The founders of audiology could not have envisioned the many ways in which this profession would evolve to meet the needs of children and adults with hearing and balance disorders. Breakthroughs continue to come in all areas of audiological diagnosis and treatment, resulting in a profession that is more exciting and rewarding today than ever before.

Treatment is the goal of audiology, and treatment is impossible without diagnosis. Some people have developed the erroneous opinion that audiology is all about doing hearing tests. Surely, testing the hearing function is essential; however, it might appear that many tests could be performed by technical personnel who lack the education required to be total hearing healthcare managers. Historically, the profession has rejected this approach and has developed a model wherein one highly trained, self-supervised audiologist carries the patient and family from taking a personal history through diagnosis and into management. Toward this end, the development of a humanistic, relationship-centered, patient–professional approach to hearing care has evolved, one in which the audiologist guides patients and families to the highest success levels possible.

The profession has moved away from requiring a master’s degree to requiring the Doctor of Audiology (AuD) as the entry-level degree for those wishing to enter the profession of audiology. This is due in part to recognition of the fact that additional education and training are necessary for those practicing audiology so that they can meet the demands of an expanding scope of practice and continuing technological growth.

New to This Edition

With each new edition of this book, we strive not only to update the material to keep content current with recent research, but also to make it more user-friendly for students. Although a great deal of advanced material has been added, the primary target of this book continues to be the new student in audiology. While providing an abundance of how-to information, every effort is made to reveal to the novice that audiology can be a rewarding and fascinating career. In this edition, a number of features have been added or enhanced, including:

- Expansion of the Evolving Case Studies to include more cases.
- A new list of frequently asked questions (FAQs) in each chapter. These lists are derived from students’ actual queries in class and during instructor office hours.
- Updated references to reflect the most recent research.

In addition, for the first time, Introduction to Audiology is available in a whole new format as an eText. The advantages provided in this electronic version are numerous.
The eText Advantage

Publication of Introduction to Audiology in an eText format allows for several advantages over a traditional print format. In addition to greater affordability, this format provides a search function that allows the reader to locate coverage of concepts efficiently. Bold key terms are clickable and take the reader directly to the glossary definition. Index entries are also hyperlinked and take the reader directly to the relevant page of the text. Navigation to particular sections of the book is also possible by clicking on desired sections within the expanded table of contents. Sections of text may be highlighted and reader notes can be typed onto the page for enhanced review at a later date.

All websites provided are now active eText links to aid interested readers in additional research on a topic. It should be noted that neither the authors nor Pearson Education endorse or approve, nor are they responsible for, the content of any third-party website linked to this text. The authors and Pearson Education make no representations as to the content or accuracy of any linked websites.

To further enhance assimilation of new information, links to 20 video clips are interspersed throughout the text and are available through the eText. These video clips demonstrate different aspects of audiological practice. They include illustration of otoscopic technique and basic hearing test procedures, as well as more advanced electroacoustic and electrophysiologic tests, earmold impression technique, hearing aid assessment measures, and more.

At the end of each chapter, readers can access interactive eText multiple-choice Check Your Understanding questions to assess comprehension of text concepts as well as a variety of Activities designed to facilitate learning. Immediate feedback is provided on the appropriateness of responses. We believe use of this material can increase confidence in preparation for examinations and other challenges. In their diagnostic form, these questions and activities can help identify points of knowledge and areas of weakness or knowledge gaps to direct students in their review of materials.

It is our hope that this new eText format will enrich the student’s learning experience and further enhance the learning process. To learn more about the enhanced Pearson eText, go to www.pearsonhighered.com/etextbooks.

How to Use This Book

Throughout this book’s history of nearly four decades, its editions have been used by individuals in classes ranging from introductory to advanced levels. Students who plan to enter the professions of audiology, speech-language pathology, and education of children with hearing impairment have used it. All of these individuals are charged with knowing all they can learn about hearing disorders and their ramifications. To know less is to do a disservice to those children and adults who rely on professionals for assistance.

The chapter arrangement in this book differs somewhat from most audiology texts in several ways. The usual approach is to present the anatomy and physiology of the ear first, and then to introduce auditory tests and remediation techniques. After an introduction to the profession of audiology, this book first presents a superficial look at how the ear works. With this conceptual beginning, details of auditory tests can be understood as they relate to the basic mechanisms of hearing. Thus, with a grasp of the test principles, the reader is better prepared to benefit from the many examples of theoretical test results that illustrate different disorders in the auditory system. Presentations of anatomy and physiology, designed for greater detail and application, follow the descriptions of auditory disorders.
The organization of this book has proved useful because it facilitates early comprehension of what is often perceived as difficult material. Readers who wish a more traditional approach may simply rearrange the sequence in which they read the chapters. Chapters 9 through 12, on the anatomy, physiology, disorders, and treatments of different parts of the auditory apparatus, can simply be read before Chapters 4 through 8 on auditory tests. At the completion of the book, the same information will have been covered.

The teacher of an introductory audiology course may feel that the depth of coverage of some subjects in this book is greater than desired. If this is the case, the primary and secondary headings allow for easy identification of sections that may be deleted. If greater detail is desired, the suggested reading lists at the end of each chapter can provide more depth. The book may be read in modules so that only specified materials are covered.

Each chapter in this book begins with an introduction to the subject matter and a statement of instructional objectives. Liberal use is made of headings, subheadings, illustrations, and figures. A summary at the end of each chapter repeats the important portions. Terms that may be new or unusual appear in bold print and are defined in the book’s comprehensive glossary. Review tables summarize the high points within many chapters. Readers wishing to test their understanding of different materials may find the questions at the end of each chapter useful. For those who wish to test their ability to synthesize what they learn and solve some practical clinical problems, the Evolving Case Studies in selected chapters provide this opportunity. The indexes at the back of this book are intended to help readers to find desired materials rapidly.

Acknowledgments

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PART I

ELEMENTS OF AUDIOLOGY
The first part of this book requires no foreknowledge of audiology. Chapter 1 presents an overview of the profession of audiology, its history, and directions for the future. Chapter 2 is an elementary look at the anatomy of the auditory system to the extent that basic types of hearing loss and simple hearing tests can be understood. Oversimplifications are clarified in later chapters. Tuning-fork tests are described here for three purposes: first, because they are practiced today by many physicians; second, because they are an important part of the history of the art and science of audiology; and third, because they illustrate some fundamental concepts that are essential to understanding contemporary hearing tests. Chapter 3 discusses the physics of sound and introduces the units of measurement that are important in performing modern audiologic assessments. Readers who have had a course in hearing science may find little new information in Chapter 3 and may wish to use it merely as a review. For those readers for whom this material is new, its comprehension is essential for understanding what follows in this text.
The Profession of Audiology

**LEARNING OBJECTIVES**

The purpose of this opening chapter is to introduce the profession of audiology, from its origins through its course of development to its present position in the hearing-healthcare delivery system. At the completion of this chapter, the reader should be able to
- Describe the evolution of audiology as a profession.
- Discuss the impact of hearing impairment on individuals and society.
- List specialty areas within audiology and the employment settings within which audiologists may find themselves.
- Describe the reasons that speech-language pathologists may interact closely with audiologists as they provide services within their chosen professions.

The profession of audiology has grown remarkably since its inception only a little more than 70 years ago. What began as a concentrated effort to assist hearing-injured veterans of World War II in their attempts to reenter civilian life has evolved into a profession serving all population groups and all ages through increasingly sophisticated diagnostic and rehabilitative instrumentation. The current student of audiology can look forward to a future within a dynamic profession, meeting the hearing needs of an expanding patient base.
Prior to World War II, hearing-care services were provided by physicians and commercial hearing aid dealers. Because the use of hearing protection was not common until the latter part of the war, many service personnel suffered the effects of high-level noise exposure from modern weaponry. The influx of these service personnel reentering civilian life created the impetus for the professions of otology (the medical specialty concerned with diseases of the ear) and speech pathology (now referred to as speech-language pathology) to work together to form military-based aural rehabilitation centers.

