Chapter 11:

The Ear and Hearing

Other portions of *Your Voice: An Inside View* deal with the basic properties of sound. Chapter Ten will discuss how these sounds are heard and interpreted by the body and the brain. What—if any—role does hearing play in singing? There is certainly disagreement among the members of the singing community. Some teachers insist that singers should never listen to themselves; listening is the job of the teacher—the student should only "feel" the sound. Others insist that listening is one of the *most* important elements in proper voice production. How can these seemingly opposite approaches coexist?

Our ears are exquisitely sensitive instruments, capable of detecting changes in air pressure two million times smaller than the ambient, barometric pressure. The anatomy that accomplishes this is complex and fascinating. The ear is divided into three main sections: the *outer ear*, which collects and transmits sound to the *middle ear*, which mechanically amplifies and transfers sound to the *inner ear*, which maintains balance and converts sound vibrations to nerve impulses that are sent to and interpreted by the brain.

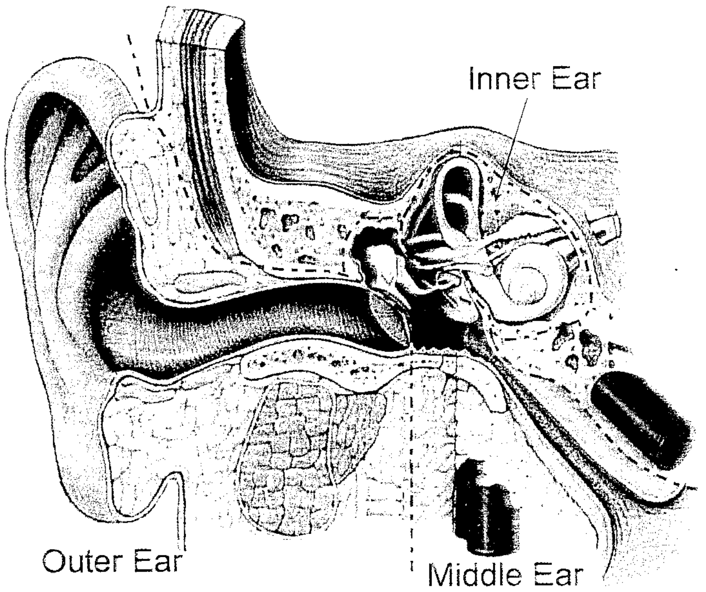

Figure 1: Divisions of the Ear. (Image of the ear from the website www.dizziness-and-balance.com, © Copyright 2002 by the author, Timothy C. Hain and Northwestern University, all rights reserved. Used with permission.)

The outer ear consists of three parts. The external portion, called the *pinna* or *auricle*, is constructed of flesh and cartilage and has a complex shape that nature has designed to help collect and direct sound from the outside world to the middle and inner portions of the ear. The pinna leads to the *bony canal*, which is a 25mm long passageway through the bones of the skull. A thin membrane is stretched across the end of this canal, called the *eardrum* or *tympanic membrane.* Subtle changes in atmospheric pressure caused by soundwaves impact the eardrum, making it vibrate.

The middle ear is an air-filled region that contains the three smallest bones in the human body: the *malleus* (hammer), *incus* (anvil) and *stapes* (stirrups). Each of these bones is no larger than a grain of rice. Together, they form the *auditory ossicles*, which connect between the back of the tympanic membrane and the *oval window* of the inner ear. (CD 11/1) Acting as a series of levers, the ossicles transfer the vibrations of sound from one structure to the other. Because the oval window is much smaller than the eardrum, the intensity of these vibrations is effectively ampli-

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fied. This phenomenon can be conceptualized through a pair of interlocking, rotating gears of two different diameters; the smaller gear will always rotate at a higher speed than the larger.

CD 11/2

Two muscles are found within the middle ear: the *tensor tympani*, which courses from the malleus to the bony edges of the auditory tube, and the *stapedius*, which connects the posterior wall of the middle ear to the stapes. With a length of only 6 mm, the stapedius is the smallest striated muscle in the human body. Both muscles serve a protective function within the ear. By contracting in response to very high amplitude sounds, they serve to inhibit movement of the ossicles. They cannot, however, protect the ear in all circumstances; indeed, exposure to loud noise, including loud music, is among the most common causes of hearing damage.

