

# Chapter 1

## Pediatric Audiology

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**I**t is our contention that audiology is the foundation of the auditory-based management of children who are deaf or hard of hearing (D/HH). In addition, we proceed under the framework that the “sky is the limit” for these individuals—as infants, toddlers, and children with hearing loss have the potential to do and be anything on which they set their sights. Excellence in diagnostic audiology and comprehensive audiologic follow-up is absolutely essential in the management of our children with hearing loss. When professionals, such as speech-language pathologists, educators, and audiologists, have a good understanding of the basics of audiology, they are better able to provide services that promote spoken language development. As a result, these children can indeed gain access to the sounds across the speech spectrum and with their hearing sensory technology and early and comprehensive intervention attain greatness!



*Photo courtesy of Phonak*

To help readers navigate the “acronym soup” of the world of audiology, *Appendix A* provides a lengthy listing of acronyms related to hearing, hearing loss, testing, and audiologic management.

### Basic Anatomy of the Ear

The three major sections of the ear include the outer, middle, and inner ear, and the sense of hearing proceeds to the auditory cortex of the brain (see *Figure 1*; <http://www.medel.com/us/anatomy-of-the-ear/>).

In fact many proponents

of listening and spoken language (LSL) teaching follow the masterful mantra of Carol Flexer stating that “we hear with the brain; the ears are just a way in” (Flexer, 2011).

### Outer Ear

Major landmarks include the pinna or auricle—made up of cartilage—which forms the outer ear. The bowl-like area of the

*Figure 1*  
**Basic Anatomy of the Ear**

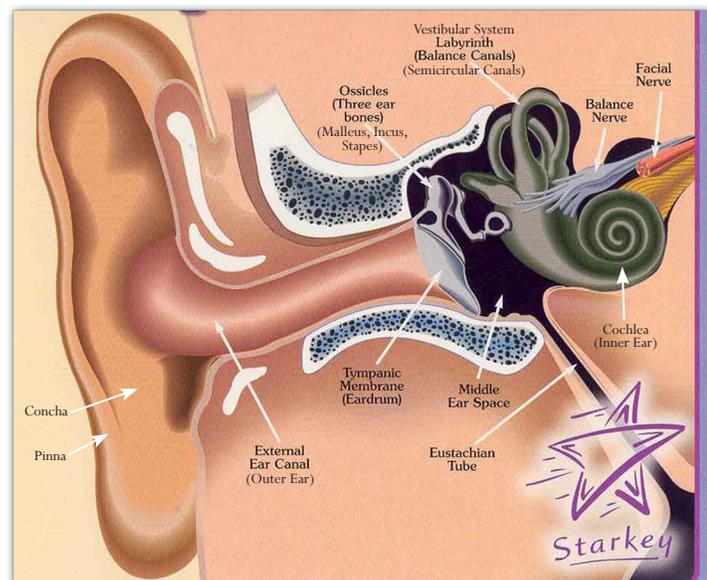


Photo courtesy of NCHAM

outer ear is the concha, which leads into the external auditory canal or meatus. Hair follicles line this pathway and play a role in the extrusion of cerumen or earwax. The canal ends at the tympanic membrane (TM) or eardrum. The TM is the dividing line between the outer ear (OE) and middle ear (ME).

### Middle Ear

This air-filled space primarily houses the ossicles or ME bones. These bones are the smallest in the human body and are from the periphery inward the malleus (“hammer”), incus (“anvil”), and stapes (“stirrup”). Traveling from the ME space towards the nasopharynx (back of the throat) is the Eustachian tube. The Eustachian tube serves to regulate the pressure within the ME space and will open and close as a person swallows. The bones make up the ossicular chain and end at the level of the oval window of the cochlea in the inner ear (IE).

### Inner Ear

The “sense organ” of hearing, located in the IE, is the cochlea—made up of three channels or scalae (the superior scala vestibuli, the scala media, and the inferiorly located scala tympani). The important cochlear duct—or Organ of Corti—includes thousands of inner and outer hair cells with stereocilia—all of

which are tonotopically arranged. Specifically, the hair cells of the base of the cochlea are tuned for high-frequency acoustic stimuli and then course towards the apex, which is tuned for low-frequency acoustic stimuli. In addition to the cochlea, the other major anatomical parts of the IE include the vestibular system and its three semicircular canals, along with the auditory-vestibular nerve (cranial nerve viii/8). The vestibular system is responsible for balance.

### Central Pathway

Beyond the cochlea (retrocochlear aspects of hearing) include the cochlear nucleus and assorted “way-stations” arranged from the inferior to superior orientation of the Superior Olivary Complex, the Lateral Lemniscus, Inferior Colliculus, and the Medial Geniculate Bodies. The ultimate “destination” of the perception of sound for detection through comprehension is Heschl’s Gyrus in the auditory cortex of the temporal lobe of the brain.

### Physiology of Hearing

A brief review of “how we hear” with the above-noted anatomical sites follows (Newman, Sandridge, & Goldberg, 2015). The OE functions to funnel sound into the ear canal to the ME. This acoustic or vibratory function is enhanced by the concave shape of the pinna and concha (bowl) of the OE and the natural resonance of the concha and the external auditory meatus (EAM; especially for the higher frequencies; the following videos show this process, <http://www.medel.com/us/how-hearing-works/>; <http://www.medel.com/us/videos/#.WOzzffjChzw>). At the level of the TM and the ME, there is an impedance mismatch between the acoustic signals from the OE and the fluids of the IE. The lever action of the ME bones and most notably the areal ratio (the area of the TM is approximately 17 times the area of the stapes footplate) enhances the transduction of the mechanical energy within the ME space.

