The newsletter of
The Acoustical Society of America

ECHOES

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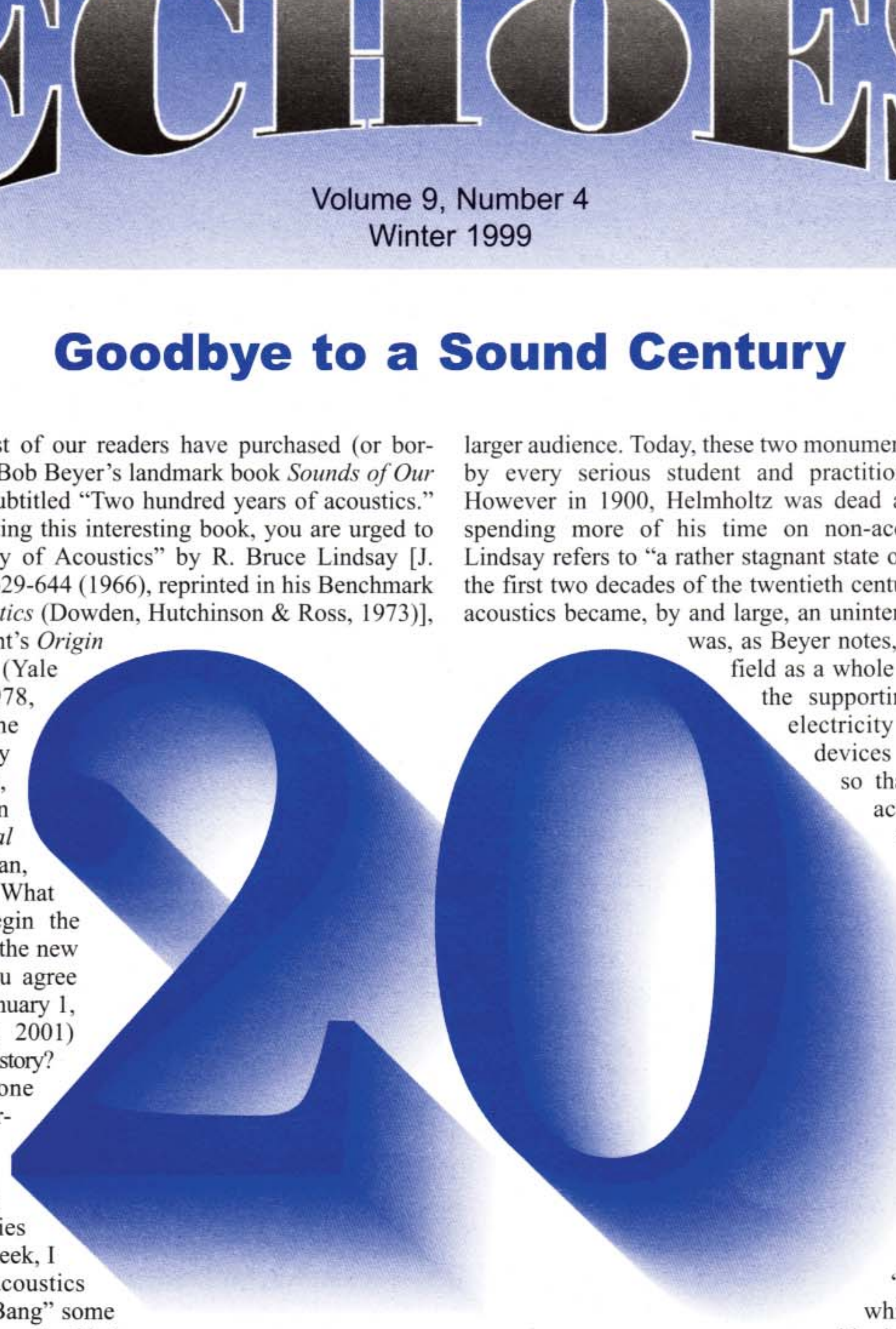
Goodbye to a Sound Century

By now, most of our readers have purchased (or borrowed) a copy of Bob Beyer's landmark book *Sounds of Our Times*, which is subtitled "Two hundred years of acoustics." Along with digesting this interesting book, you are urged to review "The Story of Acoustics" by R. Bruce Lindsay [J. Acoust. Soc. **39**, 629-644 (1966), reprinted in his Benchmark series book *Acoustics* (Dowden, Hutchinson & Ross, 1973)], and Frederick Hunt's *Origin of Acoustics* (Yale University 1978, reprinted by the Acoustical Society of America, 1992), and Dayton Miller's *Anecdotal History* (Macmillan, New York, 1935). What better way to begin the new century (and the new millennium, if you agree that it began on January 1, 2000 rather than 2001) than by reviewing history?



Of course, one could go back farther than one century; sound has been around for many centuries (with tongue in cheek, I traced musical acoustics back to the "Big Bang" some 10^{11} years ago (*Proc. Stockholm Music Acoustics Conf.*, Royal Swedish Acad. Music, 1994). However, quite enough has happened in the past one hundred years to capture our attention and make us stand (or sit) in awe.

