First Person

A Career Considered: From Audiology to Neuroscience

By Robert Frisina Sr., PhD

Audiology is a young field—the first U.S. university audiology course was offered by Raymond Carhart, PhD, at Northwestern University in 1946. In that short time, though, audiology has gone through several scientific and technological revolutions that have greatly improved the diagnosis and treatment of hearing-related disorders.

As a former doctoral student of Dr. Carhart's at Northwestern, Bob Frisina Sr. has not only had firsthand experience in these revolutions, but also served as a leader on several fronts, from early deaf education to recent research in presbycusis. Different from a typical audiologist, Bob Sr. has been instrumental in promoting audiological education and research at a global level.

When I recently met Bob Sr., who is now 89, in South Florida, he still impressed me with his intellectual curiosity, wisdom, and sharp thinking. I invited him to write this article so that we can celebrate and learn from his inspiring legacy.—**Fan-Gang Zeng, PhD, *HJ* Editorial Advisory Board Chair**

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My knowledge of deafness began in the fall of 1947, when I was introduced to deaf children, teachers, and staff at the Missouri School for the Deaf. At the time, I was pursuing a Bachelor of Arts in Biology from Westminster College in Fulton, MO, where the previous year Winston Churchill had given his "Iron Curtain" speech acknowledging the reality of the Cold War with the Soviet Union—certainly a focal point in history and for my own development.

It was troubling to learn of the destructive influence early hearing loss could have on language development in an otherwise healthy brain. My interest in limited language acquisition in children led me to accept a scholarship to the Master's Degree program in Education of the Deaf at Gallaudet College in Washington, D.C. I had the wonderful opportunity to follow this program with two years of teaching deaf youngsters, which gave me both knowledge and a real affection for these children.

With this background, I pursued Northwestern's doctoral program in audiology and psychology—my specialty was differential diagnosis of speech and language disorders in children—under the tutelage of Drs. Helmer Myklebust (infants and children) and Raymond Carhart (adults). One of my favorite classmates was an up-and-coming research audiologist, a young Jim Jerger.

DR. FRISINA GOES TO WASHINGTON

In my second year as an assistant professor at Northwestern, a call came from Gallaudet College President Leonard Elstad to establish the program in audiology and speech pathology at the institution, which was then becoming an accredited college.

Our first task at Gallaudet was to develop quantitative baseline communication data on each student. Performance on three measures—hearing, speech reading, and speech production—was translated using a one- through five-point scale. This three-part performance profile became a rich database we used to organize classes in auditory training, speech reading, and speech production. Health histories were obtained to help determine etiology and age at onset.

From this work came the recognition that approximately one-third of the student population's deafness resulted from meningitis, which meant that both the cochlear and vestibular systems were seriously damaged, rendering acoustic hearing aids of limited usefulness.

As a group, these students were poor speech readers. Given their postlingual age at onset, though, they had experienced

Dr. Frisina was granted a visa to visit the People's Republic of China in January 1978.

normal speech and language development to some extent. The combination of profound deafness, intelligible speech, and sophisticated language skills but relatively poor speechreading skills made sign language critical for this segment of the deaf population. They were often leaders in the deaf community.

Soon after I relocated to Washington, D.C., area otologists began to call upon our audiological services at Gallaudet. That activity prompted us to move forward with our plan to offer much-needed multidisciplinary diagnostic care for infants and children with hearing loss and their parents, fully implementing those services within several months.

A STINT WITH THE NAVY

As a guest at a reception for Navy physicians in 1956, I was introduced to Capt. Ashton Graybiel, head of the physiology laboratory at Naval Air Station Pensacola. He was studying the issue of astronauts' orientation in space and having trouble finding adults with dead labyrinths to serve as research participants.

Teasingly, I asked how he would like dozens of ideal control subjects—young adults with good communication skills. I was alluding to the post-meningitis students at Gallaudet.