At the level of the IE, mechanical energy must be transduced into hydromechanical energy via chemical changes within the cochlea and into neural impulses. Piston-like movements of the stapes moves into the

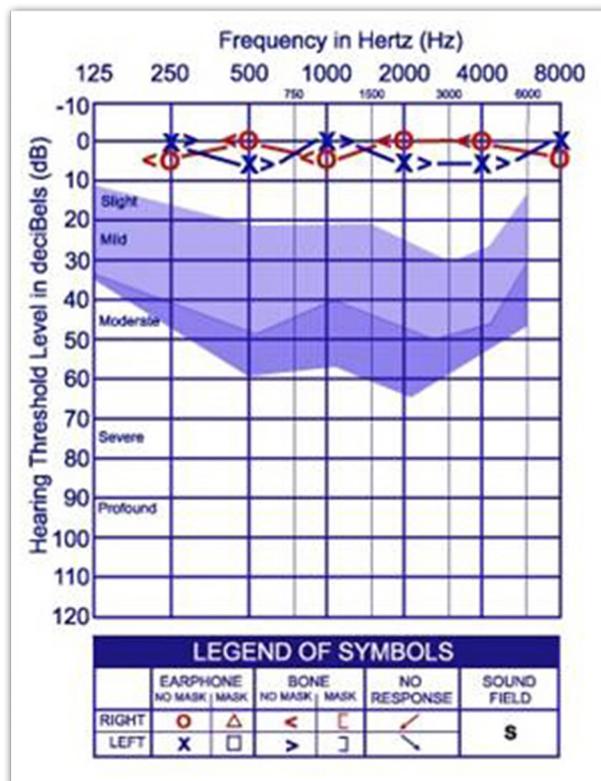
**Infants, toddlers, and children with hearing loss have the potential to do and be anything on which they set their sights.**

perilymph of the scala vestibuli, creating a traveling wave along the basilar membrane within the Organ of Corti. Fluid movements allow for “shearing” of the stereocilia of the hair cells. The resultant chemical changes excite the hair cells, and electrochemical energy results. With the release of neurotransmitters, auditory-based neural impulses are created and travel from the cochlea to the auditory nerve (Newman et al., 2015, pp. 410-413).

## Hearing Testing

The following section will attempt to present “Everything You Always Wanted to Know About Hearing Testing” and is adapted from Goldberg (2015a, 2015b). Another resource is the 2016 document developed by the A. G. Bell Association for the Deaf and Hard of Hearing (AG Bell) and the AG Bell Academy of Listening and Spoken Language titled, “AG Bell Association’s Recommended Protocol for Audiological Assessment, Hearing Aid and Cochlear Implant Evaluation, and Follow-Up” (<https://www.agbell.org/Document.aspx?id=3009>; see Figure 2).

*Figure 2*  
**The Audiogram**



### The Audiogram

An audiogram is a graphic representation of a person’s hearing or auditory responses, specifically thresholds, which are defined as the “softest” sound detected at least 50% of the time. Thresholds need to be repeatable before they are recorded on the audiogram. Across the horizontal plane (abscissa or x-axis) of the audiogram are the frequencies in Hertz [Hz—formerly referred to as cycles per second (cps)]. Frequency information reflects the physical stimuli of sound vibrations with the psychological correlate of “pitch.” A person with “typical” hearing can usually hear sounds between 20 and 20,000 Hz. During hearing testing, however, only the octave frequencies are routinely measured and are considered “frequency-specific” samples (i.e., 250, 500, 1000, 2000, 4000, and 8000 Hz). On the vertical plane (ordinate or y-axis) of the audiogram are labels of “loudness” measured in decibels (dB), with an upper case B to honor Dr. Alexander Graham Bell. On the audiogram, the dB referent is to dB HL (hearing level), whereas the physical measure is dB SPL (sound pressure level). To determine the child’s audiometric thresholds, audiologists use air and bone conduction testing.

### Air Conduction (AC)

When testing is completed with insert earphones placed in the patient’s ear canal or when headphones are used, the measurement is called AC testing. The complete pathway for AC includes the “whole system” (i.e., the OE, ME, and IE and beyond to the brain). The thresholds obtained with AC testing are placed on the audiogram as red circles for the right ear and blue Xs for the left ear. In the actual behavioral testing, the audiologist will have selected a frequency (the first frequency often tested is 1000 Hz), and by using an up and down “bracketing” procedure (Hughson & Westlake, 1944) of “louder” and “softer” pure tone or sine wave presentations, a 50% criterion of the “softest” sound level needs to be obtained. That level (in dB HL) is plotted under the vertical (y-axis) on the audiogram—in this case under 1000 Hz and at the intersection with the horizontal (x-axis) point for the X dB HL number established. Testing is completed at the other frequencies for each ear separately, and a complete AC audiogram is subsequently filled in.

### Bone Conduction (BC)

BC testing makes use of a bone vibrator or oscillator that is placed on the temporal bone of a patient—behind and to the side of the ear. Testing via BC essentially bypasses the OE and ME and literally vibrates the bones of the skull and directly measures responses from the cochlea—or sense organ of hearing—located within the IE. Thresholds from BC measures are similarly placed on the audiogram as red (<) or blue (>) brackets (these are placed directly to the left and right sides, respectively, of the vertical line reflecting the frequencies tested (typically only 250, 500, 1000, 2000 and 4000 Hz are measured by BC).