As the 20th Century began, Rayleigh's *Theory of Sound* (1877) and Helmholtz's *Die Lehre von den Tonempfindungen* (1862) had been published but hardly digested. The English translation of Helmholtz's treatise by Alexander Ellis (1875), with the title *On the Sensations of Tone* made it available to a larger audience. Today, these two monumental works are read by every serious student and practitioner of acoustics. However in 1900, Helmholtz was dead and Rayleigh was spending more of his time on non-acoustical research; Lindsay refers to "a rather stagnant state of acoustics during the first two decades of the twentieth century...academically, acoustics became, by and large, an uninteresting subject." It was, as Beyer notes, "a time when the field as a whole had to wait while the supporting disciplines of electricity and electrical devices moved forward, so that virtually all of acoustics could be redone with new, more powerful and more accurate equipment."

Beyer goes on to point out that in the first part of the 20th century, the various subbranches of acoustics began to sort themselves out. "The days in which a single individual might write papers on speech, hearing, music, electroacoustics, and acoustical propagation, generally, were drawing to a close." What a pity! How much more prestigious a science acoustics would be at the start of the 21st century if it had maintained its unity! Thank goodness the Acoustical Society (founded in 1929) has only one journal, one *Echoes* newsletter. Perhaps a measure of this unity will be re-established in the 21st century. Perhaps we need another Lord Rayleigh to emerge!

To the Editor

The day modern science was born

This responds both to your article "Sound and Light" and the item "Wanted: Reporters" in the Summer 1999 *Echoes*. Although not trained in the field of acoustics, I have had a long time interest in the unbelievable inter-relationship of sound and light, and your article was very revealing. I have been an associate member of ASA for a number of years.

It is a fact that the motion of sound played a critical role in the 20th Century development of "modern science." However, the way this happened may not be generally realized. It involves a mutual relationship of light with sound.

During the centuries prior to Isaac Newton, knowledge of the way sound traveled by vibrations of the air or other matter gave mankind a realistic understanding of all types of wave actions and other motions. Historically, it was Newton's *Mechanics*, resulting from his laws of motion developed in the 17th Century, that opened the gates for the oncoming Industrial Revolution. However, one of the early problems was the motion of light, and it was here that sound took the lead. It was concluded by scientists that light, like sound, had to have a medium through which it traveled. Although such a medium was impossible to detect, its existence was scientifically accepted and thus the "luminiferous ether" was established as the vehicle for the motion of light. Even James C. Maxwell, who in the 1860s established that light was an electromagnetic process, could not believe that light could travel "on its own" without the ether as its carrier. It was the experiments of Michelson and Morley during the final years of the 19th Century that led to the death of the assumed ether.

As the 20th Century dawned, electrodynamics became the central driving force of nature. Light became the key behind the quantum principles, and the absorption and emission of light photons by atoms led to further knowledge of atomic processes. Then came the world shaking theory that energy was the product of the mass of matter and the square of the velocity of light. This meant that the centuries-long partnership in the way light and sound traveled had finally come to an end. It also meant that modern science was born the day light was divorced from sound. But developments in the 20th Century have revealed an even more astonishing relationship of sound with light. Whereas in Newton's day light was seen to act like sound, 20th Century science has reversed that relationship and has shown that sound produces a wide range of effects exactly like light. Analysis of these remarkable effects is the subject of my Webpage "On the Electrodynamics of the Motion of Sound" at <community.webtv.net/jimtheresamcg/Ontheelectrodynamics>.

–James R. McGlathery, 2912 Mayflower St., Sarasota, FL 34231

ECHOES

Newsletter of the Acoustical Society of America

Provided as a benefit of membership to ASA members

The Acoustical Society of America was organized in 1929 to increase and diffuse the knowledge of acoustics and to promote its practical applications.

Echoes Editor .... Thomas Rossing
Graphic Design .... Jim Nelson
Printing .... Ram Offset
ASA Editor-in Chief .... Allan Pierce

Phone inquiries: 516-576-2360. Contributions should be sent to Thomas Rossing, Physics Dept., Northern Illinois University, Dekalb, IL 60115 <Rossing@physics.niu.edu>

We hear that...