These centers met with such success that, following the war, many of the professionals involved in the programs’ development believed that their services should be made available within the civilian sector. It was primarily through the efforts of the otologists that the first rehabilitative programs for those with hearing loss were established in communities around the country, but it was mainly those from speech-language pathology, those who had developed the audiometric techniques and rehabilitative procedures of the military clinics, who staffed the emerging community centers (Henoch, 1979).

Audiology developed rapidly as a profession distinct from medicine in the United States. While audiology continues to evolve outside the United States, most professionals practicing audiology in other countries are physicians, usually otologists. Audiometric technicians in many of these countries attain competency in the administration of hearing tests; however, it is the physician who dictates the tests to be performed and solely the physician who decides on the management of each patient. Some countries have developed strong academic audiology programs and independent audiologists, like those in the United States, but, with the exception of geographically isolated areas, most audiologists around the globe look to American audiologists for the model of autonomous practice that they wish to emulate.

The derivation of the word audiology is itself unclear. No doubt purists are disturbed that a Latin root, audire (to hear), was fused with a Greek suffix, logos (the study of), to form the word audiology. It is often reported that audiology was coined as a new word in 1945 simultaneously, yet independently, by Captain Raymond Carhart1 and Dr. Norton Canfield, both active in the establishment of military aural rehabilitation programs. However, a course established in 1939 by the Auricular Foundation Institute of Audiology entitled “Audiological Problems in Education” and a 1935 instructional film developed under the direction of Mayer Shier titled simply Audiology clearly predate these claims (Skafte, 1990). Regardless of the origin of the word, an audiologist today is defined as an individual who, “by virtue of academic degree, clinical training, and license to practice and/or professional credential, is uniquely qualified to provide a comprehensive array of professional services related to the audiologic identification, assessment, diagnosis, and treatment of persons with impairment of auditory and vestibular function, and to the prevention of impairments associated with them” (American Academy of Audiology, 2004).

Academic Preparation in Audiology

In the United States, educational preparation for audiologists evolved as technology expanded, leading to an increasing variety of diagnostic procedures and an expanded professional scope of practice (American Academy of Audiology, 2004; American Speech-Language-Hearing Association, 2004b). Audiology practices have grown to encompass the identification of hearing loss, the differential diagnosis of hearing impairment, and the nonmedical treatment of hearing impairment and balance disorders. What began as a profession with a bachelor’s level preparation quickly transformed into a profession with a required minimum of a master’s degree to attain a state license, now held forth as the mandatory prerequisite for clinical
practice in most states. More than a quarter of a century ago, Raymond Carhart, one of audiology’s founders, recognized the limitations imposed by defining the profession at the master’s degree level (Carhart, 1975). Yet it was another 13 years before a conference, sponsored by the Academy of Dispensing Audiologists, set goals for the profession’s transformation to a doctoral level (Academy of Dispensing Audiologists, 1988).

In recent years academic programs have transitioned to the professional doctorate for student preparation in audiology, designated as the doctor of audiology (Au.D.). At most universities, the Au.D. comprises four years of professional preparation beyond the bachelor’s degree, with heavy emphasis on didactic instruction in the early years gradually giving way to increasing amounts of clinical practice as students progress through their programs. The final (fourth) year consists of a full-time clinical placement usually in a paid position.

Although the required course of study to become an audiologist remains somewhat heterogeneous, course work generally includes hearing and speech science, anatomy and physiology, fundamentals of communication and its disorders, counseling techniques, electronics, computer science, and a range of course work in diagnostic and rehabilitative services for those with hearing and balance disorders. Through this extensive background, university programs continue to produce clinicians capable of making independent decisions for the betterment of those they serve.

### Licensing and Certification

The practice of audiology is regulated in the United States through license or registration in every state of the union and the District of Columbia. Such regulation ensures that audiology practitioners have met a minimum level of educational preparation and, in many states, that a minimum of continuing study is maintained to help ensure competencies remain current. A license to practice audiology or professional registration as an audiologist is a legal requirement to practice the profession of audiology. Licensure and registration are important forms of consumer protection, and loss or revocation of this documentation prohibits an individual from practicing audiology. To obtain an audiology license, one must complete a prescribed course of study, acquire approximately 2,000 hours of clinical practicum, and attain a passing score on a national examination in audiology.

In contrast to state licensure and registration, certification is not a legal requirement for the practice of audiology. Audiologists who choose to hold membership in the American Speech-Language-Hearing Association (ASHA) are required by ASHA to hold the Certificate of Clinical Competence in Audiology, attesting that a designated level of preparation as an audiologist has been met and that documented levels of continuing education are maintained throughout one’s career. Many audiologists select certification from the American Board of Audiology as a fully voluntary commitment to the principles of lifelong continuing education. ABA certification is an attestation that one holds him- or herself to a higher standard than may be set forth by professional associations or in the legal documents of licensure or registration.

The use of support personnel within a variety of practice settings is growing. The responsibilities of these “audiologist assistants” have been delineated by the American Academy of Audiology (1997). Licensing laws in nearly half of the states define permitted patient care assignments for audiology assistants. Assistants can be quite valuable in increasing practice efficiency and meeting the needs of a growing population with hearing loss. It is audiologists’ responsibility to ensure that their assistants have the proper preparation and training to perform assigned duties adequately.
Although the profession of audiology was formed under the aegis of the military, its growth was rapid within the civilian sector because of the general prevalence of hearing loss and the devastating impact that hearing loss has on the lives of those affected. The reported prevalence of hearing loss varies somewhat depending on the method of estimation (actual evaluation of a population segment or individual response to a survey questionnaire), the criteria used to define hearing loss, and the age of the population sampled. However, following the world health organization’s definition for hearing loss, prevalence in the United States may be as high as 30 million Americans with hearing loss in both ears or as many as 48 million with hearing loss in at least one ear (see Table 1.1).

The prevalence of hearing loss increases with age, and it has been estimated that the number of persons with hearing loss in the United States over the age of 65 years will reach nearly 13 million by 2015. The number of children with permanent hearing loss is far lower than the number of adults. However, the prevalence of hearing loss in children is almost staggering if we consider those children whose speech and language development and academic performances may be affected by mild transient ear infections so common among children. While not all children have problems secondary to ear pathologies, 75 percent of children in the United States will have at least one ear infection before 3 years of age (National Institute on Deafness and Other Communication Disorders, 2010a).

For children with recurrent or persistent problems with ear infections, the developmental impact may be significant. Studies have shown that children prone to ear pathologies may lag behind their peers in articulatory and phonological development, the ability to receive and express thoughts through spoken language, the use of grammar and syntax, the acquisition of vocabulary, the development of auditory memory and auditory perception skills, and social maturation (Clark & Jaindl, 1996). There is indication, however, that children with early history of ear infections, while initially delayed in speech and language, may catch up with their peers by the second year of elementary school (Roberts, Burchinal, & Zeisel, 2002; Zumach, Gerrits, Chenault, & Anteunis, 2010). Even so, a study reporting no significant differences in speech understanding in noise between groups of third- and fourth-grade students with and without histories of early ear infections did, however, find a much greater range in abilities for those with a positive history of ear infections (Keogh et al., 2005). This study demonstrated that some of these children experience considerable difficulty in speech understanding.

**TABLE 1.1 Prevalence of Hearing Loss and Related Disorders**

<table>
<thead>
<tr>
<th>Condition</th>
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<tbody>
<tr>
<td>50 million people have tinnitus (ear or head noises).</td>
</tr>
<tr>
<td>30 million are exposed to hazardous noise levels or ototoxic chemicals at work.</td>
</tr>
<tr>
<td>48 million people are hard of hearing in one or both ears.</td>
</tr>
<tr>
<td>10 million people have some degree of permanent, noise-induced hearing loss.</td>
</tr>
<tr>
<td>2 million people are classified as deaf.</td>
</tr>
<tr>
<td>6 of every 1,000 children may be born with hearing impairment.</td>
</tr>
<tr>
<td>1 in 6 baby boomers (ages 41 to 59) have a hearing problem.</td>
</tr>
<tr>
<td>1 in 14 Generation Xers (ages 29 to 40), or 7.4%, already have hearing loss.</td>
</tr>
<tr>
<td>15% of school-age children may fail a school hearing screening mostly due to a transient ear infection.</td>
</tr>
<tr>
<td>90% of children in the United States will have had at least one ear infection before the age of 6 years.</td>
</tr>
</tbody>
</table>

Sources: Johns Hopkins Medical Center (www.ata.org); Tinnitus Association (www.ata.org); Centers for Disease Control and Prevention (www.cdc.gov); National Institute for Occupational Safety and Health (www.cdc.gov/niosh/topics/noise); Better Hearing Institute (www.betterhearing.org).
The fact that many children with positive histories of ear infection develop no speech, language, or educational delays suggests that factors additional to fluctuating hearing abilities may also be involved in the learning process (Davis, 1986; Williams & Jacobs, 2009), but this in no way reduces the need for intervention. The impact of more severe and permanent hearing loss has an even greater effect on a child’s developing speech and language and educational performance (Diefendorf, 1996) and also on the psychosocial dynamics within the family and among peer groups (Altman, 1996; Clark & English, 2014).