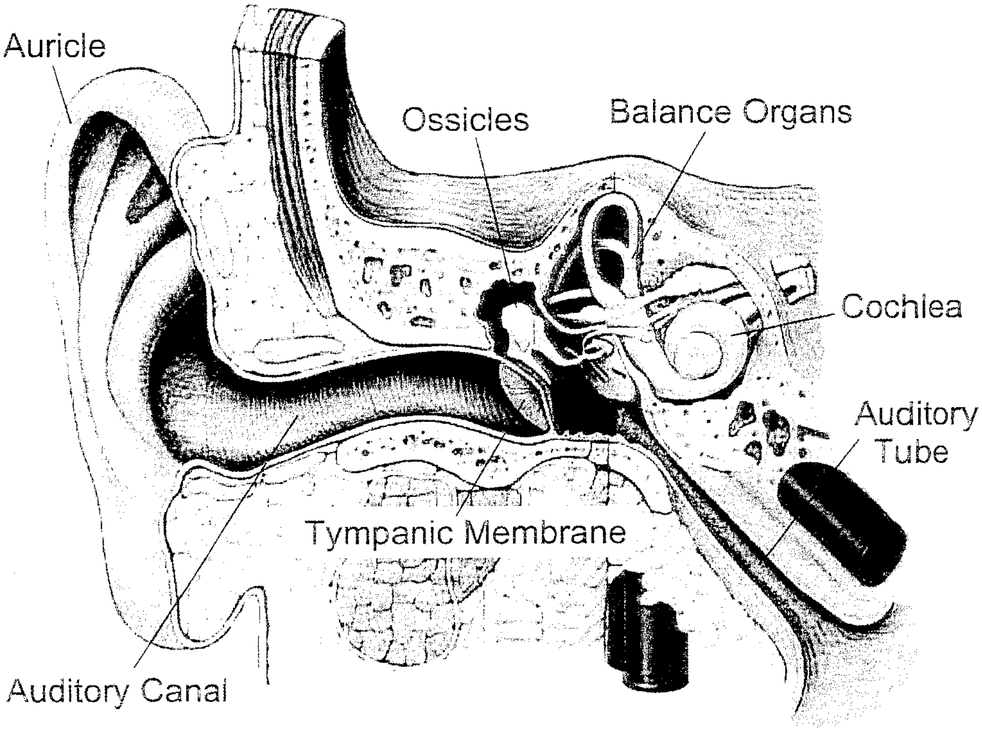

Figure 2: Structures of the Ear (Hain)

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Air pressure must be equal on either side of the eardrum for it to vibrate efficiently. If this pressure is not balanced—as often happens on an airplane during the descending portion of a flight, or while riding an express elevator in a high-rise building—we experience a subtle, temporary loss of hearing that might be accompanied by physical discomfort. Nature has provided the *auditory tubes* (also known as the *eustachian tubes*), which connect from the pharynx to the middle ear, to help keep air pressure equalized. They also serve to drain away any fluid and cellular debris that might build up in the middle ear. Many ear infections, especially in children, result in or are caused by blockage of these tubes.

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The inner ear is a fluid-filled region that serves two independent functions: maintaining balance and hearing sounds. Our sense of balance (equilibrium) is maintained through the vestibular organs, the *utricle*, *saccule* and *semi-circular canals*. Infection in these organs causes the disorder known as vertigo in which balance is disrupted and any movement leads to severe dizziness. The hearing organ of the inner ear is the *cochlea*, which is spiral-shaped and resembles a nautilus shell. The outer edge of this spiral consists of the *vestibular membrane*, which encases the *scala vestibuli* and the *scala tympani*. Between these areas lies the *basilar membrane*, which is lined with small, hair-like receptor cells called *cilia*. Vibrations of the oval window are transferred to the endolymph, then through the vestibular membrane to the scala tympani and scala vestibuli, and finally to the ciliated cells of the basilar membrane, where they are converted into nerve impulses that are carried via the *cochlear* (*auditory*) nerve to the brain where they are finally interpreted as sound. Example 11/5 on the CD-ROM demonstrates movement of the basilar membrane during transmission of soundwaves through the cochlea.

