Canadian Audiologist

The Official Publication of the Canadian Academy of Audiology

Ten Highlights from the History of Audiology: A Top-10 List of Events and Achievements in Audiology During the Last 75 years

Published September 2nd, 2019

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http://www.hearingreview.com/2019/04/ten-highlights-history-audiology/?ref=fr-title

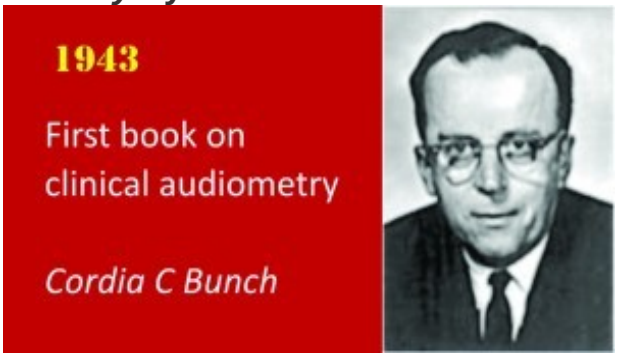
The measurement and management of hearing disorders has a long history. As early as the 4th century BC, Hippocrates wrote extensively on the causes of hearing disorders. Later, the Enlightenment brought a flurry of activity focused on tests to differentiate among the various causes and types of hearing loss. Throughout most of recorded history, however, the measurement and management of hearing loss remained the province of medical professionals.

Dr Jerger highlights 10 great events in our field's rich history, ranging from C.C. Bunch's early audiometric work to the establishment of the first AuD training program.

The modern era of audiology is only 75 years old. It began with a book on clinical audiometry by Cordia C. Bunch in 1943. Over the next seven decades audiology grew rapidly to its present strong position in the family of healthcare professions. Several signal milestones mark the progress of audiology over the past three quarters of a century. This article highlights 10 of the most important events that, in my opinion, have guided the direction of our profession since that seminal publication by Bunch. I have restricted the coverage to events impacting audiology in the United States and Canada. I also acknowledge that any such list is *highly subjective*. It would be relatively easy to come up with a dozen more events, and I invite readers to chime in, either via comments in the online version of this article or via email, about what you might include.

Event #1

1943: The Publication of *Clinical Audiometry* by C.C. Bunch



Cordia Bunch was a graduate student in psychology at the University of Iowa in 1919 when Carl Seashore, creator of the now famous Seashore Musical Aptitude Tests, convinced Bunch to construct a device to measure auditory thresholds across a broad frequency range. Bunch not only built the device but went on to test the patients of a local otolaryngologist, L.W. Dean. When Dean moved from Iowa City to St Louis, Bunch agreed to move with him and to continue the testing, now with an early Western

Electric 1A audiometer.

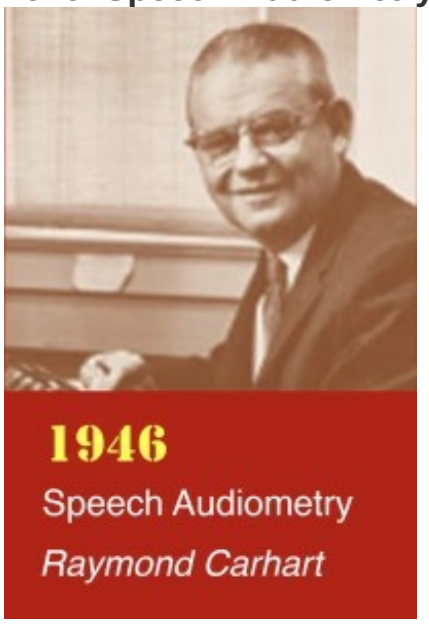
For the next 20 years Bunch gathered air-conduction audiograms on patients and wrote articles about them. His publications spanned an amazingly diverse subject matter. Here is only a partial list of the topics covered:
Use of the audiometer;

- Effect of age on audiometric thresholds;
- Importance of measuring thresholds at frequencies above the conventional audiometric range;
- Occupational and traumatic deafness;
- Progression of loss in otosclerosis;
- Deafness in aviators;
- Conservation of hearing in industry;
- Race and gender variations in hearing thresholds;
- Hearing aids;
- Otitis media;
- Calculating percentage of loss for medico-legal purposes;
- Effect of removal of one cerebral hemisphere, and
- Effect of absence of organ-of-Corti on the audiogram.

