PRESENTATION GUIDE
FOR

AUDIOMETRIC SCREENING AND PLAY AUDIOMETRY

A training program for hearing screeners.

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Child Health and Disability Prevention (CHDP) Program,
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for use in a proctored setting to support program provider education requirements

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HEARING CONSERVATION FOR CHILDREN

Hearing conservation is the term used to include a broad range of activities such as identification of individuals with hearing loss, diagnostic evaluations to determine locus of loss and provisions for rehabilitative services. An ongoing program of public education regarding the cause, nature, and effect of hearing loss is also a vital part of any hearing conservation program.

A hearing loss affects not only the ears of a child, but the whole child. Consequently, hearing conservation programs for children are important for several reasons:

1. A hearing loss seriously affects a child's ability to communicate because it interferes with the development of normal language and learning. Language is the tool for learning that allows children to store information, exchange ideas, and to express feelings.

2. A hearing loss may affect a child's ability to develop normal speech. The speech of some children with severe hearing handicaps is so distorted that the average listener cannot understand him/her.

3. Hearing loss isolates the child from everyday surroundings including parents, other family members, and playmates. Consequently, the child is deprived of the usual opportunity to learn language, speech, social skills, and develop a feeling of self worth.

4. Children with a hearing loss often demonstrate problems in adjustment. Some youngsters compensate for their loss of hearing by becoming overaggressive or disobedient, others withdraw, avoid or shun group activities.

5. Children with a hearing loss are often at a disadvantage because their parents cannot adjust to the child's handicap. The parents' lack of knowledge about the hearing loss, their anxiety about their role as parents, their feelings of guilt about the handicap may cause serious problems for the family.

6. Hearing loss is costly. It necessitates diagnosis, treatment, and special education. This financial burden is borne by both parents and the community. The cost of education programs for deaf and hard-of-hearing children are greater per child than costs per child in a regular classroom.

Hearing conservation, especially identification audiometry, is a preventive measure that can detect many of the aforementioned effects of hearing loss in children. **Early discovery of the hearing problem is the key to successful remediation.** Experience has shown many hearing problems among children respond to medical treatment. With any pathological condition, the earlier the condition is discovered, and medical care is initiated, the better the chance of successful treatment. Early attention to the developmental or educational problems caused by a hearing disability is especially important. It is easier to habilitate a child who is only a few months or a year behind in normal development than it is to help the child who has experienced repeated failure.

The California DHCS, Children's Medical Services has implemented a statewide comprehensive Newborn Hearing Screening Program to help identify hearing loss infants in the first months of life and to link these babies to appropriate services. The American Academy of Pediatrics and other professional organizations recommend screening all newborns and encourage the close monitoring of children's hearing especially through the early years.

ANATOMY OF THE EAR

The primary purpose of the human ear is to receive sound from the environment, process it, and transmit it to the higher brain centers. This function will be discussed as it relates to the four major areas of the auditory system: the external ear, the middle ear, the inner ear, and the auditory nervous system.

A. THE EXTERNAL EAR

The external ear consists of the auricle and the external auditory canal (Figure 1). The auricle (pinna), the visible portion of the external ear, serves in a limited way to collect and funnel sound from the environment into the external auditory canal.

