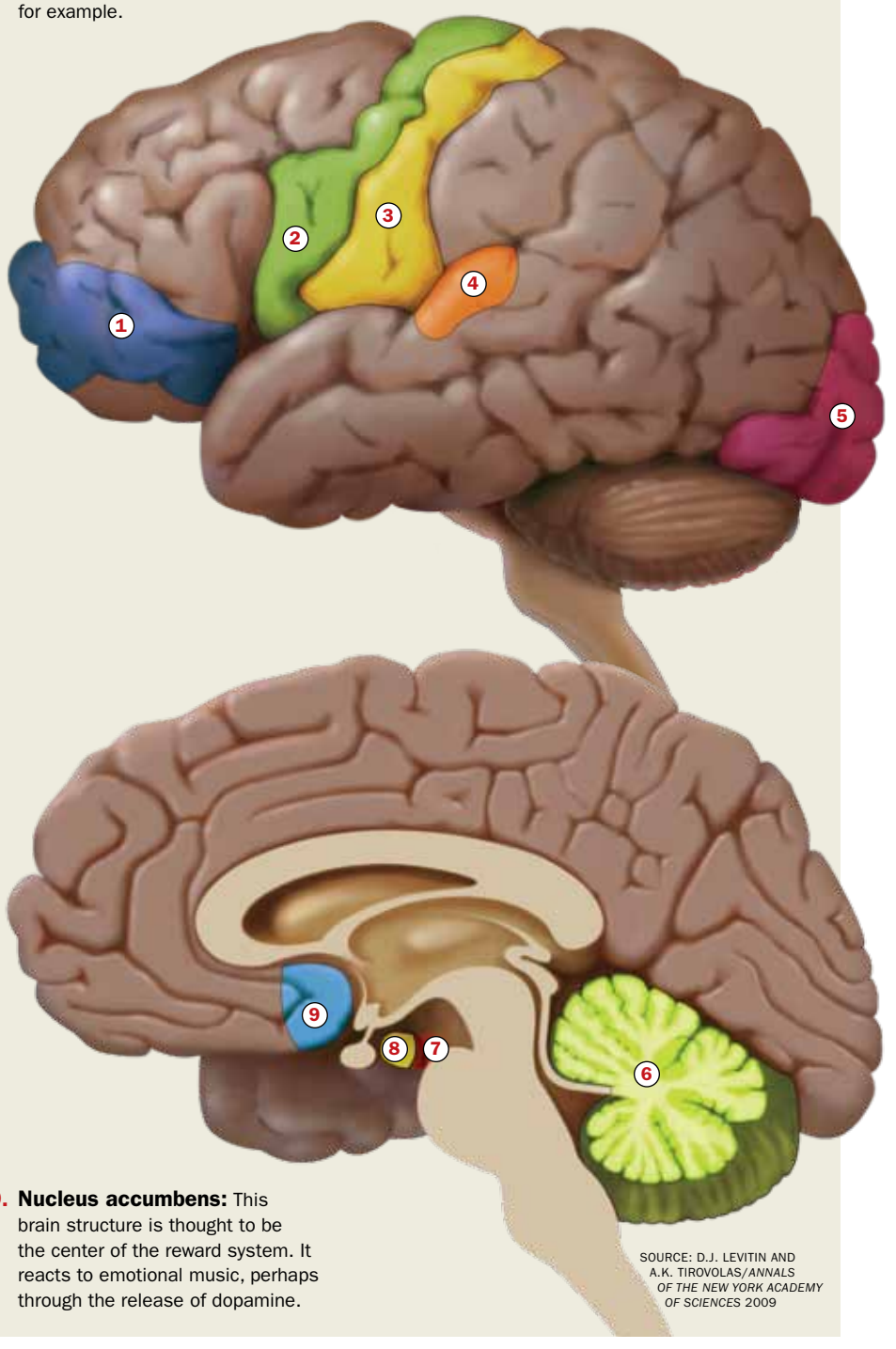
The inside track

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

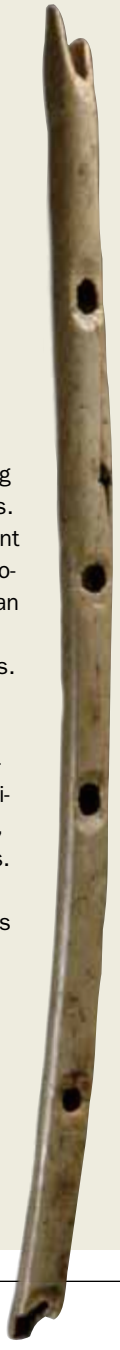
Harvard University psychologist Steven Pinker thinks of music as a gratifying diversion that offered no survival or mating advantages to human ancestors. In 1997, he dubbed music "auditory cheesecake," a pleasurable amusement that people concocted from evolved mental faculties such as language, emotions 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*

Music of the hemispheres

Playing instruments gives brains a boost

By Rachel Ehrenberg ▪ Photograph by Cary Wolinsky

Not so long ago, Mozart mania swept the nation. A small study found that students who listened to 10 minutes of a Mozart sonata performed better on a paper-folding task than their peers, and suddenly a flourishing industry sprouted. Mozart's music sang from CDs and videos marketed for children, babies and moms-to-be. The craze reached a crescendo when Georgia's governor Zell Miller included $105,000 in his state budget to send every child born in a Georgia hospital home with a classical music tape or CD.

"No one questions that listening to music at a very early age affects the spatial, temporal reasoning that underlies math and engineering and even chess," Miller said.

Actually, a lot of researchers questioned the link between listening to music and smarts. In the original study, the "Mozart effect" was minor and lasted only minutes. Follow-up studies found the effect specific neither to the composer nor to music. Students listening to Mozart were just more stimulated than those listening to a relaxation tape or silence. And while arousal can improve learning, research suggests, the effects can be fleeting and aren't limited to music. Assessments of the original report now tend to be dirges: In the May-June issue of *Intelligence*, researchers from the University of Vienna published a paper titled "Mozart effect–Shmozart effect."