- **Kenneth Stevens**, C. J. LeBel Professor of Engineering at M.I.T., has been named to receive the National Medal of Science for his research in speech sciences. Ken was president of ASA 1976-77 and received the Gold Medal in 1995. He will receive his medal on March 14 at the White House.
- **David Feit** has been appointed Treasurer of the ASA. The Search Committee was chaired by **Janet Weisenberger**.
- The Acoustical Society will co-sponsor a symposium entitled "Humans, Computers, and Speech" at the next meeting of the American Association for the Advancement of Science (AAAS), February 17-22 in Washington, DC. The symposium organizers are ASA members **Joanne Miller** and **Patti Price**. Scheduled presentations include: Human Language Technologies: Introduction; Automatic Speech Recognition: Better than Text? Automatic Speaker Recognition: Recent Progress, Current Progress and Future Trends; and Humanizing the Voice of the Machine. Further information can be found on <www.psych.neu.edu/miller/AAAS.html>.
- The Rayleigh Medal has been awarded to **George Maling, Jr.** by the Institute of Acoustics (UK) for "his outstanding contributions to to acoustics, in particular for his leadership in advancing and disseminating the discipline of noise control engineering." George is only the 6th American to receive this medal.
- **James West** and **Gerhard Sessler** were elected to the National Inventors Hall of Fame in recognition of their invention of the Foil Electret Microphone. Nearly 90% of all microphones used today are based on the foil electret principle.
- **Lawrence Crum** has been elected to a two-year term on the American Institute of Physics (AIP) Executive Committee. He will replace **Charles Schmid** who has served three two-year terms. Charles continues to serve on the AIP Governing Board and chairs AIP's Committee on Publishing Services.
- **William Lang** has retired from the presidency of I-INCE (International Institute of Noise Control Engineering) after serving 12 years, and he is succeeded in that office by **Tor Kihlman**.
- **Allan Pierce** has represented ASA on the International Union of Theoretical and Applied Mechanics (IUTAM) for the past 8 years. Ilene Busch-Vishniac is also a member of IUTAM, which is planning a meeting in Chicago in 2000 (see<www.tam.uiuc.edu/ICTAM2000>.
- An absolute pitch website has been established by **Richard Beddingfield** at the University of Michigan. The website at <www.provide.net/~bfield/abs_pitch.html> includes a bibliography, a list of famous people with absolute pitch, and links to other sites of interest.

From the Acoustical Society Foundation

As you might imagine, most notices from the Acoustical Society Foundation include pleas for funds, but not this one. As I write this, my thoughts are on the Thanksgiving holiday, so I will write a message of thanksgiving rather than solicitation. In its initial two years of active fund-raising, the Foundation has received over $300,000 in endowment gifts, with another $100,000 of pledges earmarked for contribution. Over 800 members of the Acoustical Society have contributed so far, and the spirit of thanksgiving extends internationally. Outside the US, contributions from Japan lead the way in terms of total giving and numbers of donors, followed by India, France, England, Canada, Germany, Taiwan, the Netherlands, Sweden, Brazil, Korea, China, Australia, Austria and New Zealand. Special thanks go to Paul Ostergaard, who was the major force behind the establishment of the Foundation and Leo and Gabriella Beranek, who launched the Foundation with a cash contribution of $50,000.

For more information on ways to share in the Foundation's goals and mechanisms for making donations that allow you to give while receiving, please contact Dr. Bob Frisina at 716-275-8130 or <asf@q.ent.rochester.edu>. Thank you.

–Bob Frisina

The ABCs of Acoustics

By Eric E. Ungar

*In **B**UILDINGS where we have employment,*
Or want to sleep or have enjoyment,
We need to stop intruding noise
From streets, TVs, and neighbors' toys,
From footfall impacts, other shocks,
Most anything that squeaks or knocks.

One person's music is another person's noise. It all depends on what we want to hear. Achievement of the desired acoustical environment in a room involves providing envelope structures that block noise intrusion from adjacent areas and adding acoustical absorption to avoid the build-up of noise that get through the envelope.

In addition to dealing with audible "air-borne" noise in adjacent areas, one also needs to address "structure-borne noise" – that is, noise that results from mechanical vibrations of the envelope structures. The walls, floor and ceiling of a room tend to act somewhat like loudspeaker membranes whose vibrations in the audio frequency range radiate sound. Structurally radiated noise in rooms may result from people walking or chair scraping upstairs and from vibrating equipment (refrigerator compressors, unisolated plumbing or the legs of pianos, for example) in contact the walls or floors.

What can you do to deal with noise from the neighbors? Ask them to avoid annoying activities at time when you don't want to hear them. Get them to install thick rugs or, better yet, a floating floor. Get vibrating equipment isolated. Build an isolated ceiling and secondary walls, so that you in effect have an isolated room within a room. Start living with permanent earplugs. Or, move elsewhere.

***C**RITERIA for floor vibration*
Or sound (that is, air oscillation)
Depend on what is really needed;
Intended usage must be heeded.
If set too tight, there's undue cost;
if set too loose, there's function lost.

In the index of any book on acoustics or on noise and vibration control you will find a profusion of listings under criteria. You will find criteria for environmental noise from aircraft and surface vehicles, for the prevention of hearing damage in industrial settings, for acceptable conditions in dwellings and offices, for efficient speech communication, for good listening conditions in classrooms and auditoriums. Also for acceptable vibration environments in buildings, surface vehicles and ships (sea-sickness effects are considered in standards being developed), for vibrations exerted on workers' hands and arms by machine tools, and for evaluation of the quality of rotating machinery. I apologize if I have omitted your favorite among the many other criteria that are available.