A truly impressive *oeuvre*! Bunch laid the foundation of audiology by vividly demonstrating the many contributions that an audiological specialist could offer to hearing-impaired persons.

Event #2:

1946: Speech Audiometry for Hearing Aid Selection

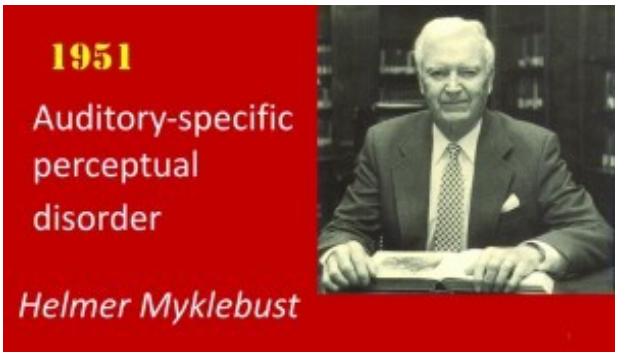


In 1943, in the midst of WWII, the Army assigned Captain Raymond Carhart to head the acoustic division at Deshon General Hospital in Butler, Penn. He was ordered to provide aural rehabilitation and to dispense hearing aids to army personnel coming home with hearing loss. Guidelines, however, did not exist.
As a trained speech scientist, Carhart looked beyond the technical engineering aspects of hearing aids, sidestepped the issue of selective amplification, and focused instead on how aids actually helped users in everyday speech communication. Using the spondee words and 50-item single-syllable PB words developed at the Harvard Psycho-Acoustic Laboratory to evaluate ground to aircraft radio systems, Carhart devised a method for evaluating how well the hearing aid user could understand speech: the spondee words to determine the speech reception threshold (SRT), and the PB lists to evaluate how well the user could understand single words presented well above the (SRT).
Bunch, in his book on clinical audiometry, had earlier suggested the need for some clinical measure of speech understanding but never carried the idea further. Carhart used his speech-oriented approach as he evaluated and, where needed, dispensed hearing aids to more than 16,000 returning veterans.
Carhart made many other contributions to our profession but the invention of speech audiometry remains his towering achievement.

Event #3

1951: Identifying Auditory-Specific Perceptual Disorder

The observations that producing and receiving language could be degraded by brain injury, the *aphasias*, had been analyzed and debated extensively by the end of the 19th Century. During WWI, however, the abundance of head wounds caused by various projectiles led Henry Head, a British neurologist, to study lower level perceptual disorders, the *agnosias*.



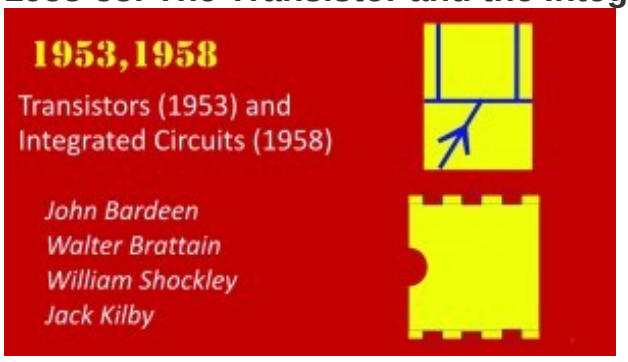
Helmer Myklebust, an American psychologist with a particular interest in hearing-impaired and deaf children, studied Head's published works closely. When he came to Northwestern University in the early 1950s, Myklebust set up a children's hearing clinic. Testing the hearing of young children was certainly primitive by today's standards, but he supplemented the extant audiological measures with various psychological analyses and with keen observation of the child's behavior.