"It's a short-lived effect and it spawned a huge industry of baby Einstein, baby Mozart CDs, all sorts of stuff," says Aniruddh Patel of the Neurosciences Institute in San Diego. "But the science behind it is pretty thin."

Yet even though listening to Mozart won't make you smarter, a growing body of evidence suggests that playing his music will. Musical training doesn't just make you a better musician — the acquired skills seem to transfer to other areas, various studies have found. And research focused on the brain's particular relationship with music and language suggests that engaging the mind with musical training could remedy language impairments such as dyslexia.

"There really is now so much evidence showing that musical experience has a pervasive effect on how the nervous system gets molded and shaped throughout our lifetimes," says Nina Kraus, head of the Auditory Neuroscience Laboratory at Northwestern University in Evanston, Ill. "This kind of transformation comes about only with active engagement with sound. My daddy always said, 'You never get something for nothing.' You're not going to get big biceps by watching wrestlers — you've got to do it."

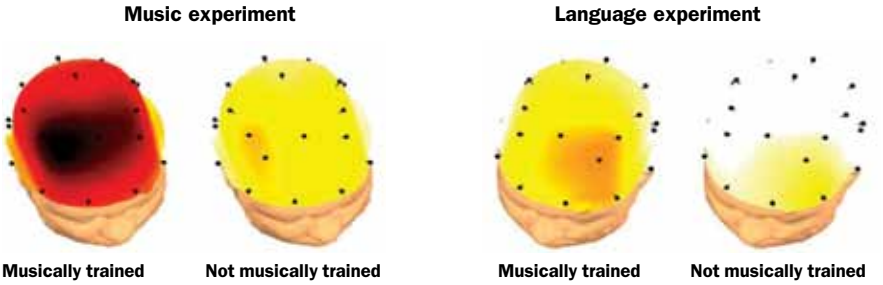
In the long run, musical training appears to improve a suite of verbal and nonverbal skills. Playing an instrument may add finesse to how people move their bodies. Making music makes you hear better, fine-tuning the ability to extract a signal from noise. Musical training also may improve grammar skills, the ability to grasp meaning from words and to distinguish a question from a command.

Until recently, establishing cause and effect for music's mental impact has been difficult. But long-term studies peering into brain structure and activity are now showing that musical training changes the brain in lasting ways.