## Hearing Loss Severities

As the audiologist evaluates the threshold results, specific guidelines are used to interpret the “degree” or “level” of hearing or hearing loss. Threshold responses for a child that are 15 dB HL or “better” (e.g., 10, 0, or even -5 or -10 dB HL) are all considered to be within normal limits (WNL). In other words, thresholds at the top of the audiogram reflect “good” hearing. As the thresholds need to be plotted further down the y-axis where dB HL numbers are higher, this indicates a more significant degree of hearing loss.

Some professionals characterize hearing loss based on an individual’s thresholds, while others rely on

**As the audiologist evaluates the threshold results, specific guidelines are used to interpret the “degree” or “level” of hearing or hearing loss.**

the numeric average for each ear at 500, 1000, and 2000 Hz called the pure tone average (PTA). Still others methodically characterize the complete audiogram—taking into consideration that rarely are the thresholds completely “flat” across the audiogram and are often more likely at “better” levels in the low frequencies (pitches) and sloping downward in the mid-frequencies, with the “worst” threshold data often in the high frequencies. This helps explain why many individuals have the most difficult time

hearing “weak” sounds with most of their acoustic energy in the high-frequency regions, such as the “f,” “s,” and “th” sounds.

The severity of a hearing loss is typically determined by evaluating the dB level and using various terms to decode the degree of the hearing loss. Most texts use the following “classic” terms to indicate degree of hearing loss:

dB HL numbers of 26-30 as a “slight” hearing loss.
31-40 as “mild.”
41-55 as “moderate.”
56-70 as “moderately severe.”
Numbers between 71 and 90 suggesting a “severe” loss.
Thresholds of 91 dB HL and above are indicative of a “profound” hearing loss.

Most audiologists avoid language that uses terms suggesting a “percent of a hearing loss” for a variety of reasons. Notably, hearing is not a % or a 100% issue. In addition, because we use measures that can reach 120 or 130 dB HL—and the audiogram scale is logarithmic—the transfer of, for example, a 75 dB HL hearing loss cannot be interpreted as a 75% hearing loss.

## Types of Hearing Loss

There are three primary types of hearing loss, which are based on the three classifications of conductive, sensorineural, and mixed hearing loss.

### Conductive Hearing Loss

By definition, a conductive hearing loss involves a problem(s) with the “conduction” of sound to the cochlea. In conductive hearing loss, the site of lesion (or the anatomical location of the problem) is in the OE and/or ME. An example might be a combination of earwax in the ear canal at the same time the child is experiencing a buildup of ME fluid. Fortunately most conductive hearing losses can be reversed, corrected, or improved.

### Sensorineural Hearing Loss

A sensorineural hearing loss (SNHL) involves the cochlea and/or the auditory nerve (the eighth cranial nerve or the auditory-vestibular nerve). In actual practice, few individuals ever have “nerve” deafness or involvement of the auditory nerve. SNHLs are typically permanent and nonreversible—resulting from heredity, birth disorders, assorted disease and disorders (e.g., meningitis), damage to the hair cells of the cochlea from medications (referred to as “ototoxic”), noise exposure, or the aging process.

### Mixed Hearing Loss

A mixed hearing loss represents a combination of a conductive and SNHL loss. The site of lesion reflect the OE and/or ME **and** the cochlea/IE and/or the auditory nerve. For many of our children with a permanent SNHL, when they also come down with otitis media with effusion, this would be reflected in a mixed hearing loss; that is a hearing loss with additional sensitivity loss due to the conductive component being added to the cochlear loss.

## Behavioral & Electrophysiological Hearing Testing

A range of behavioral and electrophysiological tests of hearing have been developed and are regularly administered by audiologists. Although the behavioral tests detailed in *Table 1* are of great importance, it is important to point out that if these tests do not quickly lead to information about the presence of hearing loss, as well as regarding the ear-specificity of the data (that is, right ear only and left ear only threshold measurements), a prompt referral must be made for followup with an audiologist with significant experience in completing auditory electrophysiologic measures—also described in *Table 1*.

## Physiological Tests

While behavioral tests provide a great deal of information about an individual's auditory perception, there are other types of objective tests that can provide the audiologist with more information about the child's auditory functioning (see *Table 2*).

## Technology Options

Currently there are different options of hearing technology available for those who are D/HH. Although these technologies work differently, they have the goal of providing a full range of sounds across the frequency spectrum. As a result, children have the opportunity to access speech sounds essential for spoken language development.



Photo courtesy of Cochlear Americas

### Hearing Aid

The most prevalent hearing technology worn by children with hearing loss are hearing aids. Every child identified as D/HH is considered a candidate for hearing aids (American Academy of Audiology, 2013). Hearing aids have the goal of making sounds audible. Hearing aids collect sound via a microphone. Most current hearing aid technology converts this analog sound energy into a digital signal. This digital signal, which is converted back into an electrical signal, is sent to the receiver (speaker). This amplified sound is sent to the ear.

### Cochlear Implant

Children who have more severe or profound SNHL may derive more benefit from cochlear implant technology. A cochlear implant consists of an internal and external component. The electrode array of the internal component is surgically implanted into the cochlea. After the incision has healed, the child will receive an external speech processor device that is placed on the child's head during waking hours. Sound is collected by the microphone of the external component, transformed into electrical signals, that are then transmitted through the skin to the internal component. The electrodes send electrical signals that stimulate the areas of the cochlea that correspond to the frequencies of the sound that was collected. These signals then travel to the auditory processing centers of the brain.

