Musical pitch perception starts early

Tasked with extracting the fundamental frequency from a complex of high harmonics, three-month-old infants outperformed many adults.

When a musical instrument plays a note, the sound wave produced is not a single frequency but a spectrum of harmonics. The composition of that spectrum determines the note's timbre: the distinguishing factor between the sounds of, for example, a flute and a trumpet, or different vowel sounds in a spoken or sung syllable. Even when the fundamental frequency is absent and only the higher harmonics are present, the adult human brain can fill in the missing fundamental and perceive the note's pitch.

Now Bonnie Lau and Lynne Werner of the University of Washington have tested whether infants in different stages of development can do the same.[1] Pitch perception is related to how infants learn to segregate different sounds occurring at the same time, an important skill in making sense of the complex environmental sounds encountered every day.

The researchers had their infant participants listen to sequences of notes drawn from a set of 10 high-harmonic complexes, 5 for each of 2 fundamental frequencies. The complexes consisted of different combinations of the 12th through 31st harmonics—between 3½ and 5 octaves above the fundamental—and they bore little resemblance to their respective fundamental frequencies. Still, Lau and Werner were able to condition the infants to associate changes in fundamental frequency with the activation of a mechanical toy (just outside the field of view in the figure).

Once they were conditioned, the infants responded behaviorally whenever the missing fundamental was changed—but before the mechanical toy was turned on. None of the adults involved in facilitating the experiment listened to the same notes the infants did; they had to judge whether the infants were hearing a change in fundamental from behavioral cues alone.

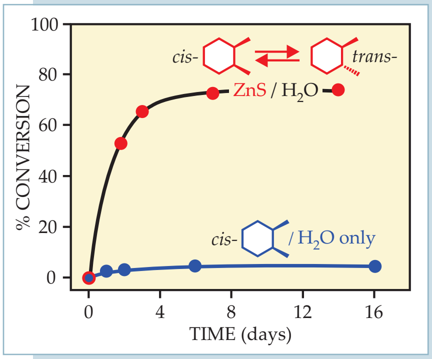
Curiously, three-month-old and seven-month-old infants performed equally well at the task, even though the sensory pathways in the brain change radically between those ages. At three months, the auditory cortex is not yet mature, and sounds are most likely processed in the brain stem.

Lau and Werner then repeated the experiment with adult participants, who were instructed, cryptically, to lis-

physics update

These items, with supplementary material, first appeared at http://www.physicstoday.org.

Zinc ore catalyzes Earth's organic chemistry. Carbon compounds are ubiquitous, even in deep ocean sediments, in subduction zones, and at mid-ocean ridges. Although the essential ingredients of the chemical reactions in such environments are well known—organic molecules, hot pressurized water, and minerals—studies of the ways in which individual minerals influence reactivity are virtually nonexistent. That's partly because geochemical organic reactions tend to generate complex product mixtures, which can obscure the mechanism. Hilairy Hartnett and a team of researchers at Arizona State University have now presented the first description of mineral catalytic effects on the most fundamental aspect of an organic reaction: the breaking and making of a covalent bond. In the group's experiments, when the model alkane *cis*-1,2-dimethylcyclohexane was placed in a chamber at 300 °C and 1000 atmospheres and allowed to react with water alone, little happened. A mere 5% of the isomer converted into the *trans-* form of the alkane over a two-week time span, as shown by the blue curve. But when the hydrothermal reaction occurred in the presence of sphalerite, a mineral form of zinc sulfide commonly found on the sea floor among black smoker vents, the conversion rate rose dramatically (red curve). The *trans-* structure was primarily produced until an equilibrium between the stereoisomers was reached. The result is consistent with a mechanism in which sphalerite breaks a C–H bond to form an intermediate that can then reform the bond as either the *cis-* or *trans-* isomer. The catalysis of C–H bonding is not new, but the Arizona State experiments may interest industrial chemists. Unlike most organometallic catalysts, minerals are inexpensive, are robust, and require no synthesis. (J. A. Shipp et al., *Proc. Natl. Acad. Sci. USA* **111**, 11642, 2014.) —RMW



Quantum electrodynamics in a semiconductor vacuum. An isolated atom is, in many regards, the quintessential quantum system, but it interacts only weakly with its electromagnetic environment. As described by cavity quantum electrodynamics (QED), however, atom–photon interactions can be manipulated by placing an atom in a highly reflective optical cavity (see the article by Serge Haroche and Daniel Kleppner, PHYSICS TODAY, January 1989, page 24). With modern nanofabrication techniques, the coupling of an artificial atom, such as a quantum dot or superconducting qubit, to a nearby transmission-line resonator or other microwave circuit can analogously be engineered, in what's dubbed circuit QED (see PHYSICS TODAY, November 2004, page 25, and the article by J. Q. You and Franco Nori, November 2005, page 42). Although many properties of artificial atoms can be readily tuned, the quantum states typically have short coherence times. Now Andrea Morello and colleagues at the University of New South Wales in Sydney, Australia, report a promising new scheme: a lone phosphorus-31 atom embedded in an isotopically purified substrate of silicon-28 and magnetically coupled to a superconducting niobium resonator (the figure shows the cross section). With no net nuclear or electron spin, the ^{28}Si sub-