CHEMISTS MAKING MUSIC

Chemistry and music may seem an odd duo, indeed. But music has a home in the brains of many chemists and other scientists, including individuals who perform at world-class levels. What explains the link between pursuits that seem a million miles apart?

BY JOAN STEPHENSON, Ph.D.

Home in the Brain

(Sung to the tune of *Home, Home on the Range*)

Oh, give me a brain
with the dendrites free reign
to connect and forever to play;
Where music is heard
to reinforce every word,
and all sorts of knowledge to gain!

Home, home in the brain
Where the dendrites have free reign
to connect every thought
just the way they were taught
without any struggle or strain.

—Lyrics by Illinois school teachers Matt Owens (ACS '95), Mary Jo Loffelmacher, Sharon Martin, and Lisa Owens. From Songs for Teaching (www.songsforteaching.com/Science.html)

One enduring image from the annals of pseudoscience is the "phrenological head," a map subdivided into plots indicating the hypothesized location of a person's strengths, weaknesses, and proclivities—a patch of "mindfulness" here, a blob of "wit" there, a rectangle of "causality" there.

Although phrenology has long been abandoned, a modern-day practitioner surveying scientists, engineers, and mathematicians for interests and talents would be likely to devote substantial portions of cranial real estate to science, mathematics, and music.

Music has a home in the brains of many successful scientists, including those performing at impressive musical levels. A look at the "day jobs" of competitors in the Van Cliburn Foundation's latest International Competition for Outstanding Amateurs shows that about one-third of the 73 participants were physicians or other health professionals, engineers, computer experts, and scientists—including two chemists, one of whom tied for first place.

The fact that there are so many musically talented scientists raises some intriguing questions about a possible link between science and music, such as whether there's an overlap of skills that contribute to an affinity and ability for both music and science, or if early training in music can affect the developing brain in ways that contribute to scientific abilities.

Dual gifts

Chemists with music on their minds have made their marks in both disciplines. Perhaps the field's most prominent chemist–musician was Alexander Borodin, who achieved distinction as both an organic chemist and a composer of symphonies, chamber music, and the opera *Prince Igor*.

"Borodin was a really good and insightful organic chemist," said ACS past-president Ronald Breslow (ACS '51), a distinguished chemist and musician in his own right. Another distinguished composer, Sir Edward Elgar (known for "Pomp and Circumstance" and the "Enigma Variations") was a keen amateur chemist who conducted experiments in a home laboratory.

A remarkable number of modern chemists also have demonstrated a talent and affinity for music. Chemist and inventor Arnold O. Beckman (ACS '27), who founded Beckman Instruments, performed as a movie-house pianist and started his own orchestra in high school. Nobel laureate Jean-Marie Lehn (ACS '62), who plays the piano and organ, reportedly has three pianos at home, including a Steinway he bought with his Nobel Prize money. And the late Donald Cram (who shared the Nobel for chemistry in 1987 with Lehn and Charles Pedersen), carried firewood, emptied ashes, and shoveled snow for music lessons and later played the guitar to break the ice in chemistry classes he taught.

For some, the siren song of music finally exerts an even greater pull than science.

Victoria Bragin (ACS '90) began studying piano at age 8 in her native Philippines. Chemistry came into the picture after she sailed through senior-level college music courses and earned a music diploma at age 16. She earned a master's degree in chemistry at the University of Wisconsin, where she met her future husband, a fellow chemistry student. Music remained a vital part of her life, a welcome counterpoint to her work as a chemistry professor at Pasadena City College and subsequently as a program director in the National Science Foundation's Division of Undergraduate Education.

But winning first prize in the Van Cliburn amateur competition in 2002 marked the turning of the tide. Now Bragin is largely retired from chemistry and is relishing her new role as musician-in-residence at the Huntington Museum of Art in West Virginia.

Common ground?

Pianist–violinist–chemist Melvin Chen, who earned a doctorate in chemistry from Harvard University and a double master's degree from Juilliard in violin and piano performance, has the unusual distinction of being both a professor of music (at Yale University) and a visiting professor of music and chemistry at Bard College. An ebullient Renaissance man, Chen sees much common ground between science and music.

"For me, they're both ways of searching for knowledge in the world and the truth of the human experience," he said. "Science looks at how the world works in a systematic way; art comes at it in a complementary way."