Often, the adult patient’s reaction to the diagnosis of permanent hearing loss is to feel nearly as devastated as that of the caregivers of young children with newly diagnosed hearing impairment (Martin, Krall, & O’Neal, 1989). Yet the effects of hearing loss cannot be addressed until the reason for the hearing loss is diagnosed. Left untreated, hearing loss among adults can seriously erode relationships both within and outside the family unit. Research has demonstrated that, among older adults, hearing loss is related to overall poor health, decreased physical activity, and depression. Indeed, Bess, Lichtenstein, Logan, Burger, and Nelson (1989) demonstrated that progressive hearing loss among older adults is associated with progressive physical and psychosocial dysfunction.

In addition to the personal effects of hearing loss on the individual, the financial burden of hearing loss placed upon the individual, and society at large, is remarkable. The National Institute on Deafness and other Communication Disorders (2010b) reports that the total annual costs for the treatment of childhood ear infections may be as high as $5 billion in the United States. When one adds to this figure the costs of educational programs and (re)habilitation services for those with permanent hearing loss and the lost income when hearing impairment truncates one’s earning potential, the costs become staggering. Northern and Downs (1991) estimate that for a child of 1 year of age with severe hearing impairment and an average life expectancy of 71 years, the economic burden of deafness can exceed $1 million.

A survey conducted by the Better Hearing Institute of over 44,000 American families reported that those who are failing to treat their hearing problems are collectively losing at least $100 billion in annual income (National American Precis Syndicated, 2007). While many people think of hearing loss as affecting mainly older individuals, most people with hearing loss are in the prime of their lives, including one out of six baby boomers ages 41 to 59 years. While the Better Hearing Institute study reported that the use of hearing aids can reduce the effects of lost income by nearly 50 percent, only one in four with hearing problems seeks treatment.

A Blending of Art and Science

Audiology is a scientific discipline based upon an ever-growing body of research on the fundamentals of hearing, the physiologic and psychosocial impacts of lost hearing, and the technological aspects of both hearing diagnostics and pediatric and adult hearing-loss treatments. Over the years, some have cautioned that audiology should avoid becoming mired in the technological aspects of service delivery. Indeed, as Hawkins (1990) points out, the importance of the many technological advances seen in audiology may be of only minor importance to the final success with patients when compared to the counseling and rehabilitative aspects of audiological care.

The blending of the science of audiology with the art of patient treatment makes audiology a highly rewarding profession. The humanistic side of professional endeavors in audiology is what brings audiologists close to the patients and families they serve and makes the outcomes of
provided services rewarding for both the practitioner and the recipient of care. All patients bring to audiology clinics their own life stories, personal achievements, and recognized (and unrecognized) limitations. Audiologists must learn to listen supportively, thus allowing patients to tell their own stories, so that both diagnostics and rehabilitation may be tailored to individual needs effectively (Clark & English, 2014).

**Clinical Commentary**

Speech-language pathologists often find that they work in close concert with audiologists. This may be true with children, whose hearing loss can have a direct impact on speech and language development, as well as with older adults, who have a higher incidence of age-related communication disorders. The frequent coexistence of hearing disorders and speech and language problems has led the American Speech-Language-Hearing Association to include hearing-screening procedures, therapeutic aspects of audiological rehabilitation, and basic checks of hearing aid performance within the speech-language pathologist’s scope of practice (ASHA, 2001, 2004a).

**Audiology Specialties**

Most audiology training programs prepare audiologists as generalists, with exposure and preparation in a wide variety of areas. Following graduation, however, many audiologists discover their chosen practice setting leads to a concentration of their time and efforts within one or more specialty areas of audiology. In addition, many practice settings and specialty areas provide audiologists with opportunities to participate in research activities to broaden clinical understanding and application of diagnostic and treatment procedures. When those seeking audiological care are young or have concomitant speech or language difficulties, a close working relationship of audiologists with professionals in speech-language pathology or in the education of those with hearing loss often develops.

The varied nature of the practice of audiology can make an audiology career stimulating and rewarding. Indeed, the fact that audiologists view their careers as both interesting and challenging has been found to result in a high level of job satisfaction within the profession (Martin, Champlin, & Streetman, 1997). In 2013, audiology was ranked as the fourth most desirable profession in the United States out of 200 rated occupations, based on five criteria including hiring outlook, income potential, work environment, stress levels, and physical demand (CareerCast, 2013). The appeal of audiology as a career choice is heightened by the variety of specialty areas and employment settings available to audiologists.

**Medical Audiology**

The largest number of audiologists are currently employed within a medical environment, including community and regional hospitals, physicians’ offices, and health maintenance organizations. Audiologists within military-based programs, Department of Veterans Affairs medical centers, and departments of public health often work primarily within the specialty of medical audiology. Many of the audiology services provided within this specialty focus on the provision of diagnostic assessments to help establish the underlying cause of hearing or balance disorders (see Figure 1.1). The full range of diagnostic procedures detailed in this
text may be employed by the medical audiologist with patients of all ages. Results of the final audiological assessment are combined with the diagnostic findings of other medical and nonmedical professionals to yield a final diagnosis. Medical audiologists may also work within newborn-hearing-loss-identification programs and monitor the hearing levels of patients being treated with medications that can harm hearing. Additional responsibilities frequently include nonmedical endeavors such as hearing aid dispensing.

**Educational Audiology**

Following the federal mandates dictated by Public Law 94-142, the Education for All Handicapped Children Act, in 1975 and Public Law 99-457, the Education for the Handicapped Amendments, in 1986, the need for audiologists within the schools has increased. Yet fewer than half the audiologists required to meet the needs of children in the public schools are serving in that capacity. Educational audiologists bear a wide range of responsibilities in minimizing the devastating impact that hearing loss has on the education of young children, and in the educational setting they may work closely with professionals in the education of deaf and hearing-impaired children and speech-language pathology. Audiologists in this specialty are responsible for the identification of children with hearing loss and referral to medical and other professional services as needed; the provision of rehabilitative activities, including auditory training, speechreading, and speech conservation; the creation of hearing-loss-prevention programs; counseling and guidance about hearing loss for parents, pupils, and teachers; and the selection and evaluation of individual and group amplification (Johnson & Seaton, 2011).
Pediatric Audiology

Work with children and their families has perhaps more far-reaching effects than any other challenge audiologists undertake. In addition to developing a honed proficiency in the special considerations involved with the diagnostic evaluation of young children, pediatric audiologists must be prepared to bring to their clinical endeavors an empathy that will help guide parents and families through what is an exceptionally difficult time in their lives. One of the pediatric audiologist’s primary roles is facilitating parents’ efforts to meet the many (re)habilitative challenges the child and family will face.

Nonaudiology professionals who work in the areas of communication and education for children with hearing loss frequently work closely with pediatric audiologists. Audiologists within a variety of employment settings may work with children and their families. However, those within pediatric hospitals, large rehabilitation centers, and community-based hearing and speech centers often see a higher percentage of the pediatric population.