Any skepticism about my veracity disappeared suddenly with the surprise launch of Sputnik by the Soviets in 1957. By then we had completed communication profiles and health histories on all Gallaudet students, from which we identified a pool of 104 probable candidates for Capt. Graybiel's research project.

His team then selected 16 men who volunteered to participate in a multiyear series of behavioral measures in response to centrifuge, rotating platforms, the KC-135 airplane simulation of weightlessness, and even a wild October ride on a New England fishing boat. In contrast to the normal-hearing astronauts in training, none of the deaf subjects experienced disorientation, nausea, or motion sickness.

FAST FLIGHT TO HONG KONG

As audiology and speech–language pathology were flourishing at Gallaudet in 1962, the U.S. Department of State, on behalf of the United Nations Educational, Scientific, and Cultural Organization (UNESCO), was seeking a so-called UNESCO expert to advise the overburdened Hong Kong government on the management of deafness. After a series of personal and professional discussions, I agreed to serve as the expert.

I landed on a small profile of reclaimed land at Hong Kong's airport. Squatters' huts ringed the island hillsides. Nightly reflections of beautiful lights on the shimmering water, complete with sampans, masked the realities of limited resources.

My plan was to absorb quickly the environment of children with hearing loss and simultaneously conduct a census of deaf and hard of hearing children and youth.

One unique feature of that trip was Hong Kong's Cantonese dialect. With the help of my interpreter, a speech–language pathologist trained in England, we assigned American alphabet hand positions to each of the Cantonese phonemes.

Using borrowed amplifiers, microphones, and headsets, we were able to demonstrate the speech and language development system with four hard of hearing children to a surprised audience of professional staff. I followed up by having two sound rooms and test equipment shipped to Hong Kong for use in the recommended diagnostic and hearing aid clinic, financed by the Hong Kong Jockey Club.

One of the fascinating spokes on our hub of research and development was the merging of microelectronic engineering with research audiology and hearing sciences.

My time in the region was a special experience for me, and I feel my visit was useful to them.

NORTH TO UPSTATE NEW YORK

Coincident with President Lyndon B. Johnson's Great Society initiatives in the mid-1960s, efforts seeking expanded post-secondary education and rehabilitation opportunities for deaf students were under way by professional and consumer organizations. Historically, 85 percent of deaf adults had been employed in unskilled or semiskilled jobs, oftentimes running printing presses, for example. College attendance was less than one percent.

These organizations' efforts culminated in the passage of U.S. Public Law 89-36, which authorized the establishment of the National Technical Institute for the Deaf (NTID).

The law required that NTID become part of an existing residential institution of higher education. Institutions were invited to submit applications, and they vied for the designation.

The first stop on Dr. Frisina's 1978 trip to the People's Republic of China was Beijing, where he and his tour group visited the Great Wall.

Eventually, the field of applicants was reduced to a short list of four for site visits.

In the end, Rochester Institute of Technology (RIT), with its long history in technical education and a new campus under construction, was selected in November 1966. The search for the founding director was completed in February 1967 with my acceptance as RIT vice president for NTID, at the request of RIT President Mark Ellingson.

The notion was that, if given a genuine opportunity, deaf students could achieve education and employment outcomes on a par with their hearing peers. This inspiration was further heightened by the idea that a successful, innovative NTID could transform educational practices and employment options, thereby enhancing the general welfare of deaf people everywhere. Achieving socioeconomic parity for deaf people remains NTID's enduring mission.

EAST MEETS WEST

As I was chairing the Institutional Advancement Commission at RIT, I was granted a visa to visit the People's Republic of China in January 1978. This visit occurred when relations with the United States were beginning to normalize, providing the rare opportunity to witness Mao's China.

The decadelong Cultural Revolution had ended, and Mao Zedong and his premier, Zhou Enlai, had died. Universities closed during the Cultural Revolution were scheduled to reopen in 1978.

Our visit started in Beijing and proceeded southward, terminating in Hong Kong 27 days later. When we got to Beijing, we were greeted with spotlighted, billboard-size photos of Vladimir Lenin and Mao, and then met the two national guides, one man and one woman, who accompanied our group for the entire period of our stay.