Chen explained that both performing music and doing science require discipline and a certain ability to take individual pieces of data or individual notes and synthesize them into something coherent.

"It's important to concentrate on both the little things and to see the big picture, to focus on both the specific and the general," he said.

Music and chemistry also have in common the fact that they use abstract symbols, which combine into an abstract language, said Chen.

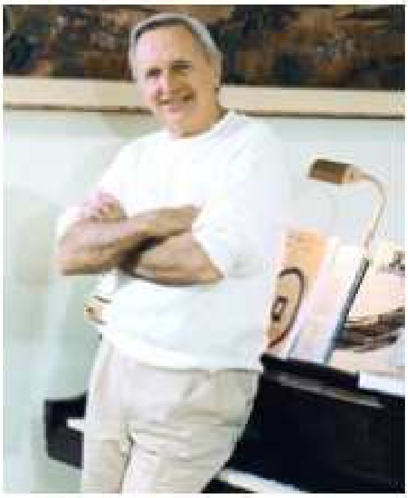
Experts who study how the brain processes music agree. Musicians and mathematicians both excel in manipulating abstract symbols.

"Whether it's using numbers or using musical notes or using letters, one has to be able to string those symbols together in a way over time that conveys some sense of meaning," said Mark Jude Tramo, director of the Institute for Music & Brain Science at Harvard Medical School, who both plays guitar and composes. "One of the great talents that terrific musicians and chemists have is the ability to see beyond the immediate next step in a sequence."

For some chemist–musicians, music provides a catalyst that facilitates their ability to leap ahead mentally.

"I've found music helpful when I was working in the lab," said Chen. "When I had a problem that I couldn't figure out, I would practice the piano for a while and find I'd have the answer—who knows how?"

Playing music can be a relief from doing science because it engages the brain in a way that is not consciously analytic, said Breslow, who favors improvisational playing and claims to be "infamous for bumping guys off pianos in bars" to play. Breslow's love of music and talent as a pianist are so well known to colleagues, in fact, that they commissioned a piano composition for an an all-day symposium held in 2001 to mark his 70th birthday and contributions to chemistry.



RONALD BRESLOW (ACS '51), a talented pianist, has been known to "bump guys off pianos in bars" for a chance to play.

VICTORIA BRAGIN (ACS '90) began studying piano at age 8 and won first prize in the 2002 Van Cliburn amateur competition.

The title: "Liberating Chemistry from the Tyranny of Functional Groups."

Though music is "enormously relaxing," said Breslow, the analytic part of the brain may be working quietly in the background.

Music and the brain

In recent years, there's been a flowering of research, much of it by neuroscientists who are skilled musicians themselves, into how the brain processes music and music's effects on the brain. Researchers who study the brain stress that while it's possible to localize some aspects of music processing to specific regions of the brain, listening to and playing music are complex processes that involve memory, learning, emotion, and (especially for playing) motor skills, making it likely that many areas of the brain are important in experiencing the emotional riches of music.

Just the act of listening to music is an impressively complex activity. "People have no idea just what geniuses they are in terms of what they do when they turn on the radio and listen to music," said Tramo. The operations involved in apprehending the emotion of a Mozart concerto, for example, are very complex, and are carried by a kind of relay system in the brain, he explains.

First, the brain collects and processes sensory input, the kind of data that reaches the retina or the ear. Scientists have known for some time that the part of the brain that receives sensory input—sight, sound, touch—lays this information out in a map-like way, which enables the brain to process relative distances between, say, two objects.

Recently, neuroscientist Petr Janata and colleagues at Dartmouth College found the brain not only maps individual pitches (frequencies) but also the 24 major and minor keys in Western music, some of which we perceive as being more similar to each other than others. Janata and his colleagues used a brain imaging technique called functional magnetic resonance imaging (fMRI) to track the brain activity of volunteers as they listened to a tune that moved through all 24 major and minor keys in Western music. "We found that the distance relationships among the keys (how similar or different they are to each other) can be represented on the surface of a torus, a donut shape," he said. (See graphic.) This map for musical activity is in an area in the front of the brain that some researchers suggest plays a role in introspective thinking.

"To some extent, a certain amount of introspection and creative character in science is consistent with music," said Breslow. "Both performing and doing science require a lot of time alone." To keep one's skills polished, he said, musicians require practice time alone, and "science, to some extent, is a lonely profession that requires a lot of sitting quietly and thinking about what things mean."