Dispensing/Rehabilitative Audiology

Nearly 40 years ago, ASHA rescinded its previous ban on the dispensing of hearing aids by audiologists. Since that time, audiologists have become increasingly active in the total hearing rehabilitation of their patients. (See Chapter 14.) While many audiologists establish their dispensing/rehabilitative practices within hospitals or physicians’ offices, a growing number are attracted to the greater autonomy afforded by an independent practice within their communities. Regardless of employment setting, hearing aid dispensing is part of the audiologist’s responsibilities.

Industrial Audiology

As discussed in Chapter 11, exposure to high levels of noise is one of the primary contributors to insidious hearing loss. Many of today’s industries produce noise levels of sufficient intensity to damage employees’ hearing permanently. According to the National Institute for Occupational Safety and Health (2001), more than 30 million U.S. workers are exposed to hazardous noise levels, resulting in noise-induced occupational hearing loss being one of the most common occupational diseases and the second most commonly reported occupational injury. Allowable levels and duration of employee noise exposure have been set by the U.S. Department of Health. To ensure that adequate hearing protection is provided by the employer and used effectively by the employee, audiologists who work in industry design hearing-conservation programs to identify and measure excessive noise areas, consult in the reduction of noise levels produced by industrial equipment, monitor employee hearing levels, educate employees on the permanent consequences of excessive noise exposure, and fit hearing protection for those employees with excessive exposure. While some audiologists practice full-time exclusively within industrial settings, most who work with industry provide these services as part-time contracted consultants, or as an adjunct to their work within other practice settings. As consultants to industry, audiologists may work in conjunction with attorneys, industrial physicians and nurses, industrial hygienists, safety engineers, and industrial relations and personnel officers within management and unions.

Tele-Audiology

The practice of tele-medicine is finding ways to reach out to remote areas of the world to serve patients whose inaccessible locations preclude inclusion for medical diagnosis and treatment in traditional ways. This branch of audiology has proven to be especially valuable for those
living in remote and developing areas of the world. Further discussion of tele-audiology can be found in Chapter 15. The World Health Organization (WHO) reports that hearing loss is now the number one disability, so it was inevitable that tele-audiology would become more important. As a matter of fact, the vast majority of individuals, perhaps as many as 90 percent of those in need (Nemes, 2010), live away from centers that deliver traditional audiological diagnosis and treatment and can benefit from this novel approach.

Using tele-audiology, an entire battery of hearing-care services can be delivered to persons in need who do not have the means or opportunity to travel sometimes great distances to receive services traditionally located in urban areas. These regions literally encompass the entire world, but they can also include low-income areas in the United States. This is what has led to the development and implementation of the tele-audiology network.

Special models need to be developed with application to different geographic, cultural, and financial situations. There is little doubt that the desire of the profession of audiology to reach all those in need of hearing healthcare will lead to many changes and improvements in this unique specialty.

Recreational and Animal Audiology

While some audiologists will find themselves working largely or wholly within other specialty areas of audiology, most who work within either recreational or animal audiology do so as a smaller part of their employment responsibilities. Chapter 11 details the deleterious effects of intense sounds on human hearing. One must only wonder at the human proclivity to place one’s sense of hearing willingly in harm’s way. Yet it is true that many activities, ranging from the enjoyment of music and the use of firearms to the growing recreational use of motorboats, snowmobiles, motorbikes, and racecars, can have a negative impact on human hearing. Recreational audiologists continue to find opportunities to provide hearing-conservation services to those who enjoy excessively loud forms of recreation.

An even more recent, and smaller, specialty area in audiology lies in the audiological assistance given to nonhuman animals, particularly the canine, “man’s best friend” (see Figure 1.2). There are more than 80 breeds of dogs with documented congenital hearing loss, and many dogs experience the same age-related declines in hearing seen in humans. Counseling about dog safety and communication issues is an important service provided by
animal audiologists (Scheifele, Clark, & Scheifle, 2012). Hearing conservation for service animals, especially military working dogs, is also a concern of animal audiologists and these dogs’ handlers, especially considering the substantial time and money that is invested in the training of these animals. Ongoing research continues on effective hearing-loss prevention and management for canines.

**Employment Settings**

While some audiologists list their primary employment function as a researcher, administrator, or university teacher, more than 82 percent consider themselves to be direct clinical service providers (American Academy of Audiology, 2010). As noted in Figure 1.3, more audiologists deliver services within a medical environment than within any other single employment setting. Private practice constitutes the second largest employment affiliation for audiologists.

The trend of most students in master’s degree programs to state a preference for employment within a medical setting may be giving way to Au.D. students’ aspirations of future employment within private practice (Freeman & Doyle, 2001). By far the most rapidly growing employment setting for audiologists is that of private practice. Today, private-practice audiology concentrates on the dispensing/rehabilitative efforts of the audiologist; however, a number of practices offer a wide array of diagnostic services as well.

**FIGURE 1.3** An American Academy of Audiology membership survey reports that the majority of audiologists are employed within a medical setting (hospital, clinic, or physician’s office). More than 82 percent of surveyed audiologists report that they are direct providers of clinical services. Unlike just a few years ago, the single primary employment setting for audiologists is private practice.

Note: Responses = 9,203.
(Source: American Academy of Audiology, Membership Demographics, 2010.)
A number of professional societies for the advancement of the interests of audiologists and those they serve has evolved as the profession itself has grown. The American Speech Correction Association (originally founded in 1927 as the American Society for the Study of Disorders of Speech) adopted the new profession of audiology in 1947 when its name was changed to the American Speech and Hearing Association (ASHA). Renamed the American Speech-Language-Hearing Association in 1978 (while retaining its recognized acronym), ASHA was instrumental in setting standards for the practice of audiology and for the accreditation of academic programs for audiologists and speech-language pathologists. ASHA provides continuing education and professional and scientific journals for these two professions, which share a common heritage.

Because of the need for a strong national association that could represent the unique needs and interests of the audiology profession, the American Academy of Audiology (AAA) was founded in 1988. Rapidly embraced by the profession, AAA became the home of more than 6,000 audiologists before it was 10 years old and well over 10,000 by the time the academy was 20 years old. The academy is committed to the advancement of audiological services through increased public awareness of hearing and balance disorders among the U.S. population as well as national governmental agencies and congressional representatives. The academy’s journals and continuing education programs are instrumental for audiologists’ maintaining a high level of expertise in their chosen profession. AAA, along with ASHA, continues to set and revise practice standards, protocols, and guidelines for the practice of audiology to ensure quality patient care.

In addition to belonging to one or both of the national associations for audiology as well as their state academy of audiology, many practitioners belong to organizations that promote their chosen area of expertise. Audiologists may affiliate with other audiologists with similar interests through the Academy of Rehabilitative Audiology, the Academy of Doctors of Audiology, or the Educational Audiology Association. The American Auditory Society presents a unique opportunity for audiologists to interact with a variety of medical and nonmedical professionals whose endeavors are largely directed toward work with those who have hearing impairment. Some audiologists find professional growth through affiliation with one or more of the primarily consumer-oriented associations such as the Hearing Loss Association of America and the Alexander Graham Bell Association for the Deaf and Hard of Hearing.

Relative to other professions in the health arena, audiology is a newcomer, emerging from the combined efforts of otology and speech pathology during World War II. Following the war, this new area of study and practice grew rapidly within the civilian sector because of the high prevalence of hearing loss in the general population and the devastating effects on individuals and families when hearing loss remains untreated. To support the needs of those served most fully, especially within the pediatric population, audiologists often maintain a close working relationship with speech-language pathologists and educators of those with hearing impairment. A mutual respect for what each profession brings to the (re)habilitation of those with hearing impairments leads to the highest level of remediation for those served.

Today the profession of audiology supports a variety of specialty areas. Given projected population demographics, students choosing to enter this profession will find themselves well placed for professional growth and security.
Websites

The following websites will help you connect to professional and consumer organizations related to audiological concerns, professional issues, legislative initiatives, service providers, and consumer education.