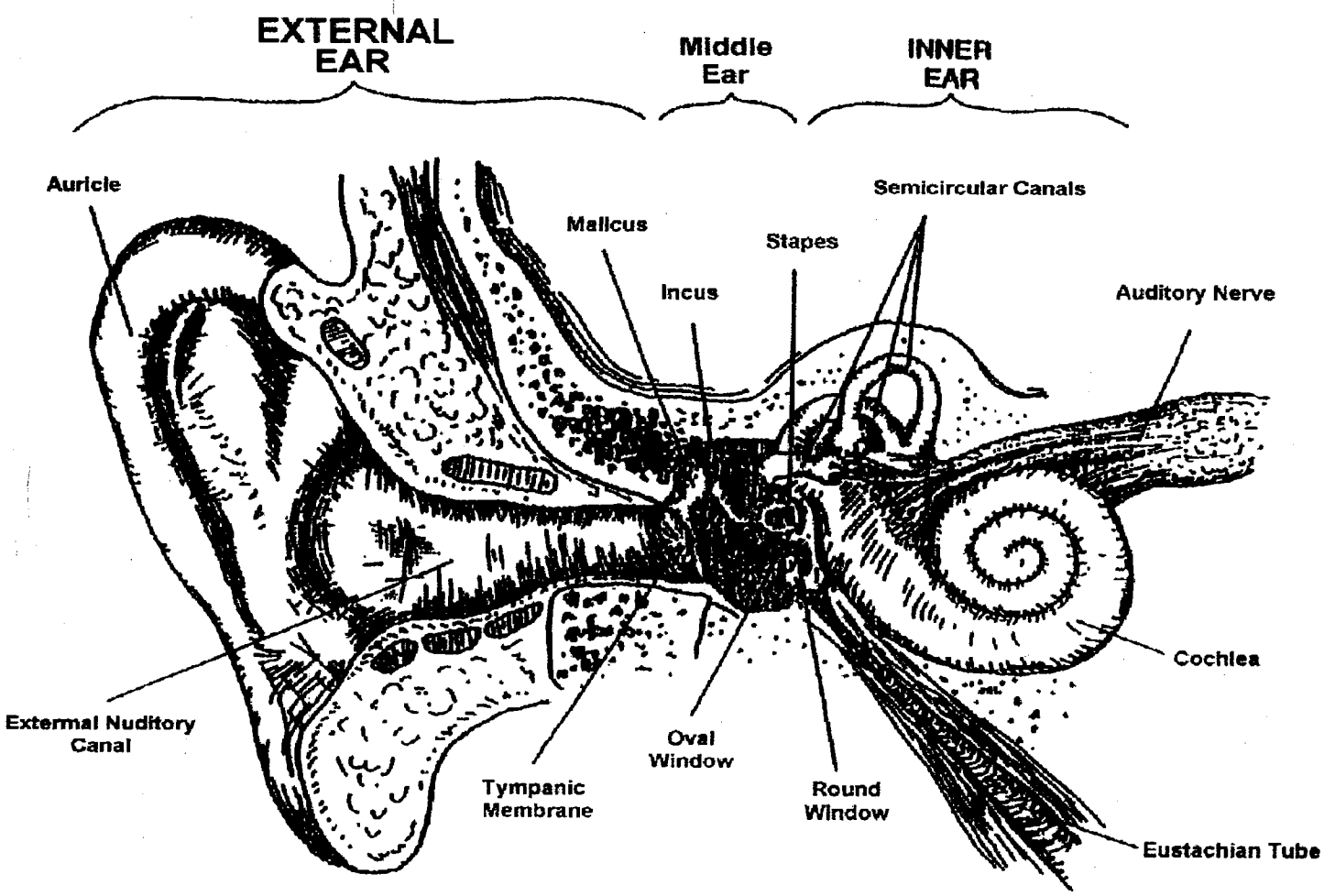
The external auditory canal is slightly curved and is approximately 1.25 inches in length and .25 inches in diameter among adults. This canal carries sound to the eardrum. Within the external auditory canal are hair follicles, sweat glands, and oil glands. The shape of the canal, the hair follicles, and the wax (cerumen) produced by the aforementioned glands serve to protect the delicate eardrum from foreign objects. This also helps to maintain constant temperature and humidity in the region surrounding the eardrum.

B. THE MIDDLE EAR

In an adult the middle ear is an air-filled cavity about the size of an aspirin tablet or 2 cubic cm (Figure 1). The walls of this cavity are characterized by certain landmarks. The outer wall contains the tympanic membrane (eardrum) which is the entrance into the middle ear cavity. The eardrum is a very thin, translucent membrane which vibrates in response to the sound waves funneled through the external auditory canal. The posterior or back wall of the middle ear cavity provides an entrance into the boney mastoid process, which is the posterior portion of the temporal bone that is situated behind the external ear. The anterior or front wall of the cavity contains the opening of the Eustachian tube. This tube extends from the middle ear to the back wall of the mouth. It serves to equalize air pressure between the person's environment and the cavity of his middle ear. It further provides an avenue for the drainage of fluid from the middle ear cavity. The internal wall of the middle ear contains two important windows. The Oval window serves as the entrance for sound energy to enter the inner ear and the Round window serves to release pressure of this energy from the inner ear.

The primary function of the middle ear is to transfer movements of the eardrum through the ossicular chain to the fluid in the inner ear. The ossicular chain is composed of the three smallest bones in the body. These bones are commonly called the hammer, anvil, and stirrup, while the anatomical terms for these tiny bones are the malleus, the incus, and the stapes. The malleus is attached to the

eardrum and moves in synchrony with it. The malleus is also attached to the incus, which is, in turn, attached to the stapes. Thus, these three bones form a bridge across the middle ear space and transmit sound vibrations to the fluid medium of the inner ear.



ANATOMY OF THE HUMAN EAR

Fig. 1

C. THE INNER EAR

The inner ear is composed of two sensory organs: the organ for balance and the organ for hearing. These organs are encased in a bony capsule of the temporal bone and are both fluid filled. The organ for balance (vestibular mechanism), consists of semicircular canals which helps to maintain a person's equilibrium. The organ of hearing (cochlea) resembles a snail shell which is coiled two and three-quarter turns. The cochlea consists of three fluid-filled chambers, or tunnels, which run the entire length of the coil (Figure 2). These chambers are termed the scala vestibuli, the scala media, and the scala tympani. The scala vestibuli and the scala tympani are filled with an outer fluid known as perilymph. The opening from the middle ear into the scala vestibuli is referred to as the oval window. This window contains the footplate of the stapes. When the stapes begins its pumping action, the fluid within the inner ear is set into motion. Because the bony capsule cannot expand, it is necessary to have some type of a release valve so the fluid can move. The release valve is located in the scala tympani. It is covered by a thin membrane and is called the round window. The footplate of the stapes pushes inward on the oval window, the fluid movement results in an outward bulge of the membrane covering the round window.