Myklebust identified what might be expected in hearing-impaired and deaf children; in the process, however, he observed that there were other children, referred for possible deafness, who appeared to have difficulty processing auditory input in spite of relatively normal audiometric threshold levels. For these children Myklebust coined the term "auditory disorder." Eventually this morphed into the current term "auditory processing disorder" or "APD." Based on Head's work with head injury, Myklebust viewed the problem as a centrally-based auditory perceptual disorder.

Much of today's interest in auditory processing disorder, especially in children, can be traced to Myklebust's pioneering observations.

Event #4

1953-58: The Transistor and the Integrated Circuit



The invention of the transistor by John Bardeen, Walter Brattain, and William Shockley—and the subsequent creation of the integrated circuit by Jack Kilby—changed hearing aids substantially. Prior to these historic events miniature vacuum tubes provided electronic amplification. These tubes required considerable battery power; a 6-volt battery for the heating elements of the vacuum tubes and a 20-40 volt battery for their controlling grids. All of this was packed into a box about the size of a package of cigarettes, typically carried in a shirt pocket, or in a harness suspended from the neck. The amplifier box was connected to the ear via a long cord attached to a transducer mounted in a fully occluding earmold.

But the electrical power requirement of transistors was only a single 1.5-volt unit, and the space it occupied was much smaller than a single miniature vacuum tube.

These two reductions—battery capacity and physical dimensions—made possible an aid that could be fitted on the head or in the ear canal. All of this made actual binaural hearing aids a reality. The importance to the hearing aid user can scarcely be imagined.

Event #5

1962: The First Infant Screening Program

We can date the identification and treatment of hearing-impaired infants and young children into two eras: before Marion Downs and after Marion Downs. Before Marion Downs, there was a widespread philosophy that, since you could not actually test the hearing of children until at least age 3, intervention for children suspected of substantial hearing loss was potentially dangerous and should be avoided. But as early as 1959, Downs was fitting aids to children as young as 6 months with suspected severe losses. She was guided by the strong belief that, if you waited 3 years before intervening, you had forever lost the most important years of language learning.

In 1962, at the University of Colorado Health Sciences Center, she initiated the first infant screening program, designed to identify hearing loss at the earliest possible age. She based it on a series of systematic observations of the infant in a controlled listening environment—the first such program in the nation.

The importance of the earliest possible intervention for suspected hearing loss in infants and young children has been repeatedly confirmed over the next five decades and has since become standard orthodoxy in our profession. When Marion Downs died in 2014 at the age of 100 years, audiology lost one of its most beloved heroes.

Event #6

1964: The Birth of Immittance Audiometry

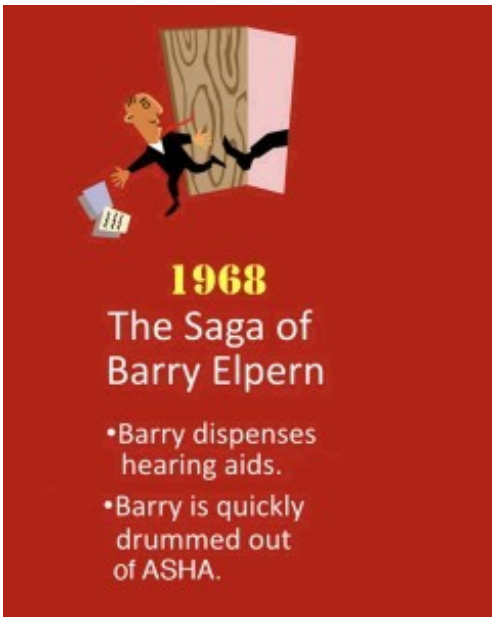
We can thank four of our Scandinavian colleagues for leading the world in the introduction of what is now called immittance audiometry. Two Danish investigators, Knud Terkildsen and K.A. Thomsen, and a German working in Denmark, Otto Metz, were responsible for the ultimate development of the first electro-mechanical impedance bridge by the Madsen Company in Copenhagen in the early 1960s. Metz built the first practical device for objective measurement of the middle-ear muscle reflexes; Terkildsen and Thomsen developed the Madsen Z0 60, and later, the Z0 70 impedance bridges, the first to make routine clinical measurements of middle-ear status possible. Terkildsen further gave the name “tympanometry” to the process of plotting immittance as a function of air pressure in the closed external ear canal. Gunnar Liden of Sweden later described the three basic tympanometric shapes. Together, tympanometry and the detection of middle-ear muscle reflexes, now collectively named “immittance audiometry,” have had a profound influence on diagnostic audiometry for many years.