• Academy of Doctors of Audiology, www.audiologist.org
• Academy of Rehabilitative Audiology, www.audrehab.org
• Alexander Graham Bell Association for the Deaf and Hard of Hearing, www.agbell.org
• American Academy of Audiology, www.audiology.org
• American Auditory Society, www.amaunderitorysoc.org
• American Board of Audiology, www.americanboardofaudiology.org
• American Speech-Language-Hearing Association, www.asha.org
• American Tinnitus Association, www.ata.org
• Better Hearing Institute, www.betterhearing.org
• Educational Audiology Association, www.edaud.org
• Facility for the Education and Testing of Canine Hearing/Laboratory for Animal Bioacoustics, www.fetchlab.org
• Hearing Health Fundation, www.hearinghealthfoundation.org
• Hearing Loss Association of America, www.hlaa.org
• Military Audiology Association, www.militaryaudiology.org

Frequently Asked Questions

Q How do you know when to go to a physician and when to go to an audiologist?
A Generally audiologists see patients whose primary concern is hearing loss, and physicians see those with a history of pain or disease.

Q Is it possible to lose one’s hearing completely?
A Yes, this is possible, but total loss of hearing is extremely rare.

Q What is an otologist? Does it relate to an otolaryngologist (ENT)?
A Otologists are otolaryngologists who limit their practices to diseases of the ear. Other ENT specialists may concentrate only on diseases of the nose (rhinologists) or throat (laryngologists).

Q Does the field of audiology exist in other countries?
A Yes, but the requirements for practice vary. In Australia, New Zealand, and Canada, requirements for certification are similar to the United States. Most other countries require audiologists to be physicians, usually otolaryngologists, who supervise the more technical aspects of the field (like testing), which is carried out by technicians.

Q What is the difference between a license in audiology and certification in audiology?
A A license, or registration with the state, is required by all 50 states and the District of Columbia to practice audiology, while certification is not. Certification in audiology is available through both the American Board of Audiology and the American Speech-Language-Hearing Association. Certification is not legally required to practice audiology.

Q What is the difference between the two certifying agencies for audiology?
A Certification through the American Board of Audiology (ABA) is a voluntary certification designed to demonstrate a practitioner’s dedication to a high level of continuing education. ABA certification is independent of membership in any of the national audiology associations. Those holding certification through the American Speech-Language-Hearing Association (ASHA) must maintain membership in ASHA.

Q Do many audiologists conduct research outside a university setting?
A The majority of research publications are associated with universities, but many come from other places, such as private practice, community speech and hearing centers, and Veterans Administration hospitals. The exact numbers are not known.

Suggested Reading


Endnote

1. Dr. Raymond Carhart (1912–1975), largely regarded as the father of audiology.
Chapter 2

The Human Ear and Simple Tests of Hearing

**LEARNING OBJECTIVES**

The purpose of this chapter is to present a simplified explanation of the mechanism of human hearing and to describe tuning-fork tests that provide information about hearing disorders. Because of the structure of this chapter, some of the statements have been simplified. These basic concepts are expanded in later chapters in this book. At the completion of this chapter, the reader should be able to:

- Define basic vocabulary relative to the ear.
- Understand the core background for study of more sophisticated hearing tests.
- Describe the general anatomy of the hearing mechanism and its pathways of sound.
- List and describe the three types of hearing loss presented.
- Outline the expected tuning-fork test results for different types of hearing loss.

**ANATOMY IS CONCERNED** with how the body is structured, and physiology is concerned with how it functions. To facilitate understanding, the anatomist neatly divides the mechanisms of hearing into separate compartments, at the same time realizing that these units actually function as one. Sound impulses pass through the **auditory tract**, where they are converted from acoustical to mechanical to hydraulic to chemical and electrical energy, until finally they are received by the brain, which makes the signal discernible.

We test human hearing by two sound pathways: **air conduction (AC)** and **bone conduction (BC)**. Tests of hearing utilizing **tuning forks** are by no means modern, but they illustrate hearing via these two pathways. Tuning-fork tests may compare the hearing of the patient to that of a presumably normal-hearing examiner, the relative sensitivity by air conduction and bone conduction, the effects on bone conduction of closing the opening into the ear, and the lateralization of sound to one ear or the other by bone conduction.
Anatomy and Physiology of the Ear

A simplified look at a coronal section through the ear (see Figure 2.1) illustrates the division of the hearing mechanism into three parts. The outer ear comprises a shell-like protrusion from each side of the head, a canal through which sounds travel, and the eardrum membrane (more correctly called the tympanic membrane) at the end of the canal. The middle ear consists of an air-filled space with a chain of tiny bones, the third of which, the stapes, is the smallest in the human body. The portion of the inner ear that is responsible for hearing is called the cochlea; it is filled with fluids and many microscopic components, all of which serve to convert waves into a message that travels to the stem (base) of the brain via the auditory nerve. The brain stem is not coupled to the highest auditory center in the cortex by a simple neural connection. Rather, there is a series of waystations that receive, analyze, and transmit impulses along the auditory pathway. Stimuli reaching the inner ear directly by bone conduction bypass the conductive mechanisms of the outer ear and the middle ear.

Pathways of Sound

Those persons whose primary interest is in the measurement of hearing sometimes divide the hearing mechanism differently than do anatomists. Audiologists and physicians separate the ear into the conductive portion—consisting of the outer and middle ears—and the sensory/neural portion—consisting of the inner ear and the auditory nerve. This type of breakdown is illustrated in the block diagram in Figure 2.2.

Any sound that courses through the outer ear, middle ear, inner ear, and beyond is heard by air conduction. It is possible to bypass the outer and middle ears by vibrating the skull mechanically and stimulating the inner ear directly. In this way, the sound is heard by bone.
Therefore, hearing by air conduction depends on the functioning of the outer, middle, and inner ear and of the neural pathways beyond; hearing by bone conduction depends on the functioning of the inner ear and beyond.

**Types of Hearing Loss**

**Conductive Hearing Loss**

A decrease in the strength of a sound is called **attenuation**. Sound attenuation is precisely the result of a conductive hearing loss. Whenever a barrier to sound is present in the outer ear or middle ear, some loss of hearing results. Individuals find that their sensitivity to sounds that
are introduced by air conduction is impaired by such a blockage. If the sound is introduced by bone conduction, it bypasses the obstacle and goes directly to the sensory/neural mechanism. Because the inner ear and the other sensory/neural structures are unimpaired, the hearing by bone conduction is normal. This impaired air conduction with normal bone conduction is called a conductive hearing loss and is diagrammed in Figure 2.2B. In this illustration, the hearing loss is caused by damage to the middle ear. Outer ear abnormalities produce the same relationship between air and bone conduction.

**Sensory/Neural Hearing Loss**

If the disturbance producing the hearing loss is situated in some portion of the sensory/neural mechanism, such as the inner ear or the auditory nerve, a hearing loss by air conduction results. Because the attenuation of the sound occurs along the bone-conduction pathway, the hearing loss by bone conduction is as great as the hearing loss by air conduction. When a hearing loss exists in which there is the same amount of attenuation for both air conduction and bone conduction, the conductive mechanism is eliminated as a possible cause of the difficulty. A diagnosis of sensory/neural hearing loss can then be made. In Figure 2.2C, the inner ear was selected to illustrate a sensory/neural disorder, although the same principle would hold if the auditory nerve were damaged.

Hearing loss resulting from damage to the inner ear or to the auditory nerve was once called either a “perceptive loss” or a “nerve loss.” Both these terms are inaccurate (although the latter is, regrettably, still used today by some individuals). The term perceptive loss is misleading as perception is achieved by centers in the brain and thereby removed from either the inner ear or the auditory nerve. The term nerve loss is equally misleading given that the auditory nerve is far less common than the inner ear as the site of these hearing losses.

Several decades ago the term sensori-neural was introduced to suggest that the problem involved the inner ear and/or the auditory nerve. This was a considerable advance toward accuracy in scientific terminology, although technically a hyphenated word must contain two accepted words and sensori does not appear in the dictionary. The term sensori-neural also suffers from the fact that a hyphen implies a connection between two words, but not one and/or the other. Over time the hyphen was dropped and the compound word sensorineural was coined, a term that fails to acknowledge that such losses are rarely both sensory and neural. The term adopted for this book uses the slash with a slight spelling change, namely, sensory/neural, because this more strongly indicates that the damage may be to the inner ear, to the auditory nerve, or possibly both. Diagnostic audiology is well on its way toward differentiating sensory from neural hearing losses, and when that eventuality is fully realized, the use of hyphens, slashes, or compound words will no longer be necessary.