The brain on beats

Playing an instrument calls upon circuitry from many areas of the brain, says Daniel Levitin, director of the music perception, cognition and expertise laboratory at McGill University in Montreal. For a long time, music was considered a creative "right brain" endeavor. That idea has now gone the way of the Macarena. Music processing is distributed throughout the brain, says Levitin, and playing an instrument, in particular, is an ensemble activity. It involves paying attention, thinking ahead, remembering, coordinating movement and interpreting constant feedback to the ears, fingers and, in some cases, lips.

"It's one of the most complicated tasks that we have," Levitin says. "Take a symphony orchestra. What you have is 80 or 100 of the most highly trained members of our society — more highly trained than astronauts or surgeons in terms of the numbers of hours and years of preparation — and they are performing the works of some of the greatest minds that ever lived. It's really extraordinary."



Say what? When children with musical training hear a sequence that ends with a "hanging" chord, their brains respond more strongly than do other children (shown at left, darker is more intense). These kids also show stronger responses to violations in sentence syntax (shown at right).

S. JENTSCHKE AND S. KOELSCH/*NEUROIMAGE* 2009; PHOTO: THANKS TO THE SOUTH SHORE CONSERVATORY

The breadth of the musician's task and the required cognitive effort are probably behind much of the enhancement of other skills, says neuroscientist Laurel Trainor, director of the auditory development lab at McMaster University in Hamilton, Canada. Playing an instrument "engages basically most of your brain," Trainor says. The activity appears to boost executive function, being the boss of your body and mind. Evidence suggests that with musical training comes improved memory, finer motor skills and better attention control — the ability to ignore one thing and pay attention to something else. "Our working hypothesis is that it's these control processes that are what is key for the transfer effects," Trainor says.

Some musicians are certainly musically inclined to begin with. But recent work suggests that the superior performance demonstrated by musicians on some tasks is more about nurture than nature. Teasing out that balance has been a recent focus of Gottfried Schlaug's music and neuroimaging research at the Beth Israel Deaconess Medical Center and Harvard Medical School.

A study by Schlaug's team found that after 15 months of weekly keyboard lessons, 6-year-olds showed greater change in their brains than kids who attended a weekly music class without instrument training. Among the most changed were a part of the auditory cortex and brain regions involved in control of movements. Kids with training also did better on tests related to finger movement and discerning melodies and rhythm, Schlaug and colleagues reported last year in the *Journal of Neuroscience*.

For most people, the transfer effects

Though the "Mozart effect" appears to be hype, studies do show that musical training can improve language and auditory skills.

of musical training are probably modest, says Trainor. "Otherwise, we'd expect musicians to be the most intelligent people on the planet," she says. But musical training may strike a particularly rich chord for people with language difficulties. "There is quite a bit of evidence now that musical training does have benefits for people with dyslexia and language impairments," Trainor says.

Peas in a syntactic pod

Evidence that the brain holds music and language in one embrace began to mount when imaging studies by Patel, Stefan Koelsch of the Freie Universität Berlin and others suggested that areas of the brain instrumental for processing language are also important for music. While some circuitry appears to be specific to music or language, new evidence emphasizes areas of overlap. Both music and language have syntax — just as there are rules governing the construction of sentences from words, there are rules for "building" a piece of instrumental music. You don't just randomly throw notes together. (As with language, these rules may differ across cultures.) The brain seems to tap into the same neural circuitry when processing how the building blocks of language or music fit together into a greater, hierarchical structure.

"You can have overlap in the machinery that puts the pieces together," Patel says. "They may be different pieces, but the machinery that puts them together is shared."

Shared processing of music's and language's building blocks is evidenced by the brain's recognition of construction gone awry. Within milliseconds of hearing a sentence spoken with irregular structure, neurons fire in a specific area of the brain, researchers have learned. The brain also reacts to violations in chord structure.

Musically trained kids are better at hearing these violations than kids without training, says Sebastian Jentschke, now at University College London. Musically trained brains are also better at detecting violations in sentence structure, Koelsch and Jentschke reported in *NeuroImage* last year. The inverse relationship also holds; kids with Specific Language Impairment, marked by difficulties with grammar and complex syntax, also have trouble processing musical syntax, Koelsch, Jentschke and collaborators reported in 2008 in the *Journal of Cognitive Neuroscience*.