Event #7

1968: The Saga of Barry Elpern

Barry Elpern practiced audiology at the University of Chicago in the 1960s. One wintry night he drove home from work in a raging blizzard. His car soon became mired in deep snow, and Barry

was forced to walk the rest of the way home. It was a transformative event for him. Throughout the trek he kept asking himself *"Is this any way for a reasonable person to live?"* Finally reaching home, cold and wet, he announced to his family that they were moving to Arizona.



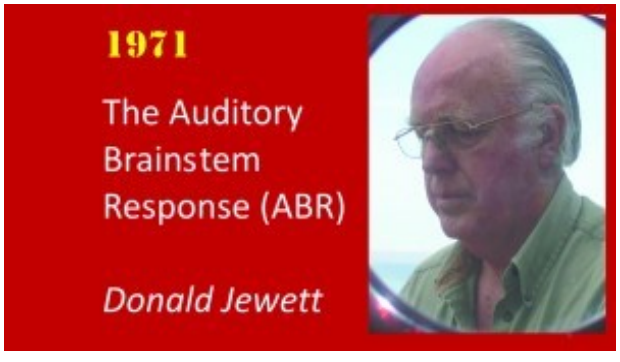
And they did. After wrapping up his affairs in Chicago, Barry moved his entire family to Phoenix. But no jobs were available in audiology. There was, however, a small company attempting to design a better hearing aid. To stay in business they needed the income from selling their no-longer-needed experimental aids. Because they wanted to be sure that the aids were fitted appropriately they enlisted Barry to fit and dispense them. But the American Speech-Language-Hearing Association (ASHA) had decreed that members were in violation of the ASHA code of ethics if money changed hands. Barry, they pronounced, was no longer a member of ASHA. He had lost his professional home.

Many of his colleagues thought that Barry had been treated badly (indeed, others would find themselves in the same fix). For some time a number of influential audiologists argued that the ASHA edict signaled the permanent prevention of the development of private practice, one of the bases of a viable healthcare profession. They saw Barry's ouster from ASHA membership as an ominous sign that would forever limit the scope of practice of the fledgling field. This single event accelerated a growing sense that audiologists needed their own professional home, free of the constraints imposed by an organization oriented toward the wants and needs of the overwhelming majority of the ASHA membership, speech-language pathologists. As these murmurings multiplied, ASHA—finally, in 1979—revised its code of ethics to permit the dispensing of hearing aids. This opened the door to the growth of private audiological practice, now one of the pillars of the profession.

Event #8

1971: The Auditory Brainstem Response

Don Jewett, an electrophysiologist at the University of California San Francisco, is credited with the first observation of the auditory brainstem response (ABR). Initially recording from the region of the auditory nerve in cats, he observed four small bumps in the recording within the first 10 msec after signal onset. Because they were unexpected at such an early latency, he turned to human recordings. Here he found the same four "bumps," as well as a fifth bump. We now know these as the five classic peaks of the human ABR.