### Bone Anchored Hearing Aid (Baha™)

Often referred to as bone anchored hearing aid (Baha™; trademarked to Cochlear Corporation), an implantable bone conduction hearing device (IBCHD) or auditory osseointegrated implant system (AOIS) are options for children who have conductive hearing loss, mixed hearing loss, or single-sided deafness (SSD). The IBCHD consists of an implanted titanium component and external sound processor. The microphone on the external sound processor collects the sound and is converted into mechanical, vibratory energy. This vibratory signal is transmitted to the titanium component through the skull—vibrating the cochlear structures. These devices are typically not implanted until the child is 5 years of age to allow for greater maturation of the skull. Children who do not yet meet the age requirement may wear a soft headband that is coupled to the external sound processor.

## Table 1 Behavioral & Speech Perception Tests

### Behavioral Observation Audiometry (BOA)

BOA, as the name suggests, is contingent upon careful observation of a patient's behavior and notably his/her face in response to the presentation of sound stimuli. The child—often under 6 months of age—is typically seated on a parent's lap, and a pediatric test assistant should be situated in front of the patient and

parent. As narrow band noise (NBN) stimuli or frequency-modulated/FM (warble) tones are presented to a loud speaker in the field or test booth, the audiologist and the test assistant should agree upon any repeatable response observed (e.g., head turn, eye brow raising, etc.). The responses may more likely be

a minimal response level (MRL)—that is may not be a true threshold but a response slightly above “true” threshold. An important caution with testing of hearing in the soundfield is that unless headphones or ear inserts are used, when sound is delivered to loud speakers, the “better ear” is being tested, if a better ear exists.

### Visual Reinforcement Audiometry (VRA)

VRA is based on the testing paradigm model of B. F. Skinner. In hearing testing using VRA, the patient is typically situated between two speakers that have been equipped with toys or characters that can be illuminated and made to move. As sound is delivered to the speaker, and the VRA equipment lights up and moves, the child is directed to that speaker and told, “I heard that!” Each of the speakers should be used, and the patient eventually should demonstrate the stimulus-response control of a head turn with the sound

and lighting/animation. Then the testing proceeds to the presentation of the sound alone to one speaker, and immediately following the head turn behavior (should it occur), the character/toy lights up and is set in motion as a reinforcement to his/her response. Threshold testing then proceeds at a variety of frequencies. VRA is often dependent upon quick testing behaviors and a collaborative working relationship of the audiologist and test assistant in an effort to obtain as much data as possible. Another key component of VRA

testing is to keep the child at midline, so that random head turns toward the speaker/toys are not interpreted as response behaviors when they more likely reflect a child interested in seeing the toy light up and move! Patients undergoing VRA testing are often in the age range of 7 months to 2 years. As with BOA, the better ear is being tested, if a better ear exists, if the VRA testing is completed in the free field or soundfield in contrast to when headphones or ear inserts are used, which does result in ear-specific threshold data being obtained.

### Conditioned Play Audiometry (CPA)

Once the child is willing to allow for ear inserts or headphones to be used—provided the patient can be reliably taught to “drop a block” or put a ring on a spindle immediately after the presentation

of sound stimuli—complete ear-specific threshold data can be compiled. Although many suggest a child be 2 or 2½ years old, it is our recommendation that CPA testing techniques be attempted as early as

possible—even when the youngster is just over 1 years old. A key component of CPA testing is the ability of the test assistant to keep the child interested in the materials being used for the “drop” task.

### Speech Audiometry

As people are not only asked to hear frequency-specific “beeps,” the use of speech stimuli is also an important component of a

comprehensive hearing evaluation. Typically the testing will include a speech recognition threshold (SRT) for the right ear and left ear and the

determination of speech perception for each ear with stimuli presented at a comfortable listening level, the word recognition testing (Goldberg, 2015b).

## Speech Recognition Threshold (SRT)

Using spondee words (two-syllable words with equal stress, i.e., hot dog, baseball, cowboy), the audiologist will first familiarize the patient with a list of these words and then determine the “softest” level that 50% of the spondaic words can be heard. The SRT number is reported in dB HL (i.e., 15 dB HL). If needed, instead of

repeating back the spondee words, a child might be asked to point to the item named via a picture spondee board. The SRT is “acoustically” most closely matched to low-frequency hearing levels (e.g., 500 Hz) and the suprasegmental (melodic) characteristics of the stimuli. The SRT is often compared to the same ear’s PTA as an interest

reliability check (the SRT should be within + 6 dB of the PTA) and is used to determine the internal reliability by the patient for each ear being tested. The SRT was developed as an auditory-only threshold test or task, so that information obtained reflects the ability to perceive auditory versus auditory and visual cues.

## Word Recognition Testing

The other commonly administered “speech” test is a word recognition measurement or word recognition score (WRS) often involving phonetically balanced (PB) words. These words are made up of sounds that are reportedly reflective of the frequency of occurrence of various phonemes used in spoken English. The most commonly used speech sounds are therefore predominant in sounds that make up monosyllabic PB words. The testing is completed at the patient’s most comfortable loudness level and reported as a percent correct at its specific presentation level. The intensity level must be reported and should be “interpreted” for the family (e.g., a presentation level

of 45 to 50 dB HL approximates the “loudness” of conversational speech). Like the SRT testing described above, word recognition testing should also be based on auditory-only word presentation, so that the information reflects auditory abilities versus one’s access to both auditory and visual cues.