Located between the scala vestibuli and the scala tympani is the scala media. The middle compartment in the cochlea is filled with inner fluid (endolymph). The scala media is most important as it houses the sensory receptor for hearing called the organ of Corti, which rests on the very flexible basilar membrane. This receptor has thousands of microscopic hairs, which detect the fluid movements within the inner ear. The bending of these hairs results in nerve impulses in the auditory nerve. Each of the tiny receptors transmits specific information about the sounds being heard.

D. THE AUDITORY NERVOUS SYSTEM

The auditory nervous system is composed of the auditory nerve (eighth cranial) beginning at the cochlea and its associated pathways to the brain (Figure 3). The nerve impulses, initiated by the bending of the hair cells on the organ of Corti, travel along thousands of fibers of the auditory nerve. These fibers twist in a manner similar to a wire cable and progress through a bony canal (internal auditory canal) entering the lower portion of the brain stem. From the brain stem, the fibers progress along a well-defined pathway to their final destination in the auditory portion of the temporal lobe of the brain.

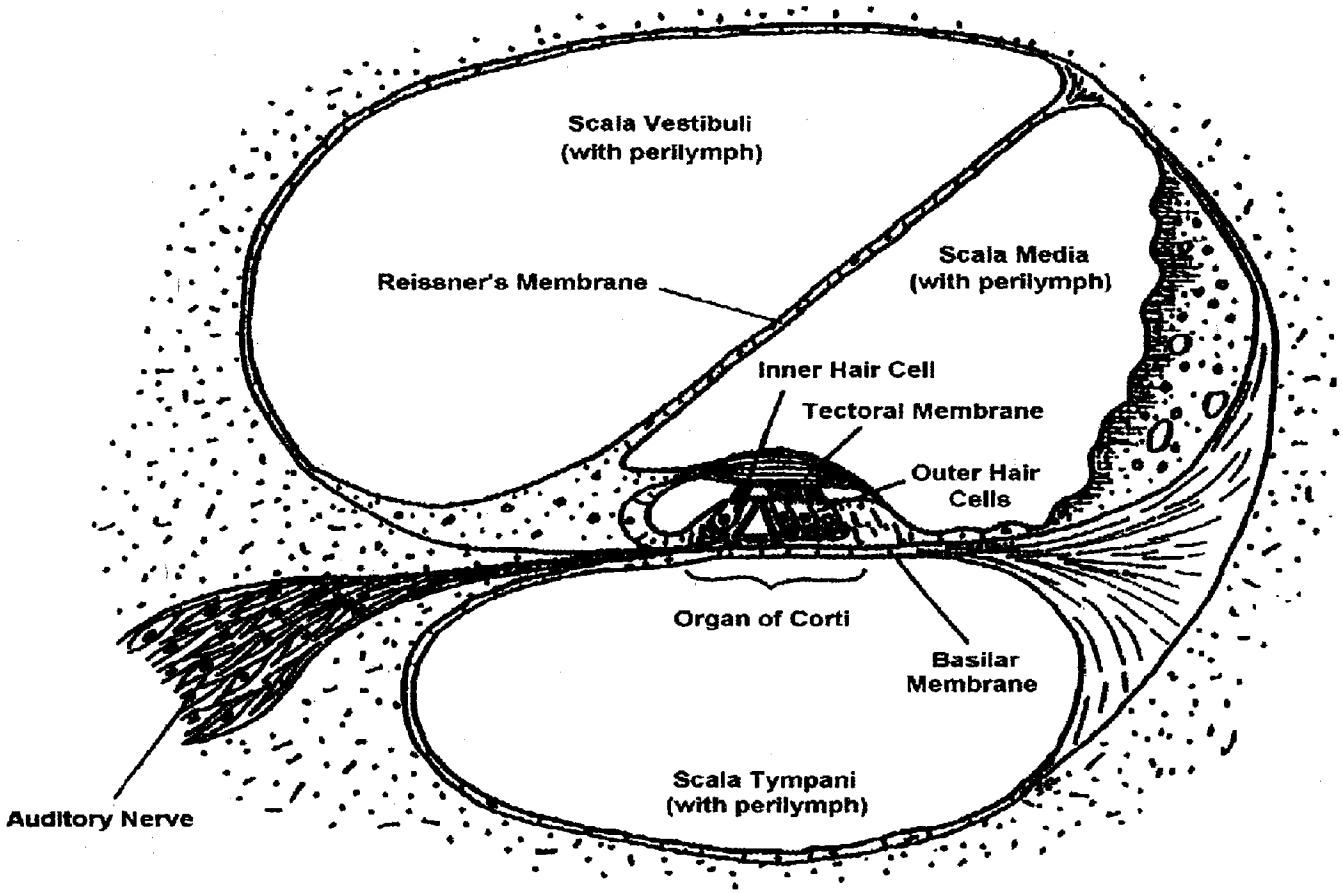


Fig. 2 CROSS - SECTION OF COCHLEA

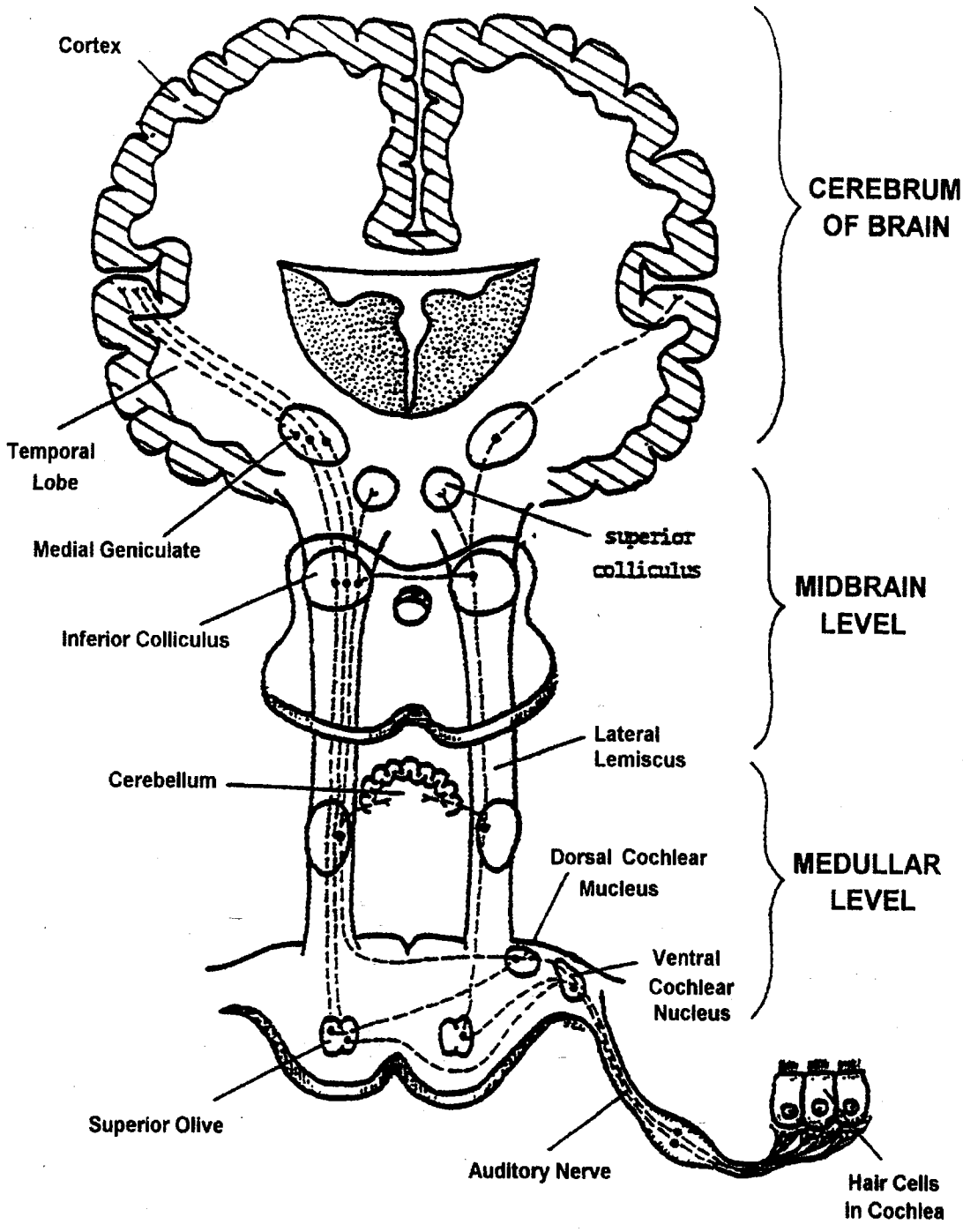


Fig. 3 **AUDITORY PATHWAY OF THE CENTRAL NERVOUS SYSTEM**

HEARING DISORDERS

A disorder of hearing may be defined as a problem with any part of the hearing mechanism, which prevents it from functioning normally. Hearing disorders are commonly classified into major categories: *conductive, sensorineural, mixed, nonorganic* hearing losses, and *central auditory processing.*