We later picked up one additional local guide at each of the major districts we visited—Beijing, Nanjing, Shanghai, and Guangzhou. We traveled by train from Beijing to Nanjing, but, for short intercommunity travel, we had an old, unheated Mercedes bus that required the radiator water to be drained every night because antifreeze was not readily available.

We were able to find one school that had a class of deaf students. There was a dusty audiometer no one knew how to use, and the class was engaged in oral recitation. I noticed one child moving her fingers. She was spelling phonemes à la Hong Kong sign language. It turned out that the teacher was a regular classroom teacher who knew nothing about deaf students.

In Shanghai, we found a group of deaf adults working in a meter manufacturing plant and communicating in sign language. You can imagine their excitement at simply meeting a Westerner, but one who could communicate in signs? They did not want me to leave.

AUDITORY NEUROSCIENCE AND MICROELECTRONICS

Meanwhile, my administrative work at RIT continued to grow into the 1980s, expanding to development, public relations, and admissions. The timing was coincident with my son Bob's acceptance of a postdoctoral position at the University of Rochester (UR) School of Medicine and Dentistry, followed by his appointment as assistant professor of otolaryngology and physiology in 1985.

The Global Center for Hearing and Speech Research was established at the University of South Florida in 2010 to carry out an auditory aging research grant, as well as other projects.

After my son was made associate chair for research two years later, we began to have serious conversations about blending the NTID research audiology experience with his interests in auditory neuroscience, leading to our establishment of the International Center for Hearing and Speech Research (ICHSR), a joint program between RIT and UR. Preliminary funding from a private foundation enabled me to resign from my RIT administrative role to become founding director of ICHSR in 1989.

One of the fascinating spokes on our hub of ICHSR research and development was the merging of microelectronic engineering with research audiology and hearing sciences. The former was spearheaded by Dr. Lynn Fuller, then director of microelectronic engineering at RIT, and the latter was superlatively represented by Dr. Joseph Walton, director of audiological research at UR.

These efforts resulted in the development of several patents for noise-suppression hearing aid chips, which eventually found their way into the marketplace in thousands of new hearing aids in the mid-1990s.

With the help of a five-year National Institutes of Health (NIH) K25 grant from the National Institute on Deafness and Other Communication Disorders, this merger of microelectronics and auditory neuroscience led more recently to much progress in microsystems drug delivery techniques for the inner ear (*IEEE Trans Biomed Eng* 2011;58[4]:943-948; *Hear Res* 2010;268[1-2]:2-11; *Ann Biomed Eng* 2013; 41[10]:2130-2142).

ADVANCING KNOWLEDGE OF PRESBYCUSIS

After discussions with program officers at NIH, particularly Dr. Andrew Monjan of the National Institute on Aging (NIA), I had the privilege in 1990 to help organize and lead a talented group of sensory researchers focused on advancing knowledge of the characteristics and neural bases of presbycusis. Our P01 team included audiologists, psychoacousticians, neuroscientists, biomedical engineers, and molecular biologists.

To foster further collaboration and clinical translation, I would like to mention some examples of our key findings and breakthroughs. These are illustrative and not intended to be all-inclusive of our team's numerous publications, invited talks, and press releases.