For younger children, a word recognition task might involve asking the child to point to his belly, touch her nose, and point to his shoulder. For slightly older toddlers and preschoolers, picture books (e.g., Northwestern University Children’s Perception of Speech—or NU-CHIPS—by Nelson, 1970; or the Word Intelligibility by Picture

Identification—or WIPI—by Ross and Lerman) are commonly used. The child scans the four (or six) pictures on the page and is asked to “point to dress,” for example. For older children and most adults, the prompt is for the individual to repeat back the last word in the carrier phrase, “Say the word \_\_\_\_\_” from an open set of words. A score on a 0 to 100% scale is calculated. As noted above, the intensity of the stimuli for the presentation level must be reported, or the utility of this score would be minimal (again 45-50 dB HL would be an “average loudness” level; however numbers, such as 65-70 dB HL, reflect quite “loud” levels).

## Other Pediatric Speech Perception Measures

In addition to the SRT and WRS testing described above, many pediatric clinicians also make use of tools to allow for the determination of auditory functioning on the “hierarchy” of detection (presence/absence of sound), discrimination (determination of same/different), recognition (selection of a named item or pointing to a named picture

in a field—closed set), identification (the repeat back of a named item), or comprehension (understanding of information). Long versus short could be determined with a rabbit going “hop hop hop” versus a train going “chooo chooo.” The Early Speech Perception (ESP) test (Moog & Geers, 1990) allows for the determination of pattern perception,

as well as subtests with spondee and word recognition measures. The familiar Ling Sound Test (Ling & Ling, 1978) that makes use of the auditory-only presentation of sounds that reflect the acoustics from low- to mid- to high-frequency (specifically, /oo/, /m/, /ah/, /ee/, /sh/, /s/) can also be used to determine specific hearing abilities of young patients.

## Table 2 Physiological Tests

### Acoustic Immittance

This is a test that measures ear canal volume, tympanic membrane function, and acoustic reflexes. While acoustic immittance is not a test of hearing ability, the results provide a great deal of information, and it is an integral part of an audiological evaluation.

A small probe tip is placed in the child's ear canal. As air pressure is changed in the ear canal, a tone is presented, and the reflected sound is measured. The eardrum mobility (i.e., stiff, compliant) and stapedius muscle contractions (acoustic reflexes) are measured in this

non-invasive test. One example of ME dysfunction commonly experienced by children, which can be observed in acoustic immittance results, is otitis media. Depending on the severity of the otitis media, the TM may be less mobile.

### Otoacoustic Emissions (OAEs)

OAEs are a test of outer hair cell function and have been used for screening purposes (e.g., newborn hearing screening programs) and as part of a diagnostic battery. Evoked OAEs, such as transient-evoked

OAEs (TEOAEs) or distortion product OAEs (DPOAEs), are low-level sounds that are generated by the cochlea in response to tones or clicks presented via a probe tip. This procedure is noninvasive and can

help the audiologist determine if a hearing loss is sensory or neural in nature. ME function must be normal (as determined through acoustic immittance measures) to ensure that the test results are accurate.

### Auditory Brainstem Response (ABR)

An ABR is a test of peripheral auditory system integrity where sound is presented via headphones, ear inserts, or a bone oscillator, and responses are measured through electrodes that are placed on the scalp and earlobes. These responses are generated by electrical activity produced by neurons in the auditory nerve (8th cranial nerve) and brainstem for the first 10 milliseconds after the presentation of a sound. An automated ABR (AABR) is a screening tool commonly used in newborn hearing screening. A screening level is selected (e.g., 35 dB HL), auditory stimulus is presented via inserts/headphones, and the results of AABR is a pass or refer for further audiological evaluation.

In a threshold ABR, responses are collected at various intensity levels, and the audiologist will interpret the resulting waveforms. The level at which the lowest visible response is present is the ABR threshold. With a threshold ABR, the audiologist can determine degree of hearing loss, the presence or absence of a conductive component, and some frequency-specific information. However, behavioral testing yields greater frequency-specific information and more information at higher intensity levels. Threshold ABR can be administered for a variety of reasons, such as to determine degree and type of hearing loss in infants or in those who may not be able to give reliable results, to

assess the integrity of the auditory pathway, such as in evaluating for Auditory Neuropathy Spectrum Disorder (ANSD).



Photo courtesy of NCHAM

While cochlear implants, hearing aids, and IBCHD have been options for many children with hearing loss, there are some children who have more complex needs, such as an absent or cochlear nerve deficiency that results in fewer or no auditory nerve fibers traveling from the cochlea to the brain with variable auditory preservation (Coletti, Coletti, Mandalà, & Colletti, 2014). This results in poorer speech perception. Some of these children may receive an auditory brainstem implant (ABI), which consists of an electrode array placed on a cluster of neurons in the cochlear nuclei (Schwartz, Otto, Shannon, Hitselberger, & Brackmann, 2008). Although ABI is less widespread, it is important to be aware of this hearing technology.

## Hearing Assistive Technology Options

In addition to hearing technology, such as hearing aids, cochlear implants, ABI, and IBCHD, children with hearing loss can benefit from other types of hearing assistive technology (HAT), such as wireless remote microphone systems. These include:

Frequency modulation (FM) systems that use radio waves to transmit the desired speech signal

Digital modulation (DM) systems that use digital signals to transmit the speaker's voice to the child.

Both FM and DM systems provide additional help in more challenging listening situations. Although HATs can be used by individuals across all age groups, this chapter focuses on those that have the most application to school-aged children, and those students who have transition plans.