Many criteria that have been developed on the basis of extensive studies have gained broad acceptance, have been set forth in international and national standards, have been the basis of ordinances and regulations and have been cited in cases involving litigation. But how firm are these criteria and standards? Standards are meant to represent the consensus of experts, and they do – to the extent that the experts participating in development of the standards can agree. Unfortunately, the number of specialists involved in this development process typically is small, some may have limited ranges of interest and concern and some may have certain prejudices. Therefore, standards tend to reflect only the small amount of information on which the participants in the development process can agree. And even then, the consensus is not always one hundred percent. Some standards only address how measurements should be made, leaving criteria – the (usually controversial) magnitudes against which to judge the measured values – to appendixes that are not official parts of the standard.

Some criteria, for example those limiting the exposures of sensitive equipment, are set forth by the equipment suppliers. These criteria often are more stringent than necessary, perhaps because the sensitivity of the equipment is not well known or – as a suspicious person may feel – to give the supplier the opportunity to blame the noise and vibration environment for the occasional less then optimal performance of his equipment.

Equipment criteria often are written by non-specialists in acoustics and vibrations. This has lead to problems with inappropriately specified noise spectrum weightings, with confusion between vibratory displacements and acceleration, and with omission of measurement duration and bandwidth requirements, among others. I have spent much time explaining to suppliers of optical equipment that relative displacements of the optical components are important, and not the absolute vibratory displacements of the equipment's support points. And I have often tried to convince clients that one cannot limit the displacement amplitudes of buildings to very small values in a range of frequencies that extends down to zero, relying on the argument the moon induces tidal motions in the earth much as it does in the oceans and we as yet don't have the technology to hold the moon still.

Reprinted with permission from Sound & Vibration, *September 1999. Eric's verse on the letter* **A** *appears in the Summer issue of* Echoes.

Echoes From Columbus

Lots of Music!

The Columbus ASA meeting was one of the most enjoyable meetings your old Editor can recall. One factor, of course, was all the fine music, much of it provided by faculty and students at Ohio State University, and we are largely indebted to James Pyne for arranging these musical offerings. The music got off to a great start with the tutorial on the art and science of music by Uwe Hansen and Jim Pyne, reached a crescendo with the memorable concert by the Ohio State University Marching Band, "The Pride of the Buckeyes." The tutorial included demonstrations by several faculty members and by the Ohio State University Chamber Orchestra. We were also treated to performance demonstrations by an African ensemble, a jazz group, and gospel music by the African American Music Chorale.

Dan Martin was appropriately honored by a pipe organ demonstration and memorial recital in the First Congregational Church as well as a technical session. Gabriel Weinreich gave a memorable lecture on the History of Musical Acoustics, and of course there were several technical sessions on various musical subjects, including modeling and synthesis of musical instruments. Even the grand piano in the hotel lobby became part of the musical show as several ASA members sat down and played favorite pieces for passersby. The 1150 people who attended the Columbus meeting were fortunate to hear so much music!

Physics professor Gabriel Weinreich, University of Michigan, lectures on the History of Musical Acoustics

Synthetic Orchestra

by Dick Campbell

The special session at Columbus on Integration of Synthetic Musical Instruments with Acoustic Environments (2pAA) that K. Anthony Hoover and I organized had its genesis in several conversations I had with Bill Hartmann. We are both working in this area, and we felt the research in this field is gaining momentum within a broad spectrum of applications where synthetic music either has already entered (music theater, sound for film and television, advertising) or is knocking at the door (grand opera, solo accompaniment, home entertainment).

Participants at this session, which drew a standing-room-only crowd, reported on an astonishing variety of research which, one way or the other, fit the scope of the session title and led to a better understanding of the technical problems associated with synthetic music generation. My opening remark that "we really love live musicians" elicited nervous laughter from the audience. After the session I detected a buzz in the hallway which revealed a variety of reactions, from "some of the papers were technically inappropriate" to "why do we want to pursue this direction and adversely affect the lives of real musicians?"

The purpose of this short article is to attempt to clear the air and to open a dialog where differing viewpoints on this subject can be expressed. I personally feel that this is important because I will admit to a certain discomfort about the rapidly improving quality of synthetic music and its impact on the livelihood of musicians.

For several decades, acoustics researchers have attempted to emulate real musical instruments. There is a substantial body of knowledge on the physics of the instruments, how musicians use them, and myriad minute spectral and dynamic details of the sounds they make. In spite of this, it has been an uphill battle to achieve convincing sonic emulation by purely electrical means. In my memory, organ pipes succumbed first, followed by brass instruments. Then piano sounds became quite convincing when played through adequate speaker systems. In the midst of this appeared the Musical Instrument Digital Interface (MIDI) standard. The current crop of MIDI keyboard synthesizers delivers some remarkably authentic sounds, and for music theatre, seems to be widely accepted for live performance.

Then came the application of digital signal processing (DSP) to recorded sound fragments sampled from real musical instruments. DSP has enveloped every aspect of electroacoustics and has opened the floodgates for dramatic improvements in synthetic music emulation. One can argue that it is not emulation all when the real thing is merely played back to the listener. However, the samples themselves and the methodology of conditioning them and hooking them together into a musical piece are so strongly coupled that it is their union which makes the technology, not any one of them alone.