- We substantiated the notion that older adults with good hearing ability still have trouble with speech detection in background noise at suprathreshold levels (*Hear Res* 1997;106[1-2]: 95-104; *Speech Commun* 2006;48[6]:591-597). Through a series of multidisciplinary animal model studies with mice, we identified neural circuitry in the auditory brainstem underlying acoustical temporal processing that deteriorates with age, with deficits starting to occur in middle-aged animals (*J Assoc Res Otolaryngol* 2008;9[1]:90-101; *Hear Res* 2006;216-217:216-223; *Neurobiol Aging* 2011;32[1]: 168-178).
- The auditory efferent feedback system from the superior olivary complex to the hair cells of the cochlea has important roles in hearing and may be involved in the cochlear gain control needed to help separate speech or vocalizations from background noise for optimal complex sound perception. We discovered in human and animal model experiments that this system starts to decline in middle age (*Hear Res* 2005;209[1-2]: 60-67; *J Comp Neurol* 2007;503[5]:593-604; *J Acoust Soc Am* 2007;121[1]:EL29-EL34). In terms of mechanisms, it appears that changes in voltage-gated K+ channels may be involved in this age-linked decline of the olivocochlear auditory efferent system (*J Assoc Res Otolaryngol* 2007;8[2]: 280-293).
- We conducted the largest gene discovery study of the aging auditory system to date, utilizing Affymetrix gene chips and, in one experiment, probes for about 15,000 genes. A series of investigations revealed novel insights into gene pathways involved in presbycusis at both inner ear and auditory brainstem levels, including apoptosis (*Apoptosis* 2008;13[11]:1303-1321), immune responses and inflammation (*Open Access Bioinform* 2011;3:107-122), fluid balance (*Brain Res* 2009;1253:27-34), and key neurotransmitters of the auditory system (*Neurobiol Aging* 2007; 28[7]:1112-1123; *J Neurosci Methods* 2008;171[2]:279-287).
- Using a comprehensive battery of audiological tests and health history information in our human studies lab, we found that progesterone can have a negative influence on hearing in older women taking hormone replacement therapy (HRT), whereas estrogen does not (*Proc Natl Acad Sci U S A* 2006;103[38]:14246-14249). We found similar results in aging female CBA/CaJ mice (*Hear Res* 2009;252[1-2]:29-36; *Sem Hear* 2012;33[3]:231-241) and are continuing these mouse studies to uncover neural and molecular mechanisms and to see if the deleterious effects of progesterone progress, halt, or reverse themselves upon termination of HRT treatment.
- Further, we investigated relationships between medical

comorbidities and presbycusis. For example, we found that type 2 diabetes is associated with the progression of age-related hearing loss in humans (***Hear Res*** **2006;211[1-2]:103-113**) and CBA/CaJ mice (***Hear Res*** **2009;249[1-2]:44-53**). We also uncovered clinical connections between declining serum aldosterone levels and hearing abilities in old age (***Hear Res*** **2005;209[1-2]:10-18**).

- Using DNA samples from 687 older human subjects, we identified a role of the *GRM7* gene in presbycusis (***Hear Res*** **2012;294[1-2]:125-132**). *GRM7* makes a protein intimately involved in hair cell/auditory nerve fiber glutamate neurotransmission.
- Lastly, through creative mouse breeding, we developed a "Golden Ear" mouse that models those few lucky individuals, mostly women, who have good audibility in old age–i.e., good peripheral hearing–but still have an "old" brain, allowing the teasing out of peripheral versus central presbycusis mechanisms (***Neurobiol Aging*** **2011;32[9]:1716-1724**).

GOING GLOBAL AT USF

It has been quite fulfilling, both personally and professionally, to lead such a creative and productive group of hearing scientists in the longest post I have held in my entire career.

Funded by a number of five-year NIH awards and foundation grants, the ICHSR in Rochester flourished. In 2010, we established the Global Center for Hearing and Speech Research (GCHSR) at the University of South Florida (USF) to carry out our fourth NIH P01 award for auditory aging research, as well as other NIH and National Science Foundation (NSF) grants.

In the second year of the current P01 grant period, my son Bob succeeded me as principal investigator. The GCHSR at USF is a novel joint program between the Colleges of Engineering and of Behavioral & Community Sciences, in the Departments of Communication Sciences & Disorders and of Biomedical Engineering, and in the School of Aging Studies.

Adapting from audiology to administration to neuroscience demonstrated to me that problems are really opportunities in disguise. Happily, these opportunities have introduced me to many dear friends and led me to the cherished gift of working with a talented scientist and generous son.

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