A. CONDUCTIVE HEARING LOSS

A conductive hearing loss is defined as a malfunction of the external and/or middle ear while the Inner ear and nerve are normal. The effect of a conductive hearing loss is reduction in the level of sound being conveyed or "conducted" to the inner ear. The symptoms associated with this type of impairment may vary with the degree of the hearing loss but, in general a person with a conductive hearing loss:

- demonstrates either a hearing loss predominately in the **low frequencies** or a hearing loss **extending equally across all frequencies**;
- understands speech well when the **loudness of the speaker is increased** sufficiently to overcome the amount of the conductive hearing loss;
- is usually **not annoyed** by the presence of **loud sounds** in his/her environment;
- appears to **understand speech in a noisy environment better** than a person who has normal hearing;
- may **speak** in a relatively **soft voice.**

The causes of a conductive hearing loss are described according to the part of the hearing mechanism, which is affected: the *external ear* or the *middle ear*.

1. The External Ear

a) The absence or malformation of the pinna and the external auditory canal. This condition is most often a birth defect commonly referred to as atresia. The treatment may involve the surgical construction of the pinna and the external canal.

b) Obstruction of the external auditory canal. The presence of a foreign object or a build up of cerumen in the external canal may cause a reduction in the level of sound reaching the eardrum. The treatment is the removal of the obstruction.

2. **The Middle Ear**

a) Inflammation or infection of the lining of the middle ear cavity. This inflammatory process is commonly referred to as *otitis media* and may result from an upper respiratory infection which has gained access to the middle ear through the Eustachian tube. The infection often results in a build up of fluid in the middle ear space, which, because of its presence, reduces the normal transmission of sound across the ossicular chain. Also, a similar problem occurs when the opening of the Eustachian tube is blocked because of enlarged adenoids. In both cases, if drainage from the middle ear space does not occur and the volume of fluid is increased within the cavity, the eardrum begins to bulge from the force of the fluid pressure. The fluid build up is referred to as middle ear effusion or "serous otitis media". A further increase in fluid build up may result in severe pain and possibly a ruptured eardrum. A short-term problem of otitis media is referred to as *acute otitis media*, whereas, a long-term involvement is referred to as *chronic otitis media*. Another cause of hearing loss among children is related to allergies. The result of this condition is very similar to those described above.

The treatment for middle ear infections may depend on the severity of the problem or, on the specific cause. Therefore, the treatment may vary from the administration of antibiotics, to the insertion of ventilation tubes through the eardrum, the removal of the tonsils and adenoids, or allergy management. If the presence of a long-term infection has destroyed or damaged the ossicles, or has entered the air-filled spaces of the mastoid, it may be necessary for the physician to remove the infected area and surgically rebuild the damaged structures at a later time.

(b) Perforation of the eardrum. Damage to the eardrum may be the result of punctures produced by foreign objects, extremely loud sudden sounds such as an explosion or gun fire, increased external pressure, or by fluid pressure build up within the middle ear space. If the eardrum does not spontaneously repair itself, the physician may find it necessary to patch the perforation.

(c) Otosclerosis. This conductive hearing loss is not thought to be a disease process found in children, but is restricted usually to young adult and older age groups. However, there are isolated reports of this condition occurring among children. Otosclerosis is caused by deposits of a bony substance around the footplate of the stapes. Upon the hardening of the bony substance, the stapes cannot move and the level of the sound reaching the inner ear is reduced.

The treatment for otosclerosis consists of the surgical removal of the stapes or other affected members of the ossicular chain. Following the removal of these bones, the surgeon may insert a synthetic device to bridge the gap between the working portion of the ossicular chair and the oval window, which housed the footplate of the stapes.

(d) Malformation. The ossicles of the middle ear may be malformed at birth causing the sound reaching the inner ear to be reduced. The treatment for this is removal of affected area and insertion of a synthetic device to bridge the gap between the tympanic membrane and the inner ear.

B. SENSORINEURAL HEARING LOSS

A sensorineural hearing loss is defined as a malfunction of the inner ear (cochlea) and/or the auditory nerve, in the presence of a normal external and middle ear. A sensorineural hearing loss may result in both a reduction in the loudness level of sound, and a loss of the ability to discriminate speech sounds. The symptoms associated with a sensorineural hearing loss may vary with the severity of the problem or the location of the problem. A person with a sensorineural hearing loss:

- demonstrates a hearing loss, which may range from mild to profound in one or both ears which may be greater for the higher frequency sounds;
- may demonstrate a reduced ability to understand speech with the common complaint of "I can hear, but I can't understand". The limitations imposed upon the understanding of speech may vary with the amount of the hearing loss. The high frequency sounds represent majority of the consonant sounds which give most of the information to understand what is being said. Refer to figure 4 and 5 in identifying the speech range and visual clues of consonant sounds.
- may display an inability to tolerate loud sounds;
- may have poor speech because of the inability to hear others as well as to monitor oneself;
- may speak in a relatively loud voice;
- will often complain of a ringing or buzzing sound in his ears. This problem, although not totally understood, is referred to as tinnitus.