Along with this came the hardware and software tools for manipulating the samples. Careful selection, a time-consuming process, can lead to astounding results. For example, the first violin part may be studied for phrasing so that up-bow samples and down-bow samples can be correctly used for individual notes. I remember one project where we went through 18 different cymbal crashes before the composer happily selected one.

Many disciplines are involved: musical acoustics, musical interpretation, music, psychoacoustics, recording techniques, DSP, MIDI technology, sampling synthesizers, storage technology, electroacoustics, and architectural acoustics. When research in this area is presented at a scientific meeting, it is reasonable to expect technical papers to be submitted from any of these disciplines. If the subject matter of a paper contributes in any way to a better understanding and

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Acoustics in the News

Editor's note: While a quantitative study would be difficult, it certainly seems to me that acoustics is becoming an increasingly popular subject in national and local newspapers. A large proportion of the newspaper stories that come to my attention (thanks again to the folks who regularly send them to me!) are based on papers presented at ASA meetings. This is due, in large part, to the authors who submit lay-language versions of their papers and to Ben Stein and the staff at the AI Public Information office who solicit these papers and assemble them into a very attractive Online Press Room.

Sometimes the ASA paper is referenced in these stories; sometimes it is not. I guess we shouldn't be overly concerned as long as acoustics is being placed before the general public. Attendees at ASA meetings will be pleased that "they heard it first." It is of course interesting (and sometimes amusing) to note the mix of acoustics papers that are picked up by the media. A former White House press correspondent reminded us that media people are basically in the "entertainment" business (*Echoes,* Winter 1998). We can't always predict what subjects will be of interest to reporters, so the best practice is probably to supply plenty of good scientific material for the media, and to hope that they will pick up and use some of our best papers.

• The ear-catching demonstration done by William Hartmann at the Columbus ASA meeting, in connection with his paper "Local performance recording and reproduction: Application to a string quartet" was picked up by *New York Times* reporter James Glanz, who wrote a story for the November 16 issue. On two channels of an eight-channel digital recording, Hartmann managed to isolate the sounds of the first violin during a performance. He did the same with the second violin, the viola and the cello. In replaying the quartet, he gave each pair of channels its own speaker, built to have sound radiation patterns broadly similar to those of the stringed instrument, and he arranged the speakers on the floor just as the musicians originally sat. The result was seven minutes of chamber music in which the audio image of the players was vastly superior to two-channel stereo.

Hartmann began by recording each instrument with two contact microphones, one near the *f*-hole and the other near the bridge. He experimented with different mixes of these pairs of digital recordings that made it sound as if the right tones were coming from the right places. In order to do that, he used loudspeakers with two woofer-tweeter pairs on the front and one on the back. On the front, one woofer-tweeter pair transmitted sound collected mostly from an instrument's bridge and the other pair played sound recorded from the *f*-hole. The back pair transmitted the *f*-hole channel with some of the higher frequencies filtered out, since more low frequencies tend to be radiated backward in a real instrument. Four complete loudspeakers were arranged like the players in a string quartet. Leo Beranek was quoted as commenting, "It was so convincing. You moved around and the instruments seemed to be coming from a live group."

• An article in the December 25 issue of *New Scientist* by Kathryn Brown picked up on a paper by Larry Crum, Hugh Pumphrey, Ronald Roy, and Andrea Prosperetti on the underwater sounds produced by impacting snowflakes (*J. Acoust. Soc. Am.,* October 1999). Brown's article is aptly entitled "White Noise." "Think of snowflakes drifting quietly past your window, or the thick fresh snowfall that blankets the land and deadens every sound. But scientists have discovered that when a snowflake lands on water, it makes an alarming noise, radiating an underwater screech at frequencies far too high for humans to hear."

The article goes back to recordings of underwater sound made by falling rain, hail, and snow of a lake made by Joseph Scrimger some 15 years ago. Each snowflake made a faint "plink" as it hit the water and then broke into a "scream." Crum and his colleagues recognized the resemblance of this unusual sound to the sound of air bubbles formed when raindrops impact a water surface. They concluded that the radiat-

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Echoes From Columbus

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represents good research, why turn it away?

The image of a conservatory without students is not a pleasant one. I do not for a moment think that an audience will ever gather to hear a bunch of loudspeakers, scattered about a stage, play Beethoven's 9th symphony. Even though we now possess truly excellent orchestral samples and we can control dynamics and tempo in real time, the very thought of such a concert is repugnant, and we certainly want the conservatories and their students to continue doing their thing.

A tangential force accelerating the acceptance of this technology is the lament of music theatre, ballet and opera managers that the *orchestra* is their biggest problem. Unavailability of qualified musicians and onerous union rules are negative attributes, not to mention hot, crowded orchestra pits with disagreeable acoustics and visibility. This makes music theatre, ballet, and opera viable targets for this technology. The audience's attention is drawn to the action on the stage, the lighting, and the costumes, while the orchestra is largely hidden from them. Producers of touring shows are strongly attracted to cutting the pit orchestra as much as possible. At a demonstration of a synthetic pit orchestra in the theatre of a conservatory, the chair of the opera department smiled and said, "We are always looking for alternatives."