**Mixed Hearing Loss**

Problems can occur simultaneously in both the conductive and sensory/neural mechanisms, as illustrated in Figure 2.2D. This results in a loss of hearing sensitivity by bone conduction because of the sensory/neural abnormality, but an even greater loss of sensitivity by air conduction. This is true because the loss of hearing by air conduction must include the loss (by bone conduction) in the sensory/neural portion plus the attenuation in the conductive portion. In other words, sound traveling on the bone-conduction pathway is attenuated only by the defect in the inner ear, but sound traveling on the air-conduction pathway is attenuated by both middle-ear and inner-ear problems. This type of impairment is called a mixed hearing loss.
Nonorganic Hearing Loss

Individuals are sometimes seen whose test results show some degree of hearing loss, usually sensory/neural, but who either have normal hearing or insufficient auditory pathology to explain the extent of the loss. The mechanisms for this phenomenon are explained more fully in Chapter 13, but the underlying psychodynamics may be quite complex. In the past, a simple, popular dichotomy said that patients with nonorganic hearing loss were either consciously faking the problem for some financial or other gain, or there was some psychological disorder that manifested in the symptom of a hearing loss. The former condition is called malingering and the latter one psychogenic hearing loss. Some explanation of this oversimplification will be found later in this text.

Hearing Tests

Some of the earliest tests of hearing probably consisted merely of producing sounds of some kind, such as clapping the hands or making vocal sounds, to see if an individual could hear them. Asking people if they could hear the ticking of a watch or the clicking of two coins together may have suggested that the examiner was attempting to sample the upper pitch range. Obviously, these tests provided little information of either a quantitative or a qualitative nature.

Tuning Fork Tests

The tuning fork (see Figure 2.3) is a device, usually made of steel, magnesium, or aluminum, that is used to tune musical instruments or by singers to obtain certain pitches. A tuning fork emits a tone at a particular pitch and has a clear musical quality. When the tuning fork is vibrating...
properly, the tines move alternately away from and toward one another (see Figure 2.4), and the stem moves with a piston action. The air-conduction tone emitted is relatively pure, meaning that it is free of overtones (more on this subject in Chapter 3).

The tuning-fork tests described in this chapter are named for the four German otologists (ear specialists) who described them in the middle 19th to early 20th centuries. They are rarely used by audiologists, who prefer more sophisticated electronic devices. However, tuning-fork tests serve to illustrate the principles involved in certain modern tests.

The tuning fork is set into vibration by holding the stem in the hand and striking one of the tines against a firm but resilient surface. The rubber heel of a shoe does nicely for this purpose, although many physicians prefer the knuckle, knee, or elbow. If the fork is struck against too solid an object, dropped, or otherwise abused, its vibrations may be considerably altered. To see how a tuning fork is activated, see the video titled Tuning Fork Tests.

The tuning fork was adopted as an instrument for testing hearing over a century ago. It held promise then because it could be quantified, at least in terms of the pitch emitted. Several forks are available that usually correspond to notes on the musical scale of C. By using tuning forks with various known properties, hearing sensitivity through several pitch ranges may be sampled. However, any diagnostic statement made on the basis of a tuning-fork test is absolutely limited to the pitch of the fork used because hearing sensitivity is often different for different pitches.

The Schwabach Test

The Schwabach test, introduced in 1890, is a bone-conduction test. It compares the hearing sensitivity of a patient with that of an examiner. The tuning fork is set into vibration, and the stem is placed alternately against the mastoid process (the bony protrusion behind the ear) of the patient and of the examiner (see Figure 2.5A). Each time the fork is pressed against the patient’s head, the patient indicates whether the tone is heard. The vibratory energy of the tines of the fork decreases over time, making the tone softer. When the patient no longer hears the tone, the examiner immediately places the stem of the tuning fork behind his or her own ear and, using a watch, notes the number of seconds that the tone is audible after the patient stops hearing it.

This test assumes that examiners have normal hearing, and it is less than worthless unless this is true. If both examiners and patients have normal hearing, both stop hearing the tone emitted by the fork at approximately the same time. This is called a normal Schwabach. If patients have sensory/neural hearing loss, hearing by bone conduction is impaired, and they stop hearing the sound much sooner than the examiner. This is called a diminished Schwabach. The test can be quantified to some degree by recording the number of seconds an examiner continues to hear the tone after a patient has stopped hearing it. If an examiner hears the tone for 10 seconds longer than a patient, the patient’s hearing is “diminished 10 seconds.” If patients have a conductive hearing loss, bone conduction is normal, and they hear the tone for at least as long as the examiner, sometimes longer. In some conductive hearing losses, the patient’s hearing in the low-pitch range may appear to be better than normal. When this occurs, the result is called a prolonged Schwabach.

Difficulties arise in the administration and interpretation of the Schwabach test. Interpretation of test results in cases of mixed hearing losses is especially difficult. Because both inner ears are very close together and are embedded in the bones of the skull, it is almost impossible to stimulate one without simultaneously stimulating the other. Therefore, if there is a difference in sensitivity between the two inner ears, a patient will probably respond to sound heard through the better ear, which can cause a false normal Schwabach. Thus, the examiner may have difficulty determining which ear is actually being tested. To see a demonstration of the Schwabach test, see the video titled Tuning Fork Tests.
The Rinne Test

The Rinne test\(^2\) compares patients’ hearing sensitivity by bone conduction to their sensitivity by air conduction. This is done by asking them to state whether the tone is louder when the tuning-fork stem is held against the bone behind the ear, as in the Schwabach test (see Figure 2.5A), or when the tines of the fork that are generating an air-conducted sound are held next to the opening of the ear (see Figure 2.5B). Because air conduction is a more efficient means of sound transmission to the inner ear than bone conduction, people with normal hearing hear a louder tone when the fork is next to the ear than when it is behind the ear. This is called a positive Rinne. A positive Rinne also occurs in patients with sensory/neural hearing loss. The attenuation produced by a problem in the sensory/neural mechanism produces the same degree of loss by air conduction as by bone conduction (see Figure 2.2C).

If patients have more than a mild conductive hearing loss, their bone-conduction hearing is normal (see Figure 2.2B), and they hear a louder tone with the stem of the fork behind the ear (bone conduction) than with the tines at the ear (air conduction). This is called a negative Rinne. Sometimes patients manifest what has been called the false negative Rinne, which occurs when the inner ear not deliberately being tested responds to the tone. As mentioned in the discussion of the Schwabach test, this may happen readily during bone-conduction tests. For example, if the right ear is the one being tested, the loudness of the air-conducted tone in the right ear may inadvertently be compared to the loudness of the bone-conducted tone in the left ear. If the left-ear bone conduction is more sensitive than the right-ear bone conduction, a false negative Rinne may result, giving rise to an improper diagnosis of conductive hearing loss. To see a demonstration of the Rinne test, see the video titled Tuning Fork Tests.

The Bing Test

It has been known for some time that when persons with normal hearing close off the opening into the ear canal, the loudness of a tone presented by bone conduction increases. This phenomenon has been called the occlusion effect (OE), and it is observed primarily for
low-pitched sounds. This effect is also evident in patients with sensory/neural hearing loss, but it is absent in patients with conductive hearing loss. This is the premise of the Bing test.3

When performing the Bing test, the tuning fork handle is held to the mastoid process behind the ear (see Figure 2.5A) while the examiner alternately closes and opens the ear canal with a finger. For normal hearers and those with sensory/neural hearing loss, the result is a pulsating sound, or a sound that seems to get louder and softer (called a positive Bing). For patients with conductive hearing losses, no change in the loudness of the sound is noticed (negative Bing). The examiner must not suggest to patients what their responses should be. As in the Schwabach and Rinne tests, the danger of a response to the tone by the nontest ear is ever present.

The Weber Test

Since its introduction, the Weber test4 has been so popular that it has been modified by many audiologists for use with modern electronic testing equipment. It is a test of lateralization; that is, patients must state where they hear the tone (left ear, right ear, both ears, or midline).