A challenge in educational settings is that classrooms are not ideal listening environments. There are several factors that make classrooms a more challenging listening environment for children who are D/HH. One factor is a poor signal-to-noise ratio, which is the relationship between the signal (speaker's voice) and background noise (Smaldino & Flexer, 2014). In other words, the teacher's voice should be of a higher intensity than the background noise.

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Another factor is speaker distance—or how far the speaker's voice travels to the child's ears. The greater the distance sound energy travels, the more it diminishes in energy and overall intensity. Reverberation (the persistence of sound energy), which is very similar to an echo, is an additional challenge. This occurs due to sound energy persisting and reflecting off hard surfaces, such as walls or linoleum floors. These reflections interact with each other and makes it more difficult to clearly hear the teacher's voice. In classrooms, these three factors tend to interact with each other.

As a result, children who are D/HH may expend more energy focusing on the teacher's message—potentially

missing or misunderstanding classroom content. Hearing access technology, such as FM systems/wireless remote microphone systems, are coupled to the child's hearing technology, and the teacher wears a transmitter. These systems have the goal of increasing the signal-to-noise ratio and reducing the impact of distance and reverberation. In other words, these help increase the intensity level/loudness of the speaker's voice approximately 10-15 dB above the background noise—making the speaker's voice clearer to the child (Rhoades, MacIver-Lux, & Lim, 2016).

In addition to FM systems/wireless remote microphone systems, there are other types of HAT that are available for school or home use. Some examples of these may be those that are alerting devices, such as flashing fire alarms and flashing/vibrating alarm clocks. These types of devices are important for safety issues, as well as helping the child develop the skills for independence (e.g., using an alarm clock to wake up in the morning). Technologies that can also be useful are items such as closed captioning/subtitles. Video materials presented for educational purposes should include captions/subtitles, so that the child has complete access to materials used for teaching.

## Educational Audiology Needs

Although FM systems/wireless remote microphone technologies can provide a child with greater access to the teacher's voice, there are other educational considerations that can be made. Some of these would be included in an individualized education program or plan (IEP)

or a 504 plan (see the *Educational Settings* chapter for more detailed information on IEPs and 504 plans).

A child with hearing loss will need additional support to ensure that he/she has equal access in the classroom. Typically an educational audiologist will work with the school to ensure that the child has access to auditory information in the classroom. The educational audiologist may, for example, select, fit, monitor, and maintain the child's FM system/wireless remote microphone system. He/she may also collaborate with other members of the child's team, such as the teacher(s), school speech-language pathologist, auditory-verbal therapist, parents, and other school professionals, to develop an IEP, individual family service plan (IFSP), 504 plan, or transition plan that is appropriate for the child.

As mentioned previously, classrooms are noisy, reverberant environments. Some ways the impact of reverberation can be reduced is by acoustically treating the classroom with items that absorb some sound energy. Examples of these can include using rugs on linoleum floors, hanging drapes over windows, acoustic tiles on ceilings, placing corkboards and posters on walls, and placing books on shelves.

Other ways the child can be supported are through different instructional strategies and accommodations. Examples of some teaching strategies that can support learning of *all* children in the classroom, whether or not they have typical hearing or are D/HH, can include the following:

1	Rephrasing questions and responses from other students.
2	Summarizing or providing transcripts of PA announcements.
3	Providing transcripts of items that may not be captioned/subtitled (e.g., song lyrics).
4	Placing oneself in a visible spot (i.e., not with one's back facing a window).
5	Making sure one's back is not facing the class when speaking.
6	Ensuring that the child's attention is focused on the speaker.
7	Implementing a "buddy system."
8	Communicating with the child's parents/guardians about material that is taught or will be taught in the classroom, so concepts can be reinforced at home.

A long-term goal can also include a focus on developing self-advocacy skills. Educators can facilitate this development by encouraging the child to problem solve, take care of their own hearing devices, and use good communication repair strategies. These self-advocacy skills are lifelong skills that can be instilled starting at a young age. A helpful resource with suggestions for providing good support for children with hearing loss in the educational environment is *Success for Kids with Hearing Loss* (<http://successforkidswithhearingloss.com/>).

## Conclusion

Hearing loss has been known to affect different areas of a child's life. These can include auditory development (Sharma, Dorman, & Spahr, 2002) and spoken language acquisition (Moeller, 2000), which can then affect different skills, such as reading (Moeller, Tomblin, Yoshinaga-Itano, Connor, & Jerger, 2007; Parault & Williams, 2010), theory of mind (Ziv, Most, & Cohen, 2013), and socio-emotional development (Greenberg & Kusche, 1993). A child whose hearing loss was identified early and who receives appropriately fit hearing technology (Sharma, Dorman, & Kral, 2005), an auditory-based early intervention will have the best opportunity for stimulated growth of the auditory and language centers in the brain.

With an understanding of a child's hearing, hearing loss, hearing technology, and how to support the child in the classroom setting, an educator can best support the child's learning. It is with the skills and knowledge of excellent educators, as well as other support personnel (e.g., audiologist, auditory-verbal therapist, auditory-verbal educator, and speech-language pathologist), that the child can grow as a student and individual.