Playing an instrument or singing makes additional demands on the brain. Skilled musicians require impressive motor skills, and the movement of fingers, hands, arms, lips and so on is directed by specialized motor areas of the cerebral cortex. The brain also has to integrate the sound a musician is producing and movement, interpret touch information (from fingers or lips and mouth as they work an instrument), and process the emotional response to music.

Lisa Saunders Baugh (ACS '90), a polymer chemist–violist–violinist who recently joined *Chemistry*'s editorial board, said she isn't surprised that performing music appeals to many scientists. She is with ExxonMobil Corp. Strategic Research in Annandale, NJ.

"Scientists like to think about multiple things, to be challenged," said Baugh, who plays violin and viola in chamber music groups and with the Central Jersey Symphony (a semipro group) and a community orchestra. "Playing in an orchestra takes every ounce of concentration you have," reading the music, watching other people, making precise physical movements with arms and fingers, and matching the sound of one's instrument with that of 70 other people. This intense focus "totally wipes everything else out of my mind," said Baugh. "It's the only thing that is intense enough to do that."

Douglas C. Neckers (ACS '59), a photochemist at Bowling Green State University,

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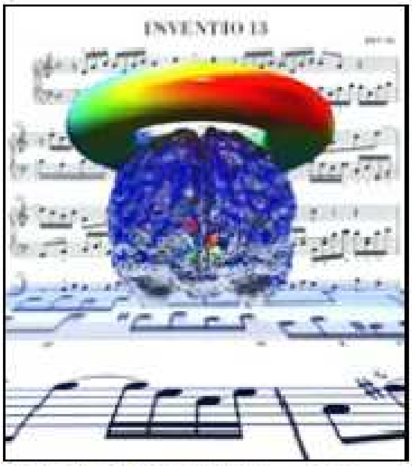


MUSIC ON THE MIND, depicted in a graphic from Petr Janata's group, which found that the distance relationships among the musical keys (how similar or different they are to each other) can be represented on the surface of a torus, or donut shape. The group has found and mapped the area in the brain that processes and tracks music. This location is also active during reasoning and memory retrieval. Janata's group used functional magnetic resonance imaging (fMRI) to map brain activity while volunteers listened to a piece of original music. The fMRIs indicated that knowledge about the harmonic relationships of music is maintained in the rostromedial prefrontal cortex, which is centrally located, right behind the forehead. This region is connected to, but different from, the temporal lobe, which is involved in more basic sound processing. The region is important for a number of functions, such as assimilating information that is important to one's self, or mediating interactions between emotional and non-emotional information.

agrees that an intense focus is something science and music have in common. He sings in an Anglican professional choir that travels to England to perform in some of the country's great cathedrals when the resident choirs are on vacation.

"You have to be very intense to be successful in either discipline," he said.

The brain interprets the auditory information it receives, an activity that involves processing many types of information in addition to the auditory data. The common final pathway in this network of relay stations leads to the ancient structures in the brain that function as the organ's emotional centers, said Tramo, and the resulting emotions are the embodiment of the aesthetic experience.

Common threads

Some scientist–musicians suspect that an appreciation for logic and structure, as well as an affinity for mathematics, may be a common thread in science and music.

"There is a logic to music and there is an art to science," said Kenneth Jolls, a professor of chemical engineering at Iowa State. He's an accomplished vibraphone player who's performed with symphony orchestras, jazz bands, and other groups. Jolls recently performed and talked about the physics of the vibraphone at the Cornelia Street Cafe in New York's Greenwich Village as part of a monthly program called "Entertaining Science."

Organized by Nobel Prize-winning Cornell University chemist and poet Roald Hoffmann (ACS '63), the evening brings together the realms of art and science—realms that have human creativity in common. Jolls needs no persuasion that the arts have a role to play in science education. "Nowhere is there a better example of art in science than in classical thermodynamics," a subject he teaches. Visual images of thermodynamic models "give you semitangible entities to tie to things that are perceived otherwise in the blind abstract," he said.


PHOTO © SUSAN WILSON

MELVIN CHEN, renowned pianist–violinist–chemist, earned a doctorate in chemistry from Harvard University and a double master's degree from Juilliard in violin and piano.