When performing the Weber test, the tuning fork is set into vibration, and the stem is placed on the midline of the patient’s skull. Figure 2.5C shows placement on the forehead, which is probably the most popular location. Other sites are also used, such as the top or the back of the head, the chin, or the upper teeth. In most cases the upper teeth produce the loudest bone-conducted sound. Patients are simply asked in which ear they hear a louder sound. Often the reply is that they hear it in only one ear.

People with normal hearing or with equal amounts of the same type of hearing loss in both ears (conductive, sensory/neural, or mixed) report a midline sensation. They may say that the tone is equally loud in both ears, that they cannot tell any difference, or that they hear the tone as if it originated somewhere in the middle of the head. Patients with sensory/neural hearing loss in one ear hear the tone in their better ear. Patients with conductive hearing loss in one ear hear the tone in their poorer ear.

The midline sensation is easy to understand. If the ears are equally sensitive and equally stimulated, equal loudness should logically result. One explanation of the Weber effect in sensory/neural cases is based on the Stenger principle. The Stenger principle states that if two tones that are identical in all ways except loudness are introduced simultaneously into both ears, only the louder tone will be perceived. When the bone-conduction sensitivity is poorer in one ear than in the other, the tone being introduced to both ears with equal energy will be perceived as softer or will not be perceived at all in the poorer ear.

Results on the Weber test are most poorly understood in unilateral conductive hearing losses. The explanation for the tone being louder in the ear with a conductive loss than in the normal ear is probably based on the same phenomenon as prolonged bone conduction, described briefly in the discussion of the Schwabach test.

The Weber test has been known to avert misdiagnosis of unilateral sensory/neural hearing loss as conductive when false normal Schwabach or false negative Rinne results are seen, but the tone is heard in the poorer-hearing ear rather than the expected better-hearing ear. The Weber test is quick, easy, and often helpful, although like most auditory tests, it has some drawbacks. Clinical experience has shown that many patients with a conductive hearing loss in one ear report hearing the tone in their better ear because what they are actually experiencing seems incorrect or even foolish to them. Again, care must be taken not to lead patients into giving the kind of response they think is “correct.” Interpretation of the Weber test is also difficult in mixed hearing losses.
Clinical COMMENTARY

Electronic tests for testing hearing by bone conduction have largely supplanted tuning-fork tests in audiological testing; however, tuning-fork tests continue to be used by many otologists. The Bing and Weber tests can be performed easily with today’s electronic test equipment and can prove useful in separating conductive from sensory/neural hearing loss if other testing proves somewhat ambiguous.

Evolving CASE STUDIES

As you read the following case histories, try to see why they have been placed in their different diagnostic categories. For each of the cases, predict what the results would be on the Rinne, Schwabach, and Weber tuning-fork tests when these are possible. Make your predictions before you read the Test Results and Conclusions. In later chapters, you will be asked to conjecture about a variety of other, more sophisticated test and management procedures for these six cases as diagnostic and treatment information about these cases unfolds in the ensuing chapters.

Case Study 1: Conductive Hearing Loss—Outer Ear Disorder

The parents of a 9-year-old boy bring him to the audiology clinic. The most noticeable details about this child are that he has downward slanting eyes, a small lower jaw, underdeveloped cheekbones, drooping lower eyelids, and absent external ears and ear canals. He appears bright and friendly and communicates fairly well using a bone-conduction hearing aid. The parents and the child have been seen by several ear, nose, and throat specialists and told that nothing medically or surgically can be done to correct his problems. He has been referred to you by a speech-language pathologist to see whether the child may be helped further.

Case Study 2: Conductive Hearing Loss—Middle Ear Disorder

This 23-year-old woman has a history of middle-ear infections and drainage in both ears since early childhood. She says that while she is always aware of a hearing loss, it appears to vary in degree. She says she can understand speech well if people are close to her or speak loudly. The otologist who referred her for testing says that, while there is evidence of past infection, her eardrum membranes are both intact.

Case Study 3: Sensory/Neural Hearing Loss—Inner Ear Disorder

This 79-year-old male denies any history of ear infection or exposure to loud noise. He first noticed some difficulty in hearing in both ears about 10 years earlier and says that it has progressed. He notes that he does much better in quiet surroundings than in noisy places or when several people are speaking at the same time. His difficulty in correctly identifying words is more bothersome than the loss of the loudness of speech and he
does not like people shouting at him. His wife volunteers that in recent years the patient has significantly reduced his interactions with others and avoids movies, the theater, and religious services because he has so much trouble understanding words. The cause of the hearing loss appears to be aging but that is a conclusion that should await further testing.

Case Study 4: Sensory/Neural Hearing Loss—Auditory Nerve Disorder
This 36-year-old woman presents with a main complaint that the hearing in her left ear has diminished gradually over the previous several years. Because her hearing is normal in the right ear, she communicates pretty well except when there is a lot of background noise or when several people speak at once. She has recently seen a neurologist because of dizziness and headaches, and he has ordered several tests, which have not yet been performed. Because of the gradual and unilateral nature of the hearing loss, it is precautionary to suspect a possible lesion on the left auditory nerve.

Case Study 5: Organic Hearing Loss
This patient, a 45-year-old male who works in a factory, has recently brought a legal suit against his employer because of a claimed hearing loss. He states that one day at work there was a very loud explosion about 10 yards to his left, and since that time he can hear nothing in his left ear and has a very loud ringing in that ear. He states that he has no trouble hearing in his right ear. When you stand several feet away on his right side, he is able to answer all your questions. He claims that he cannot hear people if they speak to him on his left side. He speaks adamantly about his belief that his work setting is responsible for his difficulty and also claims to have very loud ringing in his left ear.

Case Study 6: Pediatric Patient
Interview with the parents indicates that your patient is a 3-year-old female who uses no spoken language. The parents have sought a diagnosis of her delayed language from a variety of specialists, including her pediatrician and a psychologist. Several tentative diagnoses have been made, including mental handicap and autism. Her older brother was speaking in complete sentences when he was much younger than this little girl. The parents are desperate for a diagnosis so they can begin to try to help their child. Recently the patient was seen by a speech-language pathologist who suggested the possibility of hearing loss as an etiological factor and referred her to you. The child has no history of ear infections and there is no known family history of childhood hearing loss. She is reported to respond inconsistently to sound, although her mother has always believed that some hearing loss exists. This child passed a neonatal hearing screening before she was released from the hospital, but the possibility, however small, of a false negative test result or a later onset hearing loss must be borne in mind given the history.

Case Study 1: Conductive Hearing Loss—Outer Ear Disorder
Most audiologists do not do tuning-fork tests. However, given this child’s age of 9 years, he would undoubtedly respond very well to tuning-fork tests if they were completed. The results would be as follows: Schwabach—normal in both ears, Rinne—negative in
both ears, Weber—not lateralized. These are all consistent with a conductive hearing loss, but even with these results, it cannot be determined at this point whether the loss is caused entirely by the absent ear canals or whether the middle ear is also involved.

**Case Study 2: Conductive Hearing Loss—Middle Ear Disorder**

The patient would show a negative Rinne in both ears and a normal Schwabach, and the tone would not lateralize on the Weber test, but rather would be heard equally loud in both ears or in the middle of her head. These results are consistent with a conductive hearing loss and her history of ear infections, but more sophisticated testing must be done to determine the extent of the loss and related factors.

**Case Study 3: Sensory/Neural Hearing Loss—Inner Ear Disorder**

This patient would show a positive Rinne and a prolonged (lengthened) Schwabach in both ears. The Weber would be unilateraled. The case history, especially the difficulty in speech understanding even when the signal is sufficiently loud, is consistent with a sensory/neural hearing loss, which would be borne out by these tuning-fork test results. Given the age of onset of the hearing loss, it can be supposed that his hearing loss was produced by aging and suggests that the primary problem exists in the cochlea of the inner ear. Further testing is obviously needed.