The cause of sensorineural hearing loss can best be described according to the time in life when the hearing loss begins. If the hearing problem develops before birth, it is termed congenital; if it occurs after birth, it is termed acquired.

1. Congenital Hearing Loss

A congenital hearing loss is one that is present at the time of birth. The causes of congenital hearing problems are listed in the Joint Committee on Infant Hearing (JCIH), 2000 Position Statement which can be found online at: http://www.jcih.org/posstatemts.htm

2. Acquired Hearing Loss

An acquired hearing loss is one that occurs after birth. This loss can be caused by ototoxic medications, infections, exposure to loud noise and others factors. Review the causes of acquired hearing loss listed in the JICH, 2000 Position Statement (http://www.jcih.org/posstatemts.htm).

Since the sensorineural hearing loss is rarely corrected through the use of medication or surgery as is a conductive hearing loss, the first and most practical approach to the reduction of sensorineural hearing loss is through a program of prevention. This program should include the identification of drugs that damage the inner ear (ototoxic drugs), inoculation against childhood diseases, control of noise levels, and counseling with regard to hereditary and Rh blood incompatibility problems.

For those individuals who have been born with or have acquired a sensorineural hearing loss, there are rehabilitation programs designed to reduce the effects of these problems. These may include selection of a suitable hearing aid, a cochlear implant (which is a electronic device surgically implanted into the cochlea with external transmitter and microphone) for those with a profound hearing loss, development of auditory speech reading skills (lip reading), speech therapy, sign language, special educational placement, and psychological counseling.

C. MIXED HEARING LOSS

A mixed hearing loss is a combination of a conductive and a sensorineural loss in the same ear. An example of this is the individual who has a sensorineural congenital hearing loss, while at the same time, is experiencing a conductive hearing loss because of the presence of a middle ear infection.

The symptoms associated with a mixed hearing loss may be either characteristic of a sensorineural or conductive problem, or may be a combination of the symptoms of both disorders. Causes and treatments for mixed hearing losses

are the same as those discussed previously in the sections entitled "Conductive Hearing Loss" and "Sensorineural Hearing Loss".

D. NONORGANIC HEARING LOSS

A nonorganic hearing loss may be defined as a hearing loss for which there is no known physical basis but is thought to be a result of the psychological state of the individual. Some of these children may have a positive history of ear infections, a factor which can be misleading to the audiometrist. The following are symptoms which may be associated with this hearing disorder:

- The hearing test usually reflects mild to moderate, flat, bilateral "hearing loss".
- A child who displays a nonorganic hearing loss usually has good speech and no difficulty in communicating in normal conversation. When the hearing of the person is audiometrically tested, however, the results are significantly poorer than would be predicted.
- The results of repeated hearing tests are often inconsistent for an individual manifesting a nonorganic hearing loss.

In these cases it is essential to determine if a hearing loss is indeed present and to find out if there are factors that may have led to the child falsely elevating their thresholds. In children these factors are more commonly a desire for increased attention and may be accompanied with disruptive social behaviors. Dealing with these behaviors will be the necessary treatment.

E. CENTRAL AUDITORY PROCESSING DISORDER

Central auditory processing refers to the way the brain uses the auditory information it receives that originated from the outer, middle and inner ear. A central auditory processing disorder (CAPD) is an auditory communication disorder. CAPD is not a dysfunction of the mechanisms of hearing. People with this disorder have difficulty understanding, interpreting, and using the information they hear. Children may exhibit poor language and/or listening skills and, although, they may have adequate to high intelligence, their academic performance falls below their estimated potential. The major complaint of parents and teachers is that the child is performing below expected levels at school and doing so for reasons that are not clear. While the cause of CAPD is not known, the resulting communication problems are well documented. Those affected have trouble following verbal directions and may seem distracted and inattentive. CAPD can exist alone or with other problems such as attention deficit disorder, learning disabilities, and language disorders. There is a higher incidence in children with middle ear pathologies.

Children with CAPD often give the impression that they are not listening. Listening, one of the basic tools of learning is a skill used to develop speech, language, and psychosocial behavior. In the first two years of school, children are exposed to verbal information between 75 and 95 percent of the time. The child with CAPD has difficulty listening and following rapid verbal information, this difficulty leads to frustration and to an ever widening learning gap. As academic and social demands increase, children frequently become discouraged, and may lose self-esteem. Children with auditory processing difficulties need to experience success and build self-esteem, even more than they need to increase memory and listening skills. When a central auditory problem is suspected or identified, immediate measures must be taken to improve the child's listening environment, especially in the classroom.

The child with normal hearing on traditional audiologic tests, but with a case history that leads one to suspect the child's auditory skills, is a prime candidate for central auditory evaluation and can be confirmed by central auditory testing.