The technology for providing an alternative has, conveniently, evolved at the right time, and the breadth of disciplines within the ASA includes all of it. Prepare yourselves: Tony Hoover and I have scheduled a similar session for the Newport Beach ASA meeting.

Scanning the Journals

by Thomas D. Rossing

• In congenitally deaf cats, the **central auditory system** is deprived of acoustic input because of degeneration of the organ of Corti before the onset of hearing. Primary auditory afferents survive and can be stimulated electrically. By means of an introacoclear implant and an accompanying sound processor, congenitally deaf kittens were exposed to sounds and conditioned to respond to tones, reports a paper in the 10 September issue of *Science* by a group from the Physiologisches Institut in Frankfurt. After months of exposure to meaningful stimuli, the cortical activity in chronically implanted cats produced field potentials of higher amplitudes, expanded in area, developed long latency responses indicative of intracortical information processing, and showed more synaptic efficacy than in naïve, unstimulated deaf cats. The activity established by auditory experience resembles activity in hearing animals, the researchers found.

In the same issue of *Science*, Josef Rauschecker comments on the above research. He points out that although changes in the mapping of the body surface onto the brain's somatosensory cortex have been reported in response to peripheral injury or enhanced experience, there is relatively less direct evidence for such plastic changes in the auditory cortex. He predicts that animal studies using multichannel devices to stimulate the central auditory system, combined with neuroimaging in humans, should help to determine the temporal and spatial constraints of plastic reorganization of the auditory cortex after cochlear implant surgery.

• **Multi-bubble sonoluminescence** from excited states of metal atoms has been used as a spectroscopic probe of temperatures inside cavitating bubbles, according to a paper in the 21 October issue of *Nature* by McNamara, Didenko and Suslick. The intense atomic emission allows the changing of properties of the gas-vapor mixture within the bubble, and thus varying the effective emission temperature for multi-bubble sonoluminescence from 5100 to 2300 K.

The concentration of energy during implosive collapse of a bubble is enormous; the energy of an emitted photon can exceed the energy density of the sound filed by about twelve orders of magnitude, and it has long been predicted that the interior bubble temperature reaches thousands of kelvins during collapse. However, experimental measurements of conditions inside cavitating bubbles are scarce, and there have been no previous studies of interior temperature as a function of experimental parameters. Although these studies show that the observed emission temperature within imploding cavitation bubbles depends on both the polytropic ratio and the thermal conductivity of the bubble contents, the processes occurring within the bubble are more complex than can be described by the simple physics of compressional heating. A cavitation bubble functions as a small chemical reactor, and so the identity of the bubble contents will change during bubble collapse.

• The Composer gas composition controller from Leybold Inficon uses a Helmholtz resonant chamber with separate modules for stimulating and measuring sound intensity on opposite ends, thus enabling the **speed of sound in a gas mixture** to be determined, according to a note in the July issue of *R&D Magazine*. The speed of sound in an ideal gas is determined by the temperature, specific heat ratio, and molecular weight. In a gas mixture, these quantities are calculated as harmonic and standard averages, respectively. Acoustic gas measurement is highly stable, has no parts that wear out, and may be easily calibrated.

• Spotted 150 years ago on the water of a canal and now routinely generated in light-carrying fibers, the solitary, long-lasting waves called **solitons** have now been seen in yet another medium: sound. In the 15 November issue of *Physical Review Letters*, a team of researchers at the University of Osaka describes how they produced acoustic solitons by altering the propagation of sound through an air-filled tube. Nobumasa Sugimoto and his colleagues grafted 148 so-called Helmholtz resonators onto a steel tube 7.4 meters long and 8 centimeters in diameter. They sent sound pulses though the tube and tracked how the sound propagated. The pulses kept their smooth profile without forming shock waves. Furthermore, the Helmholtz resonators apparently altered the sound speed depending on frequency, creating the right conditions for the acoustic solitary waves. Sugimoto and collaborators at Sanyo Electric are exploring potential applications in acoustic compressors, heat engines, and even heat pumps.

• A contributed paper on "The use of neural networks to classify **echolocation calls of bats**" at the Columbus ASA meeting by Stephen Burnett and Mitchell Masters is reported in the 19 November issue of *Science*. A self-organizing map (SOM) neural network was successfully used to estimate the number of bats that produced the set of calls on the basis of the variables describing the calls. Results suggest that this approach may yield a reasonable estimate of the number of bats in the sample even when *a priori* information is lacking. Burnett hopes eventually to use the device in the wild to see if bats recognize each other by voice.

• "**Time-Reversed Acoustics**" is the subject of an interesting article by Mathias Fink in the November issue of *Scientific American*. He begins by describing an array of microphones and loudspeakers in his Waves and Acoustics Laboratory at Denis Diderot University in Paris. If you stand in front of this array and speak into it, anything you say comes back at you, but played in reverse. Your "hello" echoes–almost instantaneously–as "olleh." Instead of spreading through the room, the sound of the "olleh" converges onto your mouth almost as if time itself had been reverse. The array is acting as a "time-reversal mirror."

