SCIENTIFIC AMERICAN™

Permanent Address: **http://www.scientificamerican.com/article.cfm?id=exploring-the-musical-bra**

Exploring the Musical Brain

Music may be even more ancient than the human race, over which it holds tremendous sway. Scientists are beginning to find out why

By Kristin Leutwyler | Monday, January 22, 2001

NEANDERTAL FIREPLACE in France may have offered warmth to our ancestors as they joined to play and listen to the animal-bone flutes recently found in the area. The remarkable musical instruments are as much as 53,000 years old¿more than twice as old as the famed cave paintings in Lascaux.

It can bring us to tears or to our feet, drive us into battle or lull us to sleep. Music is indeed remarkable in its power over all humankind. Perhaps for that very reason, no human culture on earth has ever lived without it: people making music predates agriculture and perhaps even language. Take, for instance, the recent discoveries in France and Slovenia of surprisingly sophisticated, sweet-sounding flutes, made by our Neandertal cousins. Some of these instruments, carved from animal bones, are as much as 53,000 years old¿more than twice as old as the famed cave paintings in Lascaux.

Despite the ancient and primal nature of music, though, scientists have struggled with some very fundamental questions about its origins and purpose. How does the brain process music? Are there special neural circuits dedicated to creating or interpreting it? If so, are they, like language, unique to human beings? Or do other animals possess true musical ability? Why is an appreciation for music practically universal? Has it conveyed some evolutionary advantage through time? The field of biomusicology is still fairly young, but during the past few years, it has started to answer some of these questions. Perhaps most basic, researchers have discovered that music¿like language¿stimulates many areas in the brain, including regions normally involved in other kinds of thinking. For this reason, Mark Jude Tramo of the Harvard Medical School argues in a recent issue of *Science* that the brain doesn't have a specific "music center," as others have suggested. As an example, he points to the left planum temporale. This tiny brain region is critical to the golden musical gift of perfect pitch¿the rare ability to recognize by ear a perfect middle C hit on the piano, or the E of a passing car horn. But the left planum temporale also plays an important role in language processing. Thus, Tramo writes, there is "no grossly identifiable brain structure that works solely during music cognition. However, distinctive patterns of neural activity within the auditory cortex and other areas of the brain may imbue specificity to the processing of music."

Some of the patterns Tramo talks about have revealed themselves through neuroimaging studies¿others through tests on patients that, like the subjects of Oliver Sacks's popular books, have suffered unusual forms of brain damage. In the late 1990s, for instance, Isabelle Peretz at the University of Montreal and Catherine Li¿geois-Chauvel of INSERM in Marseilles ran several experiments on 65 people who, because of epilepsy, had had part of one or the other temporal lobe surgically removed. From these studies they concluded that musicality resided primarily on one side of the brain¿the right hemisphere.

The experiments were simple: Peretz and Li¿geois-Chauvel played different songs for each patient twice. Sometimes the melodies were exactly the same. Other times, they had changed in one of several attributes, which researchers describe as "dimensions": first among them is pitch, which pertains to the actual frequency of a particular tone; the second is rhythm, or the duration of series of notes; the third is tempo, the overall pace of a piece; the fourth is contour, which describes the shape of a melody, or its pattern of rises and falls in notes; the fifth is key, or the set of pitches to which notes in a melody belong; other dimensions include timbre, loudness and spatial location.

The scientists found that people with damage to the left temporal lobe had difficulty recognizing changes only in key, whereas those with damage to the right side struggled to recognize changes in both key and contour. Later imaging studies showed a similar bias toward the right hemisphere¿particularly among nonmusicians¿although Tramo notes that more recent work calls some of this "musical hemisphere" hypothesis into question. "The belt and parabelt areas [of the auditory cortex] in the right hemisphere discriminate local changes in note duration and separation," he writes, "whereas grouping by meter involves mostly anterior parabelt areas in both hemispheres."

From Mind's Eye to Emotion's Seat

Image: NATIONAL MARINE FISHERIES SERVICE

HUMPBACK WHALES use many of the same rhythms and patterns as human composers in their songs, tempting some scientists to speculate that a universal music awaits discovery.

For certain, it is becoming apparent that unexpected and unsophisticated areas of the brain are sometimes involved in interpreting, writing, feeling or performing music. As some research has showed, even the visual cortex sometimes gets into the act. Herv¿ Platel, Jean-Claude Baron and their colleagues at the University of Caen used positron emission tomography (PET) to monitor the effects of changes in pitch. What they found¿much to their surprise¿was that Brodmann's areas 18 and 19 in the visual cortex lit up. These areas are better known as the "mind's eye" because they are, in essence, our imagination's canvas. Any make-believe picture begins there. Thus, Baron suggests that the brain may create a symbolic image to help it decipher changes in pitch.