On the other hand, he finds a grasp of the abstract also provides a dimension to music. "I was formally a theory major in music school, and a mathematical mind certainly helps one appreciate the order and regularity of music," explained Jolls.

David Schuster (ACS '56), an organic chemist at New York University and an accomplished pianist, said that both disciplines have an aesthetic appeal. "We talk about a piece of research as 'an elegant piece of work,'" said Schuster, whose particular treasure is his "magnificent 7-foot Steinway grand piano," an instrument previously owned by publishing magnate Alfred Knopf. "An idea that is 'elegant' has inherent appeal and beauty." Part of that beauty can be related to how a piece of music or research is put together, he said.

"It takes an organized mind to play piano," said Schuster, who sometimes brings a score to concerts to see how the music fits together. "You have to learn how to put together the logic of it."

Breslow seconds that idea.

"Music has a wonderful interior structure," he said. "For a scientist, music is a reminder [of] how much interesting structure there is in the world."

"There's a lot of math to music," said Tramo. "If you have to change from one key to another, if you have to learn the fret board of a guitar or a piano, you're always dealing with distances, scalar magnitudes, ratios, relationships among notes, things that are very much related to simple and recursive operations that go into a lot of what we think of as math." But different forms of math, and different aspects of the complex activity of music, involve different parts of the brain, he said.

Thus, something like algebra would be apt to involve the left hemisphere, which is specialized for speech, writing, language, and calculation functions, while geometry, which involves spatial information, is likely to involve the right hemisphere, the side dominant for spatial abilities. The same is likely to be true for music, so that activities like playing by ear, composing, reading music, or singing songs will recruit different areas of the brain.

Craving music

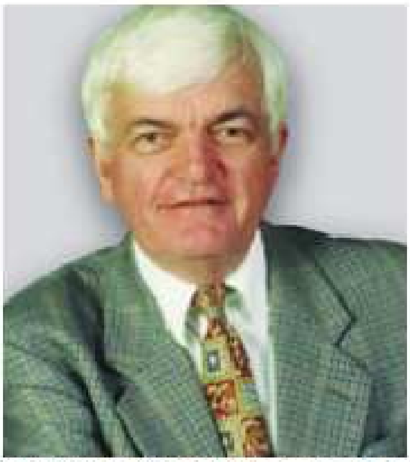
Why do humans have the capacity to make and enjoy music?

The topic intrigues researchers. Some suggest music is just a serendipitous evolutionary by-product of other perceptual and motor abilities that are crucial for survival. Others suggest that music's ability to enrapture, send shivers down the spine, and bring tears to the eyes might promote our physical and mental well-being.

"One can't escape the fact that music is something our brains seek out," said Janata.

Researchers at the Montreal Neurological Institute and Hospital have found that music activates neural pathways in the brain that are associated with euphoria and reward, areas that are activated by pleasurable activities such as eating or sex. It's possible that music lowers stress by activating parts of the brain that make us happy. There's also a lot of anecdotal information suggesting that music might have a role in pain management, in treating premature infants, and in lowering blood pressure, said Tramo.

One hypothesis suggests that music evolved to promote social cohesion. "Humanity would never have made it if it didn't form bonds, so there has to be a set of events that we can all share," said Tramo. "Look at our culture, there's nothing humans do, not even a baseball game, that doesn't involve some ritual related to music."



DOUGLAS C. NECKERS (ACS '59), a photochemist at Bowling Green State University, sings in an Anglican professional choir that performs in the United States and the United Kingdom.

Is Music Good Cross-Training?

Neuroscientists have detected a number of structural differences in the brains of musicians; these findings suggest that musical training can influence brain organization and ability.

- Several areas of the brain are larger in adults who play musical instruments than in nonmusicians. These include areas such as the primary motor cortex and the cerebellum, which are involved in movement and coordination, as well as the corpus callosum, a large band of nerve fibers that links the two hemispheres of the brain.

- A larger proportion of the auditory cortex (which brings music and speech into conscious experience) responds to piano tones in adult musicians as compared with nonmusicians. The earlier the age at which the musicians had begun lessons, the more enlarged the area. Follow-up research revealed that the brains of musicians are especially attentive to the sounds of the instruments they play; a larger area of a violinist's brain responds to hearing violin sounds than it does to hearing trumpet sounds, and vice versa.

- In trained violinists, the area of the somatosensory cortex (which interprets touch information) corresponding to the four fingers used to press down on violin strings is enlarged.