Each microphone in the time-reversal mirror detects the acoustic wave that arrives at its location and passes the ongoing signal to a computer that stores the data. When the last of the "hello" dies down, the computer reverses each microphone's signal and plays it back though the corresponding loudspeaker in exact synchrony with the other reversed signals. What emerges from the array of speakers, according to Fink, is a close approximation to the final wave, now traveling in reverse, which propagates across the room, retracing the path of the original "hello" back to the speaker's mouth. Each microphone/loudspeaker pair can be combined into a single device, such as a piezoelectric transducer, which converts sound into a voltage when the wave passes, and vibrates like a loudspeaker when a voltage is applied to it.

For time-reversed acoustics to work, the sound wave must propagate without losing too much energy to heat. This is analogous to having very little friction in a mechanics experiment. Reversing the trajectories of balls on a pool table is impractical, for example, because there is not a way to make the balls speed up correctly in the time reverse of being slowed by friction. Time-reversal mirrors have a wide range of applications, including destruction of tumors and kidney stones, detection of defects in metals, and long-distance communication and mine detection in the ocean.

• Isolated **outer hair cells in the cochlea** are able to overcome fluid forces with almost constant displacement amplitude and phase up to frequencies of at least 79 kHz, well above their place-frequency on the basilar membrane, according to a paper in the April issue of *Proc. National Academy of Science USA* by Gerhard Frank, Werner Hemmert, and Anthony Gummer, University of Tübingen, Germany. The high-frequency limit of the electromotility is inversely dependent on cell length. For frequencies up to 100 kHz, the electromotile response can be specified by an overdamped second-order resonant system, which suggests that the limiting factor for frequencies up to 100 kHz is not the speed of the motor but damping and inertia. The hair cells used in the experiments reported in this paper were from the cochleae of guinea pigs.

• A model of three-dimensional **shear wave velocity** variations in the Earth's mantle reveals a tilted low velocity anomaly extending from the core-mantle boundary region beneath the southeastern Atlantic Ocean into the upper mantle beneath eastern Africa, according to a paper in the 3 December issue of *Science*. This anomaly suggests that Cenozoic flood basalt volcanism in the Afar region and active rifting beneath the East African Rift are linked to an extensive thermal anomaly at the core-mantle boundary more than 45 degrees away. In contrast, a low velocity anomaly beneath Iceland is confined to the upper mantle. This is an example of how tomographic models of three-dimensional seismic velocity variations continue to improve our understanding of the structure of flow in the Earth's mantle, according to the authors at CalTech and Oxford.

• Paddlefish use **stochastic resonance** to detect weak noise signals made by swarms of plankton and detect distant prey, according to a paper in the 18 November issue of *Nature*. Stochastic resonance, originally proposed by physicists in the early 1980s in connection with global climate modeling, is an effect by which the ability of certain nonlinear systems to detect and transmit weak signals can be enhanced by the presence of a certain level of noise. This effect was limited to physical systems until 1991, when it was discovered in sensory neurons [*Physical Review Letters* **67**, 656 (1991)]. The challenge now is to see whether other animals and biological systems use similar effects. One likely candidate is the auditory system. The sensitivity of cochlear hair cells in frogs appears to be enhanced by the natural Brownian motion of these hair cells, and the random fluctuations associated with these may be the key to transduction of weak signals in the cochlea [*Nature Neurosci* **1**, 384 (1998)].

• **Animal communication** was a hot topic when 400 researchers from 39 countries gathered in Bangalore, India for the 26th annual Ethological Conference, August 2-9, according to a report in the 3 September issue of *Science*. Some of the most vocal discussions explored how animals speak their minds, from calling in grasshoppers to croaking in frogs. Although widely different in pitch, duration, and rhythm, the croaks of a bullfrog chorus, the relentless drone of katydids, and the calls of grasshoppers have the same purpose: males are passionately trying to attract mates. In both frogs and insects, males stay still and lure females with rhythmic calls. Females are most likely to respond to loud calls, which presumably indicate that the male is nearby and perhaps that he is vigorous. When female frogs or grasshoppers hear calls of roughly similar loudness, they listen and orient only to the male that calls first, a so-called precedence effect. From the male perspective, of course, this means that every male in the crowd wants to be first.

Although most research on frog communication has concentrated on the louder males, recent studies have found that females respond to the males with feeble calls that indicate their readiness to mate. According to herpetologist Debjani Roy, the female tree frog was observed to emerge and sit near the male that called first, which was always among the largest males. When the male stopped calling, the female gave feeble croaks, apparently indicating that she had made her choice and was ready to mate. The male then began calling again, even more loudly. Finally they mated.