Children with central auditory processing disorder will show some or all of the following behaviors:

- Inconsistent responses to sound. Parents/teachers may suspect a hearing loss, though audiometric test results are normal.
- Academic performances below their estimated potential, especially in reading, spelling, and language arts.
- Speech problems such as omissions, distortions, and substitutions of sounds in words. Poor vocal monitoring of loudness of his/her voice.
- Poor auditory attention and comprehension, especially in the presence of background noises. Does not pay attention or listen carefully to instructions. Short attention span.
- Difficulty following verbal instructions. Inability or confusion with carrying out verbal instructions.
- Difficulty distinguishing between similar words. Difficulty recalling the oral spelling of a simple word.
- Good performance in a one-to-one situation, but poor performance in the classroom.

SUGGESTIONS FOR PARENTS WITH CHILDREN WHO HAVE CAPD

Experiencing success and developing self-esteem are extremely important for anyone with learning difficulties.

Learn as much as you can about your child's disorder. Consult with teachers and other professionals regarding therapy and progress. Ask questions!

Become familiar with the management techniques used in the classroom and apply them, when appropriate, to home activities.

Create an atmosphere for success:

a. Provide a quiet room for homework away from distractions such as television or music. Children with auditory processing problems have difficulties in competing situations.

b. Expect good listening behavior, eye contact, sitting or standing still. When giving verbal instructions make sure you have your child's attention.

Experiencing success and developing self-esteem are extremely important for anyone with disabilities that interfere with learning. Focus on your child's strengths and offer praise for any accomplishment which exceeds previous levels, the result will be improved self esteem.

Information Sources:

SCHOOL: Audiologist, Speech-Language Pathologist, Special Education Teachers

COMMUNITY: Local college or university speech & hearing departments, yellow pages under Audiologists or Speech-Language Pathologists, public or hospital-based medical libraries.

AUDIOGRAM

An audiogram (figure 4) is a graphic representation of a person's ability to hear. The vertical lines on an audiogram represent pitch or frequency. The horizontal lines of the audiogram represent loudness or intensity (the strength of the sound wave vibrations).

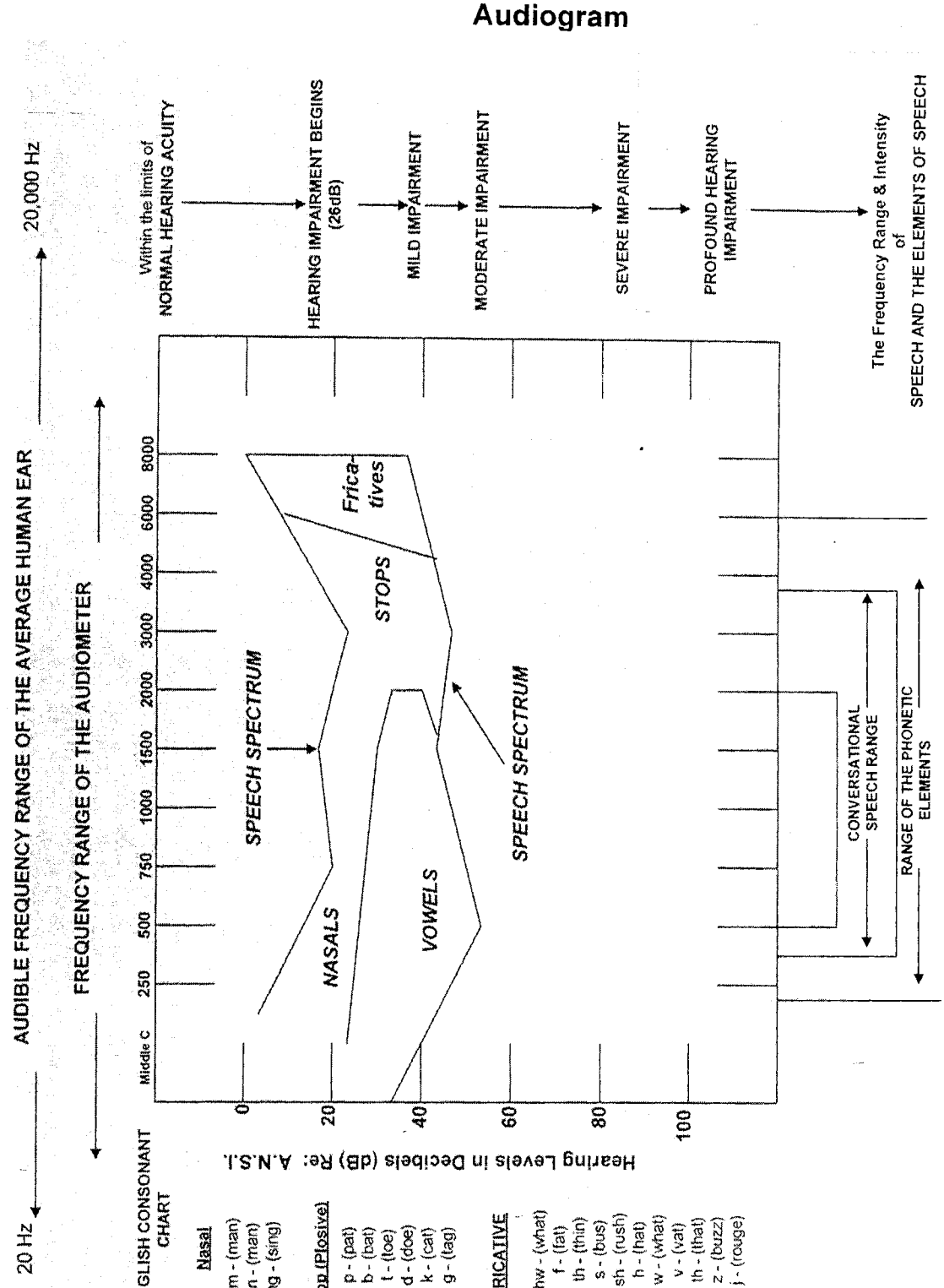
Frequency refers to the number of sound wave vibrations occurring per second. Frequency may be written as **cps** (cycles per second) or **Hz** (Hertz). One cycle per second is one Hertz. On the audiogram, figure 4, the 250Hz vertical line on the left side represents a very low pitch sound and each vertical line to the right represents a higher pitched sound. For screening purposes the most important frequencies are 1000, 2000, ad 4000 Hz because most human speech falls within this range. In individual who has a problem hearing within this range will have difficulty in understanding speech and language.