These studies highlight the neural intimacy of processing music and processing language. "It's a reasonable assumption that musical training might help with kids with impairments with processing skills in the language domain," Jentschke says.

From the top … down

Scrutinizing brains on music suggests that training influences more than the higher-level circuitry relevant to language skills.

Playing music can also change the brain from the top down, says Kraus, influencing language processing. The highfalutin circuitry of the cerebral cortex, which plays a key role in memory, perception and consciousness, can be shaped by music and in turn can fine-tune circuitry in the lower, evolutionarily ancient "lizard brain," changing how people hear.

"We used to think in a very hierarchical way — sound goes into your ear, up into your brain stem, then into your cortex and meaning happens," Kraus says. "But the lizard brain is not what it used to be. We know now that the pathways that connect the cortex and feed down to the brain

Take two stanzas and call me in the morning

From poets to politicians, people have long described music as medicine for the heart and soul. Now scientists are taking a literal look at such musings, investigating music as a means to alleviate pain and enhance recovery. Though some studies are still in the early stages, your favorite soundtrack may one day accompany a prescription.

Alzheimer's disease: Studies have shown that individuals with Alzheimer's have a better memory for lyrics when they are sung rather than spoken. The findings suggest that song may help these patients learn practical, everyday information.

Pain and nausea: Cancer patients who participated in music and relaxation-imagery sessions while recovering from bone marrow transplants had less pain and nausea than patients undergoing the standard treatment alone.

Anxiety: Listening to music before glaucoma or cataract removal surgery soothed patient anxiety, lowering blood pressure levels during and after the surgery, one study found. Another study showed that pregnant women who listen to music for 30 minutes a day report reduced levels of stress, anxiety and depression after two weeks.

Stroke: Patients who listened to music of their choosing for one to two hours a day did better on word recall tests and had fewer bouts of sadness and confusion than patients who listened to audio books or nothing at all. Research also suggests that simulating movement with music of a particular tempo may improve walking in stroke patients, and stroke patients report improved vision while listening to music.

Respiratory disease: Over eight weeks, subjects with serious lung disease who listened to music while walking showed improved fitness, a study found. Those patients covered 24 percent more ground than a nonmusic group.

Traumatic brain injury: Some patients who underwent music therapy that involved following tempo, loudness and rhythmic pattern performed better on tests of mental flexibility, suggesting such therapy may help people with brain injuries manage switching between important tasks during daily life.

— Rachel Ehrenberg

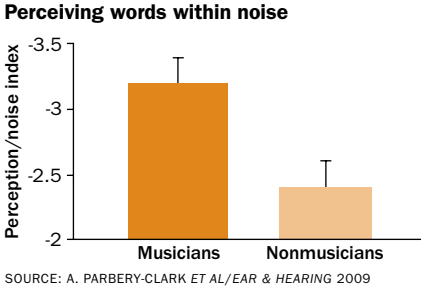
DANTODDY/ISTOCK IMAGES, PHOTO ILLUSTRATION BY E. FELICIANO

stem ... are actually more massive than the ones going upstairs."

This top-down tuning may influence a person's ability to discriminate sounds of different frequencies, the processing of pitch. Pitch is the brain's interpretation of frequency, both in terms of absolute frequency and relative position on the musical scale. (Levitin notes that pitch is the only musical attribute that varies in the first seven notes of "Mary Had a Little Lamb.") Pitch is crucial for conveying information: It determines whether the phrase "You are going to wash the dishes" is a question or a command. In languages such as Mandarin Chinese, saying the same syllable at a different pitch level gives the word an entirely different meaning.