**Case Study 4: Sensory/Neural Hearing Loss—Auditory Nerve Disorder**

The Rinne would be positive and the Schwabach would be normal on the right side. When using a high-frequency tuning fork on the left side, the patient would respond that the tones are heard in her right ear. On the Weber test, the patient would report hearing the tone in both ears using a lower-pitched tuning fork and in the right ear using a higher-pitched one. These results would bear out the patient’s report of a hearing loss only in the left ear in the higher frequencies but possibly normal hearing in the right.

**Case Study 5: Nonorganic Hearing Loss**

Results would show a positive Rinne for the right ear and the patient, as is reported in such cases, would claim that the tone in the left ear cannot be heard by either air conduction or bone conduction. The Schwabach would be normal on the right side, and the patient would claim that he does not hear any of the bone-conducted tones at all on the left side. The Weber would be reported as lateralizing to the right ear.

Suspicion of a feigned or exaggerated (nonorganic) hearing loss is first raised by the legal action, with promise of financial gain, and by the fact that a noise loud enough to cause a hearing loss in his left ear would probably have caused some hearing loss in his right ear as well. It is also true that he should have heard speech in his right ear that was directed to his left side because the shadow of sound (the amount of energy lost as a signal travels from one side of the head to the other) is only about 13 dB. If he truly had a sensory/neural hearing loss in his left ear, he would have been able to hear the
bone-conducted signals on the Rinne and the Schwabach in his right ear (with the tuning fork placed on his left mastoid) because practically no sound intensity is lost as the signal travels through the skull from one side of the head to the other.

**Case Study 6: Pediatric Patient**

Tuning-fork tests are inappropriate for children at this age. Your casual observation of the child suggests that she does not appear to respond to environmental sounds. Your first session consisted of observation and the introduction of earphones without an insistence to place the inserts in the child’s ears. A technique presenting sounds through loud speakers was briefly attempted but abandoned, as the child grew restless. The little girl was allowed to play with some toys and was observed to relax. After taking a complete history, the parents were encouraged to observe the child’s reactions to environmental sounds, follow up with the speech-language pathologist, and return in several days for further audiometric testing. The parents appeared relieved and made a new appointment. Before departure, several foam insert earphone plugs were given to the parents to acclimate the child to plug insertion at home to help ensure greater success in the clinic on the family’s return.

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**Summary**

The mechanisms of hearing may be roughly broken down into conductive and sensory/neural portions. Tests by air conduction measure sensitivity through the entire hearing pathway. Tests by bone conduction sample the sensitivity of the structures from the inner ear and beyond, up to the brain. The Schwabach test compares the bone-conduction sensitivity of the patient to that of a presumed normal-hearing person (the examiner). The Rinne tuning-fork test compares patients’ own hearing by bone conduction to their hearing by air conduction in order to sample for conductive versus sensory/neural loss. The Bing test samples for conductive hearing loss by testing the effect of occluding the ear. The Weber test checks for lateralization of a bone-conducted tone presented to the midline of the skull to determine if a loss in only one ear is conductive or sensory/neural.

**REVIEW TABLE 2.1 Types of Hearing Loss**

<table>
<thead>
<tr>
<th>Anatomical Area</th>
<th>Purpose</th>
<th>Type of Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outer ear</td>
<td>Conduct sound energy</td>
<td>Conductive</td>
</tr>
<tr>
<td>Middle ear</td>
<td>Conduct sound energy</td>
<td>Conductive</td>
</tr>
<tr>
<td></td>
<td>Increase sound intensity</td>
<td></td>
</tr>
<tr>
<td>Inner ear</td>
<td>Convert mechanical to hydraulic to electrochemical energy</td>
<td>Sensory/neural</td>
</tr>
<tr>
<td>Auditory nerve</td>
<td>Transmit electrochemical (nerve) impulses to brain</td>
<td>Sensory/neural</td>
</tr>
</tbody>
</table>
## REVIEW TABLE 2.2 Tuning-Fork Tests

<table>
<thead>
<tr>
<th>Test</th>
<th>Purpose</th>
<th>Fork Placement</th>
<th>Normal Hearing</th>
<th>Conductive Loss</th>
<th>Sensory/Neural Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Schwabach</td>
<td>Compare patient’s BC to normal</td>
<td>Mastoid process</td>
<td>Normal Schwabach—Patient hears tone as long as examiner</td>
<td>Normal or Prolonged Schwabach—Patient hears tone as long as or longer than examiner</td>
<td>Diminished Schwabach—Patient hears tone for shorter time than examiner</td>
</tr>
<tr>
<td>Rinne</td>
<td>Compare patient’s AC to BC</td>
<td>Alternate between mastoid process and opening to ear canal</td>
<td>Positive Rinne—Louder at the ear</td>
<td>Negative Rinne—Louder behind the ear</td>
<td>Positive Rinne—Louder at the ear</td>
</tr>
<tr>
<td>Bing</td>
<td>Determine presence or absence of occlusion effect</td>
<td>Mastoid process</td>
<td>Positive Bing—Tone is louder with ear occluded</td>
<td>Negative Bing—Loudness does not change with ear occluded</td>
<td>Positive Bing—Tone is louder with ear occluded</td>
</tr>
<tr>
<td>Weber</td>
<td>Check lateralization of tone in unilateral losses</td>
<td>Midline of head</td>
<td>Tone equally loud in both ears</td>
<td>Tone louder in poorer ear</td>
<td>Tone louder in better ear</td>
</tr>
</tbody>
</table>

## REVIEW TABLE 2.3 Relationship Between Air Conduction and Bone Conduction for Different Hearing Conditions

<table>
<thead>
<tr>
<th>Finding</th>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal air conduction</td>
<td>Normal hearing</td>
</tr>
<tr>
<td>Normal bone conduction</td>
<td>Normal hearing or conductive hearing loss</td>
</tr>
<tr>
<td>Poorer hearing for air conduction than for bone conduction</td>
<td>Conductive or mixed hearing loss</td>
</tr>
<tr>
<td>Hearing for air conduction the same as hearing for bone conduction</td>
<td>Normal hearing or sensory/neural hearing loss</td>
</tr>
</tbody>
</table>
As the sensory/neural component of a mixed loss increases over time, the air-bone gap is sometimes seen to decrease. This is probably due to the fact that the decibel is a logarithmic, rather than a linear, unit of measurement.

Q Is a hearing loss from the auditory nerve (VIIIth nerve) considered a sensory/neural hearing loss?
A Yes. Losses produced by lesions in either the cochlea or on the VIIIth nerve are traditionally grouped together as sensory/neural. Newer audiological tests are capable of separating these losses as either sensory (cochlear) or neural (auditory nerve and beyond).

Q Why do we study tuning forks when audiometric equipment is so much more advanced?
A We study tuning forks for several reasons. They illustrate some principles about the relationships between air conduction and bone conduction, which makes the understanding of pure-tone audiometry easier. They have an important place in the history of the development of hearing tests. And many physicians conduct tuning-fork tests and audiologists must be prepared to interpret those results.

Q Why does a unilateral sensory/neural hearing loss produce a false negative on the Rinne test?
A Unless the better ear is masked, it will hear the tone when the stem of the tuning fork is placed on the mastoid at the poorer ear. The result is that sound is louder than the air-conducted sound when the tines of the fork are held next to the poorer ear. When asked if the tone is louder in the front of the ear or behind, patients indicate that it is louder behind the ear, which can falsely be interpreted as a negative Rinne and a misdiagnosis of conductive hearing loss.

Q Why do audiologists prefer not to use tuning forks if their audiometric findings are sometimes found to be incorrect by physicians who use them?
A There is no reason for an audiometric test to produce inaccurate results that may be discovered by a physician doing a tuning-fork test. Rather than performing tuning-fork tests themselves, audiologists should concentrate on using careful, scientific audiometric practices as a cross-check.

Q During the Rinne test, what is the stem of the tuning fork held against?
A Traditionally it is held against the mastoid, which is appropriate because a bone-conducted tone is loudest from that position.

Q Does the Schwabach test compare the patient’s BC or AC to the examiner’s BC or AC, respectively?
A The Schwabach is a bone-conduction test.

Endnotes

1. Named for Dr. Dabobert Schwabach (1846–1920).
2. Named for Dr. Heinrich Rinne (1819–1868).
3. Named for Dr. Albert Bing (1844–1922).