Intensity, or volume, is measured in decibels (dB). Zero dB is usually the softest sound that can be heard by a normal hearing population at any pitch or frequency. The zero (0) decibel (dB) line near the top of the audiogram represents an extremely soft sound. Each horizontal line below represents a louder sound and may go as loud as 110dB. Decibels are measured on a logarithmic scale; each increase of 10 on the scale represents a 10-fold increase in loudness. 20dB is 10 times as loud as 10dB and 30 dB is 100 times as loud as 10dB, and so on. Normal human conversation is around 60dB; a rock concert can average between 110 and 120dB. Sound becomes painful at 125dB for most people.

A diagnostic hearing evaluation includes determining for each frequency tested the lowest intensity level at which the individual can hear the sound. The lowest intensity (loudness) at which the individual can perceive the sound is called the "threshold level." Plotting the threshold levels (up and down) by the frequency levels (left to right) on the audiogram helps to describe a person's hearing ability. Zero to 25dB at each of the three screening frequencies is considered to be normal hearing, 25-40dB is mild hearing loss, 40-70dB is moderate hearing loss, 70 to 90dB is severe hearing loss and anything over 90dB is considered profound hearing loss or deafness.

The CHDP program requires a hearing screening test and if problems are found, children should be referred to an audiologist for further testing, including the threshold level testing. The screening frequencies required in the CHDP program are 1000, 2000, and 4000Hz. 3000Hz is not required but it is recommended as very useful for obtaining reliable results. The CHDP hearing screening technique uses a constant loudness or dB level of 20 to 25 dB. 20dB is recommended as the best screening level. However, some screening facilities are not quiet enough to obtain accurate results at 20dB and screening at 25dB is acceptable.

FIGURE: 4


Audiogram
AUDIBLE FREQUENCY RANGE OF THE AVERAGE HUMAN EAR
20 Hz
20,000 Hz
FREQUENCY RANGE OF THE AUDIOMETER
Middle C
250
500
750
1000
1500
2000
3000
4000
6000
8000
Hearing Levels in Decibels (dB) Re: A.N.S.I.
0
20
40
60
80
100
SPEECH SPECTRUM
NASALS
VOWELS
STOPS
Frica-tives
SPEECH SPECTRUM
Within the limits of NORMAL HEARING ACUITY
HEARING IMPAIRMENT BEGINS (26dB)
MILD IMPAIRMENT
MODERATE IMPAIRMENT
SEVERE IMPAIRMENT
PROFOUND HEARING IMPAIRMENT
The Frequency Range & Intensity of SPEECH AND THE ELEMENTS OF SPEECH
CONVERSATIONAL SPEECH RANGE
RANGE OF THE PHONETIC ELEMENTS
ENGLISH CONSONANT CHART
Nasal
m - (man)
n - (man)
ng - (sing)
Stop (Plosive)
p - (pat)
b - (bat)
t - (toe)
d - (doe)
k - (cat)
g - (tag)
FRICATIVE
hw - (what)
f - (fat)
th - (thin)
s - (bus)
sh - (rush)
h - (hat)
w - (what)
v - (vat)
th - (that)
z - (buzz)
j - (rouge)