**With an understanding of a child's hearing, hearing loss, hearing technology, and how to support the child in the classroom setting, an educator can best support the child's learning.**

## Resources

- Alexander Graham Bell Association for the Deaf and Hard of Hearing & the AG Bell Academy for Listening and Spoken Language, [www.agbell.org](http://www.agbell.org)
- American Academy of Audiology (AAA), [www.audiology.org](http://www.audiology.org)
- American Speech-Language-Hearing Association (ASHA), [www.asha.org](http://www.asha.org)
- Boy's Town National Research Hospital, [www.boystownhospital.org](http://www.boystownhospital.org)
- Centers for Disease Control and Prevention (CDC), [www.cdc.gov/ncbddd/hearingloss/index.html](http://www.cdc.gov/ncbddd/hearingloss/index.html)
- Early Hearing Detection & Intervention—Pediatric Audiology, [www.ehdipals.org](http://www.ehdipals.org)
- Hands & Voices, [www.handsandvoices.org](http://www.handsandvoices.org)
- National Center for Hearing Assessment & Management (NCHAM), [www.infanthearing.org](http://www.infanthearing.org)

### Hearing Aid Manufacturers (Pediatric Focus)

- Phonak, [www.phonak.com](http://www.phonak.com)
- Oticon, [www.oticon.com](http://www.oticon.com)

### Cochlear Implant Manufacturers

- Advanced Bionics Corporation, [info.us@AdvancedBionics.com](mailto:info.us@AdvancedBionics.com), [www.advancedbionics.com](http://www.advancedbionics.com)
- Cochlear Corporation, [www.Cochlear.com/US](http://www.Cochlear.com/US)
- MED-EL, [implants.us@medel.com](mailto:implants.us@medel.com), [www.medel.com](http://www.medel.com)

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## Appendix A

### Acronym Soup

<b>AAA</b>	American Academy of Audiology	<b>Baha™</b>	Trademarked to Cochlear Corp. <i>NOT</i> Bone Anchored HA
<b>AABR</b>	Automatic/Automated ABR	<b>BC</b>	Bone Conduction
<b>AAO-NHS</b>	American Academy of Otolaryngology - Head & Neck Surgery	<b>Bi-Bi</b>	Bilingual-Bicultural
<b>ABG</b>	Air:Bone Gap	<b>BOA</b>	Behavior Observation Audiometry
<b>ABI</b>	Auditory Brainstem Implant	<b>BSER</b>	Brainstem-Evoked Response
<b>ABR</b>	Auditory Brainstem Response	<b>BTE</b>	Behind-the Ear (HA)
<b>AC</b>	Air Conduction	<b>CCT</b>	California Consonant Test
<b>AD</b>	Auditory Dysynchrony	<b>CI</b>	Cochlear Implant
<b>ADA</b>	<ul style="list-style-type: none"> <li>• Academy of Doctors of Audiology</li> <li>• Academy of Dispensing Audiologists</li> <li>• Americans with Disabilities Act</li> </ul>	<b>CIC</b>	Completely in-the-Canal (HA)
<b>AEP</b>	Auditory-Evoked Potentials	<b>CMV</b>	Cytomegalovirus
<b>AG Bell</b>	Alexander Graham Bell	<b>c.n. vii</b>	Cranial Nerve 7 (Facial Nerve)
<b>AI</b>	Acoustic Immittance	<b>c.n. viii</b>	Cranial Nerve 8 (Auditory-Vestibular Nerve)
<b>ALD</b>	Assistive Listening Device	<b>CNC</b>	Consonant-Nucleus-Consonant (Words)
<b>AN</b>	Auditory Neuropathy	<b>COR</b>	Conditioned Operant Reinforcement
<b>ANSD</b>	Auditory Neuropathy Spectrum Disorder	<b>CPA</b>	Conditioned Play Audiometry
<b>A/O</b>	Auditory/Oral	<b>CS</b>	Cued Speech
<b>AOIS</b>	Auditory Osseointegrated Implant System	<b>CT</b>	<ul style="list-style-type: none"> <li>• Computerized Axial Tomography</li> <li>• Computed Tomography (CAT)</li> </ul>
<b>APD</b>	<ul style="list-style-type: none"> <li>• Auditory Processing Disorders</li> <li>• (C)APD - Central APD</li> </ul>	<b>daPa</b>	Dekapascals
<b>AR</b>	<ul style="list-style-type: none"> <li>• Aural Rehabilitation</li> <li>• Acoustic Reflex</li> </ul>	<b>dB</b>	Decibel
<b>ARA</b>	Academy of Rehabilitative Audiology	<b>dB HL</b>	dB Hearing Level
<b>ART</b>	Acoustic Reflex Threshold	<b>dB SL</b>	dB Sensation Level
<b>ASHA</b>	American Speech-Language-Hearing Association	<b>dB SPL</b>	dB Sound Pressure Level
<b>ASL</b>	American Sign Language	<b>D/HH</b>	Deaf or Hard of Hearing
<b>ASSR</b>	Auditory Steady State Response	<b>DM</b>	Digital Modulation
<b>A-V</b>	Auditory-Verbal	<b>DPOAE</b>	Distortion Product OAE
<b>BAER</b>	Brainstem Auditory-Evoked Response	<b>EAC</b>	External Auditory Canal