• The February issue of *Applied Acoustics* is a special issue on **military acoustics**. One of the papers is by Charles Ross, who wrote the lead article on "Outdoor Sound Propagation in the U.S. Civil War" in the Winter 1999 issue of *Echoes*. This paper in *Applied Acoustics* by the same title, adds a discussion of the battle of Perryville (Kentucky). The lead paper "A concise history of acoustics in warfare" by Michael Namorato discusses the role of acoustics in warfare from the Battle of Jericho to the Gulf War with a special emphasis on underwater acoustics. The third paper, "Passive sensing with acoustics on the battlefield" by Gunnar Becker and Alwin Güdesen, discusses physical phenomena and boundary conditions governing the use of acoustics sensors in military systems. One of the most common military applications of acoustics is the detection and location of artillery. Strong blasts due to the exploding charge in the gun, the shock wave of supersonic shot, and the impact of the ammunition on the target or ground are three acoustic events of relevance for tactical reasons.

• The **real father of the Internet** according to a note in the 3 September issue of *Science*, was Joseph C. R. Licklider, acoustician, psychologist and computer scientist, and president of ASA in 1958. Licklider came to DARPA–then called ARPA–in 1962 after stints at Harvard University and Bolt, Beranek and Newman. Fascinated by the social and technological implications of networked computer systems, he accepted the task of directing the agency's information processing program, which he reshaped by moving money to innovative university labs. Licklider commented that he was trying to develop an "Intergalactic Network" which was later shortened to "Internet." By the time he left DARPA in 1960, his views had become the compass for the agency's work in the field.

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ed acoustic waveform from a snowflake impact with water is due to the entrainment of a gas bubble into liquid, and the subsequent oscillation of this bubble as it establishes its equilibrium state.

- Peter Nagy and Zhongyu Yan at the University of Cincinnati have combined laser heating and ultrasonic inspection to improve detection of metal fatigue cracks by a factor of 10 over previous methods, according to a story in the 26 November *Cincinnati Inquirer.* The story refers to paper 2pSA8 " Thermoelastic effects on surface acoustic wave propagation" at the ASA Columbus meeting. In their studies, a long-duration infrared laser pulse was used to irradiate a series of aluminum and titanium specimens with fatigue cracks of known sizes between 0.5 and 1.0 mm.
- Science writer Kathryn Brown picked up on an ASA Columbus paper by Diana Deutsch in her story on absolute pitch in the December 4 issue of *New Scientist*. "Perfect pitch is a rare talent possessed solely by the likes of Beethoven, Frank Sinatra and Ella Fitzgerald, right? Wrong, it's turning up all over the place," the story tells us. Although some estimates have suggested that fewer than 1 in 2000 people possess it, a growing number of studies, from speech experiments to brain scans, are now suggesting that a knack for absolute pitch may be far more common than previously thought. In her paper "Absolute pitch is demonstrated in speakers of tone languages," Deutsch found that Vietnamese and Mandarin speakers repeat words on different days with pitches within a semitone, demonstrating that tone language speakers are able to refer to a remarkably precise and stable absolute pitch template in producing words.
- "Fix Speech Problems Early, Experts Now Urge" is the title of a Health & Fitness column in the *New York Times*, November 30. Until recently, most pediatricians have advised parents to let young children learn to speak at their own pace; after all Albert Einstein, according to legend, was slow in learning to speak. Now that is changing. Today, parents are generally told to look for signs of delay early, even in a baby's first year and to seek help. Silence may be a sign of hearing loss or a neurological disorder. Studies have shown that children with speech impairments are more likely to have reading and social problems later on.

One of the authorities quoted in the column is our own Pat Kuhl, professor of speech and hearing sciences at the University of Washington and ASA president. "In this past decade, we have learned a tremendous amount about how much learning goes on in this early period, and language is a great example. Now we know that while babies are quiet, there is a tremendous amount going on in the brain." Twins are particularly interesting because they tend to speak later than average, but British pediatrician Elizabeth Bryan points out that the delay is probably environmental, not genetic. Parents tend to focus their gaze somewhere between the children, inadvertently withholding eye contact which can be crucial in the development of speech. Furthermore, twins tend to have the worst language teachers: they talk to each other, so their model for language is someone who talks as badly as they do.

- Passengers traveling in first class and business class on some American Airlines flights now have access to noise canceling headsets designed by the Bose Corporation. These headsets use active noise control to counteract engine and wind noise. According to the story in *AV Video Multimedia Producer*, Amar Bose began formulating the concept for the first Acoustic Noise Canceling headset following a disappointing experience with a passenger headphone during a commercial flight from Europe in 1979. The headsets also incorporate Bose's proprietary TriPort technology, which uses external ports to vent the earcups at certain frequencies, enlarging the air space behind the speaker without actually increasing the earcup's size for better active noise reduction.
- With ear infection the most common childhood infection after the common cold, millions of parents face a dilemma: should they have tubes surgically inserted in their child's ears to reduce the risk of this infection, or should they simply treat each infection as it occurs and wait for the child to outgrow the problem? This dilemma is discussed in a column in the January 11 issue of *The New York Times.* Ear tubes are inserted through a hole made in eardrum. The benefits of ear tubes are short-lived; they are helpful only as long as they stay in place, during which time the child's ears should be kept out of water.

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