At the time Jewett wondered why these peaks had never been reported by other investigators studying early evoked responses to auditory signals. The answer, of course, was that researchers tended to be interested in a particular response at a known frequency, and in order to improve signal-to-noise ratio, bandpass filtered the ongoing EEG narrowly around the frequency region of interest. This

was particularly true of individuals studying the middle-latency response (MLR), located at about 40 Hz on the frequency spectrum. Jewett discovered the ABR because, as an experienced electrophysiologist, he kept the bandpass of his recording system as wide as possible, especially at the low end of the frequency spectrum, in order to avoid phase distortion of the evoked response, wherever it might be.

The ABR literally revolutionized the evaluation of babies and young children because it is state-independent. It does not matter whether the child is asleep or awake: if the click gets through to the brain, those five peaks will appear. This has made it possible to test even newborn babies with comparative ease. Hearing loss can now be detected not at 3 years but at 3 hours after birth. Marion Downs' goal of genuinely early detection was finally realized.

Event #9

1978: The Discovery of Otoacoustic Emissions

In 1978, David Kemp, a British physicist then working at the Royal National Throat, Nose and Ear Hospital in London, was the first to demonstrate that auditory input generated a response in the cochlea which could be measured and recorded. These "otoacoustic emissions" have had a profound effect on auditory diagnosis, especially in screening infants.

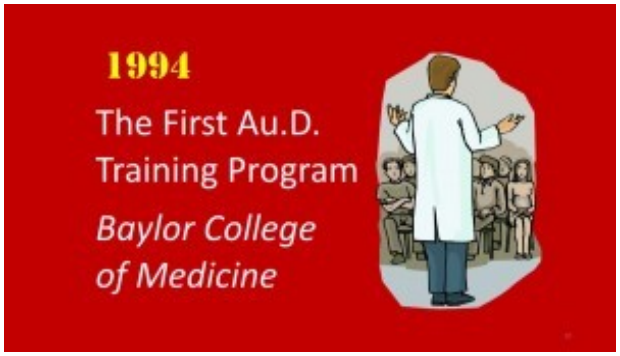
In the preface to the first edition of *Otoacoustic Emissions*, Ted Glattke and Martin Robinette eloquently summarize the importance of OAEs: "We have at our disposal a measure of preneural function in the inner ear that can be accessed using noninvasive techniques that do not require sedation. This acoustic otoscope allows us to scan the cochlear epithelium from the base to the apex and produces acoustical images that are revealing secrets long hidden from view or obscured in electrical recordings."

The combination of the ABR and otoacoustic emissions comprises a set of tools for the early detection of hearing loss in infants and young children with an accuracy unimaginable in the early days of our profession.

Event #10

1994: The First AuD Training Program

The concept of raising the level of the profession by offering a doctorate in clinical audiology had been shared by several individuals during the decades of the 1970s and 1980s. It arose from three ongoing concerns: 1) A growing discontent with the fact that the PhD degree, the measure of research competence, was being awarded to individuals whose career path was clearly clinical rather than investigative; 2) The fact that many excellent clinicians were reluctant to enter a PhD program because of the perceived challenge of the dissertation requirement, and 3) The perception that a viable healthcare profession required that the majority of members operate at the doctoral rather than at the master's degree level.



Throughout the 1980s, there was great support for establishing the first AuD training program, but no takers. In desperation, the Audiology Foundation of America (AFA) offered a $25,000 prize which set off a race to establish the first program. In Houston, I convinced the executive faculty of the Baylor College of Medicine that our program in audiology was uniquely positioned to initiate an AuD degree. There was close competition from Central Michigan University, but our program at Baylor won the AFA prize. With the strong support of the chairman of the Department of Otolaryngology and Communicative Sciences, Dr Bobby Alford, we opened the first AuD program in the nation in January 1994. Since then the number of AuD training programs has exploded, assuring a steady stream of doctoral level graduates working in diverse professional settings across the country. The Baylor College of Medicine program set us on course to become a truly doctoral level profession. These 10 highlights vividly reflect the growth of audiology from its fledgling origin only seven decades ago to its present full membership in the healthcare family.

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Original citation for this article: Jerger J. Ten highlights from the history of audiology. *Hearing Review*. 2019;26(5):10-14.