<b>EAM</b>	External Auditory Meatus	<b>Jerger Type B tymp</b>	No Measureable/Absent TPP/No Measurable/Absent/Reduced Compliance
<b>ED</b>	Early Detection	<b>Jerger Type C tymp</b>	Negative Air Pressure TPP/Normal Compliance
<b>EHDI</b>	Early Hearing Detection and Identification	<b>Jerger Type A<sub>s</sub> tymp</b>	Normal Air Pressure TPP/Reduced Compliance
<b>EI</b>	<ul style="list-style-type: none"> <li>• Early Identification</li> <li>• Early Intervention</li> </ul>	<b>Jerger Type A<sub>d</sub> tymp</b>	Normal Air Pressure TPP/Abnormally High Compliance
<b>EOAE</b>	Evoked OAEs	<b>LDL</b>	Loudness Discomfort Level
<b>FF</b>	Freefield	<b>LE</b>	Left Ear
<b>FM</b>	Frequency Modulation	<b>LL</b>	Lateral Lemniscus
<b>HA</b>	Hearing Aid	<b>LSLS</b>	Listening Spoken Language Specialist
<b>HAT</b>	Hearing Assistive Technology	<b>LSLS Cert. AVEd</b>	LSLS Certified Auditory-Verbal Educator
<b>HH</b>	Hard of Hearing	<b>LSLS Cert. AVT</b>	LSLS Certified Auditory-Verbal Therapist
<b>HR/HR Register</b>	High Risk	<b>MCE</b>	Manually Coded English
<b>Hz</b>	Hertz	<b>MCL</b>	Most Comfortable Loudness Level
<b>IA</b>	Interaural Attenuation	<b>ME</b>	Middle Ear
<b>IBCHD</b>	Implantable Bone Conduction Hearing Device	<b>MGB</b>	Medial Geniculate Body
<b>IC</b>	Inferior Colliculus	<b>MLV</b>	Monitored Live Voice
<b>IDEA</b>	Individuals with Disability Education Act	<b>mm</b>	Millimeter
<b>IE</b>	Inner Ear	<b>MRI</b>	Magnetic Resonance Imaging
<b>IEP</b>	Individualized Education Plan/Program	<b>MRL</b>	Minimal Response Level
<b>IFSP</b>	Individualized Family Service Plan	<b>MS</b>	<ul style="list-style-type: none"> <li>• Mainstreaming</li> <li>• Multi-Sensory</li> </ul>
<b>IHC</b>	Inner Hair Cell	<b>NF-2</b>	Neurofibromatosis-2
<b>IR</b>	InfraRed	<b>NIHL</b>	Noise Induced Hearing Loss
<b>ITC</b>	In-the-Canal (HA)	<b>NR</b>	No Response
<b>ITE</b>	In-the-Ear (HA)	<b>NRT</b>	Neural Response Telemetry
<b>JCIH</b>	Joint Committee on Infant Hearing	<b>NU-6</b>	Northwestern University PB Words (for Adults)
<b>Jerger Type A tymp</b>	Normal Air Pressure TPP/Normal Compliance	<b>NU-CHIPS</b>	Northwestern University Children's Perception of Speech

<b>OAE</b>	Otoacoustic Emissions	<b>ST</b>	Scala Tympani
<b>OE</b>	Outer Ear	<b>SV</b>	Scala Vestibuli
<b>OHC</b>	Outer Hair Cell	<b>TC</b>	Total Communication
<b>OM</b>	Otitis Media	<b>TEOAE</b>	Transient-Evoked OAE
<b>OME</b>	OM with Effusion	<b>TM</b>	Tympanic Membrane
<b>OW</b>	Oval Window	<b>TPP</b>	Tympanometric Peak Pressure
<b>PB</b>	Phonetically Balanced	<b>TROCA</b>	Tangible Reinforcement Operant Conditioned Audiometry
<b>PB-K</b>	PB Words Kindergarten	<b>TT</b>	Text Telephone (Formerly TTY)
<b>PE</b>	Pressure Equalization (Tubes)	<b>TTS</b>	Temporary Threshold Shift
<b>PET</b>	Positron Emission Tomography	<b>UCL</b>	Uncomfortable Loudness Level
<b>PTA</b>	Pure Tone Average	<b>UHL</b>	Unilateral Hearing Loss
<b>PTA 1</b>	PTA (500, 1000, 2000 Hz; same as PTA)	<b>UNHS</b>	Universal Newborn Hearing Screening
<b>PTA 2</b>	PTA best 2 of 500, 1k, 2k Hz (same as “Fletcher” Average)	<b>VRA</b>	Visual Reinforcement Audiometry
<b>PTS</b>	Permanent Threshold Shift	<b>VT</b>	Vibrotactile
<b>PVT</b>	Physical Volume Test	<b>VU</b>	Volume Unit (as in VU Meter)
<b>RE</b>	Right Ear	<b>WDS</b>	Word Discrimination Score
<b>RM</b>	Remote Microphone	<b>WIPI</b>	Word Intelligibility by Picture Identification
<b>RW</b>	Round Window	<b>WNL</b>	Within Normal Limits
<b>SAT</b>	Speech Awareness Threshold	<b>WR</b>	Word Recognition
<b>SC</b>	Static Compliance	<b>WRS</b>	Word Recognition Score
<b>SDT</b>	Speech Detection Threshold	<b>X-axis</b>	Abscissa
<b>SEE-2</b>	Signing Exact English	<b>Y-axis</b>	Ordinate
<b>SF</b>	Soundfield		
<b>SIG</b>	Special Interest Group—ASHA	<b>Symbols</b>	
<b>SLM</b>	Sound Level Meter	θ threshold	
<b>SM</b>	Scala Media	< RE BC threshold	
<b>SNHL</b>	Sensorineural Hearing Loss	> LE BC threshold	
<b>SNR</b>	Signal-to-Noise Ratio	O RE AC threshold	
<b>SOAE</b>	Spontaneous OAE	X LE AC threshold	
<b>SOC</b>	Superior Olivary Complex	(AU) Both Ears	
<b>SR/LR</b>	Speechreading/Lipreading	(AD) Right Ear	
<b>SRT</b>	Speech Recognition Threshold	(AS) Left Ear	
<b>SSD</b>	Single-Sided Deafness	NR = No Response	