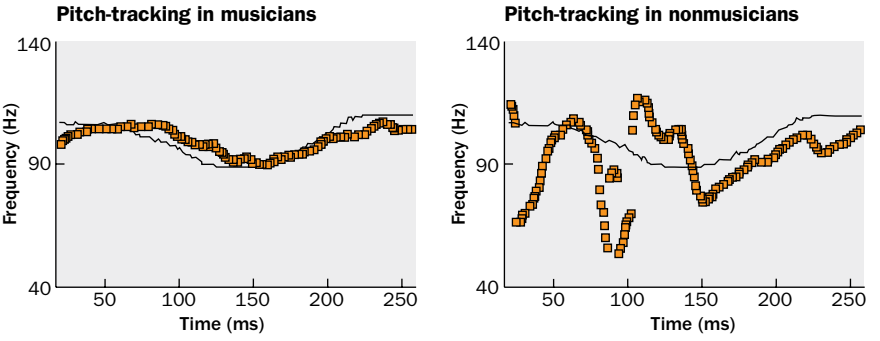
Among people unfamiliar with Mandarin, musicians are better than nonmusicians at discriminating between Mandarin syllables, Patrick Wong, Kraus and others reported in *Nature Neuroscience* in 2007. Electrodes recording brain activity revealed that a particular pitch-related neural response, thought to originate in the brain stem, was more robust in the musicians.

Other work on the effects of musical training suggests that it improves overall pitch processing. After six months, Portuguese third graders in a musical training group performed better on a reading task and on a pitch discrimination task than kids in a painting group, researchers reported last year in *Cerebral Cortex*. These results were also reflected in brain wave activity, says study coauthor Sylvain Moreno of the Rotman Research Institute and York University in Toronto.



Hear this Musically trained adults can hear words in background noise better than untrained peers (more negative index, better detection).

SOURCE: A. PARBERY-CLARK *ET AL/EAR & HEARING* 2009



SOURCE: P.C.M. WONG *ET AL/NATURE NEUROSCIENCE* 2007

Follow that tone The Mandarin language conveys word meanings with tone. When a musician with no knowledge of the language hears a Mandarin tone, activity in the brain stem (orange) tracks the frequency of the changing tone (black). The nonmusician's brain is out of sync.

This training-induced, top-down tuning appears to affect hearing in general. On a task known as backward masking, in which subjects detect a sound masked by a second sound, musicians with more than 10 years of musical training outperformed nonmusical peers, Kraus' team reports in the March *Hearing Research*. The musicians also performed better at distinguishing cartoon characters based on the pitch of their sounds.

Listening skills such as the ability to discriminate pitch or discern a signal from noise are related to some language impairments, including dyslexia, research suggests. People with dyslexia often have a hard time reading — a difficulty that is thought to result from trouble transforming the letters on a page into the sounds of language. This sound-meaning connection happens before children learn to read, says Kraus, and may be crucial for reading skills to develop.

A team that included Kraus and Jane Hornickel, also from Northwestern, looked at how the auditory brain stem responded to the sounds of different syllables for kids with a wide range of reading abilities. Kids with the weakest reading skills had a harder time distinguishing the sounds *ba, da* and *ga*, the team reported last year in *Proceedings of the National Academy of Sciences*.

Everyone has trouble hearing in a noisy restaurant. But children with dyslexia can have an even harder time perceiving sounds in noisy conditions. "If you've got a kid who is just struggling to hear what the teacher is saying, he's got very little extra neural resources to be thinking about 'What does this mean?' " Kraus says.

If musicians' responses are much less affected by background noise, she says, musicians can devote more neural resources to meaning rather than just hearing. That suggests musical skill could give children a learning benefit.

"If you have a nervous system in which the signal still comes through loud and clear in a noisy classroom, now that kid has an advantage," Kraus says.

For a clearer picture of the relationship between musical training and learning, more studies are needed. But the accumulating research is tantalizing, and it suggests that upping the quality and quantity of musical training in schools is warranted, Kraus and Northwestern colleague Bharath Chandrasekaran write in the August *Nature Reviews Neuroscience*.

"Music has the power to transform our nervous system in substantial, enormous, unambiguous ways," says Kraus.

Many researchers now equate musical training with learning to read. (Patel calls each of them a "transformative technology of the mind.") Perfectly intelligent, capable people can do fine in life without cracking a book or strumming a tune. But both can make the mind sing. ■

Explore more

- Nina Kraus' laboratory: www.soc.northwestern.edu/brainvolts/
- Daniel J. Levitin. *This Is Your Brain on Music: The Science of a Human Obsession.* Dutton, 2006.