- Trained musicians tend to use more of the left, analytical half of their brains for processing music than nonmusicians.

Scientists are also studying whether the brain changes seen in musicians enhance mental functions not associated with music—in other words whether music serves as a kind of cross-training for the brain.

- Adults with musical training perform better on word memory tests than other adults.

- Preschoolers who have had piano lessons for about six months perform better than their counterparts on puzzle-solving tests.

- Second-graders who played special computer math games and took piano lessons scored higher on math tests than students who played the same computer games but had English language instruction rather than piano lessons.

- Children who had musical training for one to five years had significantly better verbal memory than schoolmates without such training—and the longer the training, the better the verbal memory. The researchers suggest that music has a kind of cross-training effect: The extra stimulation from studying music to the left hemisphere of the brain, the side that handles language, boosts its ability to handle other left-hemisphere functions, such as verbal learning.

- "There's no way to tell if such studies have something to do with specific cognitive functions involved in music and math," said Tramo. "Or they may relate to other so-called general purpose cognitive mechanisms like attention, memory, that are involved in language and all sorts of other cognitive activities. But they do suggest that music can tap into brain mechanisms involved in these other processes and can conceivably improve them."

—JS

Many chemist–musicians would endorse the notion of music as an opportunity to connect with other people. Frank Mallory (ACS '58), an organic chemist–clarinetist at Bryn Mawr, belongs to an kind of pick-up group of like-minded scientist–musicians called the Borodin Ensemble. It includes fellow organic chemists David Schuster and Jerrold Meinwald (ACS '49), from Cornell. Mallory also plays chamber music at Bryn Mawr and spends a portion of each summer in Bennington, VT, playing at a chamber music conference.

When Meinwald is invited to speak at meetings or give a seminar, he offers to throw in a program of chamber music featuring himself on flute, his wife on piano, and any local talent that can be lined up.

"Playing music provides an opportunity to interact with musicians of any age and from entirely different walks of life," explained Meinwald, a septuagenarian who studied with legendary French flutist and teacher Marcel Moyse. "I have very little in common with a college freshman, but when playing music, that doesn't matter. You can have absolute rapport."

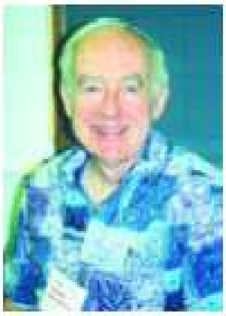
Other researchers suggest that music and language co-evolved and are closely entwined. "Pitch and melody are used to convey meaning; the very nature of human and vocal communication is musical," said Tramo.

Whatever the reason music evolved, and whatever links music shares with the scientific enterprise, the main reason scientists crave music is the same as for us all. It makes us feel good.

"Science is intellectually challenging, and there are scientific sides of music which are certainly important intellectually," said Jolls. "But the reason I play and listen to music is because it sounds so good.

"I don't think I would ever shed a tear over science, but anyone who understands what's going on in some of the Verdi and Puccini operas and keeps a dry handkerchief all the way through—well, welcome to the grave."

Joan Stephenson found this topic right in her bailiwick. A Chicago-based science writer who has a Ph.D. in biology, she is a flutist. One of her brothers is an astrophysicist and bassoonist, and the other a chemical engineer who plays the saxophone.



FRANK MALLORY (ACS '58), an organic chemist–clarinetist at Bryn Mawr, plays in the Borodin Ensemble, a group of scientist–musicians.

Periodic Table of Music

In 1863, English chemist John Newlands proposed the "Law of Octaves," after arranging the elements in order of increasing atomic mass. With a nod to Western music, he suggested that chemical properties also repeat with every eighth element.

The basic scale in Western music has a periodicity of eight notes, an octave. Newlands' theory was largely met with scorn, and soon it was eclipsed by Dmitri Mendeleev's proposed periodic table of the elements in 1869.

But much of it proved to be true. Newlands' system works for the lighter elements, because eight electrons complete the outer shell, but failed to work for the transition metals.

—JS

JERROLD MEINWALD (ACS '49) (right), a Cornell organic chemist and Borodin member, studied with legendary French flutist Marcel Moyse. Thomas Eisner (left), the Jacob Gould Schurman Professor of Chemical Ecology at Cornell, is at the harpsichord.