But music goes much deeper than that¿below the outer layers of the auditory and visual cortex to the limbic system, which controls our emotions. The emotions generated there produce a number of well-known physiological responses. Sadness, for instance, automatically causes pulse to slow, blood pressure to rise, a drop in the skin's conductivity and a rise in temperature. Fear increases heart rate; happiness makes you breathe faster. By monitoring such physical reactions, Carol Krumhansl of Cornell University demonstrated that music directly elicits a range of emotions. Music with a quick tempo in a major key, she found, brought about all the physical changes associated with happiness in listeners. In contrast, a slow tempo and minor key led to sadness.

Robert Zatorre and Anne Blood at McGill University corroborated Krumhansl's findings with PET imaging experiments. They created original melodies containing dissonant and consonant patterns of notes, and played them for a group of volunteers willing to be scanned at the same time. As expected, dissonance made areas of the limbic system linked to unpleasant emotions light up in the PET scans, whereas the consonant melodies stimulated limbic structures associated with pleasure.

That music strikes such a chord with the limbic system¿an ancient part of our brain, evolutionarily speaking, and one that we share with much of the animal kingdom¿is no accident, some researchers assert. In another recent paper in *Science*, Patricia Gray, head of the Biomusic program at the National Academy of the Sciences, and several colleagues from around the country propose that music came into this world long before the human race ever did. "The fact that whale and human music have so much in common even though our evolutionary paths have not intersected for 60 million years," they write, "suggests that music may predate humans¿that rather than being the inventors of music, we are latecomers to the musical scene."

Humpbacks, Hummingbirds and Human Composers

Gray and company note that humpback composers employ many of the same tricks human songwriters do. In addition to using similar rhythms, humpbacks keep musical phrases to a few seconds, creating themes out of several phrases before singing the next one. Whale songs in general are no shorter than human ballads and no longer than symphony movements, perhaps because they have a similar attention span. Even though they can sing over a range of seven octaves, the whales typically sing in key, spreading adjacent notes no farther apart than a scale. They mix percussive and pure tones in pretty much the same ratios as human composers¿and follow their ABA form, in which a theme is presented, elaborated on and then revisited in a slightly modified form.

Perhaps most amazing, humpback whale songs include repeating refrains that rhyme. Gray and her colleagues say that whales might use rhymes for exactly the same reasons we do: as devices to help them remember. As a recent study showed, whale songs are often rather catchy. When a few humpbacks from the Indian Ocean strayed into the Pacific, some of the whales they met there quickly changed their tunes¿singing the new whales' songs within three short years.

Image: OHIO STATE UNIVERSITY

SINGING BIRDS often pitch their songs to the same scale as Western music¿which may explain at least in part why people find them so attractive.

Back on land, birds, too, make music much like people. "When birds compose songs they often use the same rhythmic variations, pitch relationships, permutations and combinations of notes as human composers," Gray and her colleagues write, citing work done by their late co-author Luis Baptista. "Thus, some bird songs resemble musical compositions; for example, the canyon wren's trill cascades down the musical scale lie the opening of Chopin's 'Revolutionary' Etude." That same bird sings in the chromatic scale, which divides the octave into 12 semitones, and the hermit thrush sings in the so-called pentatonic scale. It is perhaps because these birds pitch their songs to the same scale as Western music that people find them so attractive.

Why would such different creatures¿with such different physical means for making sound¿all adopt such astonishingly uniform patterns for their melodies? Gray and her colleagues conclude that the similarities "tempt one to speculate that the platonic alternative may exist¿that there is a universal music awaiting discovery." But in fact, there is currently considerable debate over the purpose of music, and whether it was adaptive for humans in evolution or not.

"Auditory Cheesecake" or Evolutionary Advantage?

Linguist Steven Pinker of the Massachusetts Institute of Technology has proposed that music is merely "auditory cheesecake," or "an evolutionary accident piggy-backing on language," as Daniel J. Levitin at McGill University explained in a recent issue of the journal *Cerebrum*. But many scientists¿Levitin among them¿don't agree. "Some researchers are finding that listening to familiar music activates neural structures deep in the ancient primitive regions of the brain, the cerebellar vermis," Levitin writes. "For music so profoundly to affect this gateway to emotion, it must have some ancient and important function."

Geoffrey Miller of University College London has proposed that musical ability¿like broad shoulders or showy plumes¿may serve to demonstrate fitness to a potential mate. After all, singing or playing an instrument well requires dexterity and good memory. Another suggestion Levitin makes is that music functions as communication, perhaps mimicking the rhythm and contour of our species' primitive calls. So, too, he proposes that perhaps music conveys an advantage through stimulating our primitive timing mechanisms.

Most interesting, he suggests that music stimulates our drive to find patterns in the environment. "Our brain is constantly trying to make order out of disorder, and music is a fantastic pattern game for our higher cognitive centers," he writes. "From our culture, we learn (even if unconsciously) about musical structures, tones and other ways of understanding music as it unfolds over time; and our brains are exercised by extracting different patterns and groupings from music's performance." It is this very kind of pattern recognition¿which is extremely important for making sense of the world around us¿that Keith Devlin suggests in his book *The Math Gene* gave rise to language and stands behind mathematical ability as well. To be certain, researchers won't agree on the purpose of music anytime soon¿which fortunately shouldn't stop any of us from enjoying it.