CD 11/5

Even singers and voice teachers often underestimate the role of hearing in voice production. To make vocal sound, the brain must transform thought to physical action. Signals are sent through the central nervous system to the muscles responsible for breathing, phonation and articulation. The ears and brain monitor the resulting sounds to check for accuracy. Any deviations from the desired output are quickly and subconsciously corrected. This phenomenon is sometimes called the *auditory feedback loop*.

Imagine a simple conversation: someone has just asked for your name. What are the steps required to formulate a response? First, the sounds produced by the questioner must travel through space to your ear where they are converted from vibrations to nerve impulses. These nerve signals are sent to the auditory area in the left side of the brain for initial processing before being transferred to the sensory speech area for interpretation as language. Your response is formulated in the motor speech area. The motor cortex now takes over, sending signals to the muscles of breath and speech. The ear then takes over, monitoring and correcting the accuracy of your intended response.

In the example above, the brain is responding to sounds that have been physically heard. It can also, however, respond to sounds that are only imagined. If we imagine a major scale, the ear and brain direct the vocal folds to elongate as if we were actually singing. We imagine a bright, a nasal or a dark sound and automatically produce the appropriate timbre. This happens not just because the brain tells the body what to do, but also because the ear is present to verify the results. It is the ear that allows us to sing in tune and to vary loudness and timbre. Singers who say they do not listen to themselves but only "feel" the sound are not being completely honest. While it is possible to concentrate on the sensations rather than the sounds of singing, it is physiologically impossible to turn off the aural feedback loop; the ear is constantly monitoring and adjusting everything that is said or sung.

Two types of sound transmission are responsible for people hearing their own voices. The first is the normal propagation of sound through the medium of air. As we saw in the previous Chapter, this tends to skew the manner in which different frequency ranges are heard. Because sounds of high frequency/short wavelength travel in straight lines, singers hear them in their own voices at reduced amplitude relative to lower frequencies. This is particularly significant in higher frequency ranges, particularly 2,400 to 3,200Hz, where the brilliance or "ring" is found. To compensate for this, some singers and speakers have been known to cup a hand in front of their mouths to reflect the sound back toward the ear. This immediately increases the self-perception of brightness; however, it also increases the risk of damage to the ears from exposure to high amplitude sound.

Singers also hear their voices through sound transmitted directly through the body from the larynx to the ears. For most people, this is the dominant form of hearing. Do you remember the first time you heard your own voice on a recording? You probably did not want to believe it was you. For the first time in your life, you heard yourself as others hear you—that is, solely through airborne sound transmission. The study of singing is greatly complicated by the fact that singers do not hear themselves as others do. Therefore, one of the primary jobs of singing teachers is to help students reconcile their internal and external voices. I have often wished I could climb inside a student's head to hear the voice as the student does!

Many singers complain of not being able to hear themselves when singing in large ensembles or in noisy environments. Commercial musicians deal with this issue through monitor speakers placed on the stage or by wearing special hi-tech, miniaturized monitors that fit within the ear canal. Monitors, unfortunately, are impractical, if not impossible to accommodate in most classical genres and venues. As a result, many singers, especially those whose technique is still under development, oversing in the face of aural competition—such as the choir soprano dealing with the repeated A_5-naturals of Beethoven's *Ninth Symphony*. Some try to deal with this through the previously mentioned technique of using a hand to reflect sound from the mouth to the ear. A better method is to wear an earplug in one ear or to temporarily plug an ear with a finger. This will focus the singer's listening on the internal conduction of sound, enabling her to hear her voice without having to push, while still letting her hear all the music that surrounds her.

Internal hearing can also be used to help a singer find his optimum head and neck alignment. Try this experiment. Plug both your ears with your fingers or ear plugs, and hum a sustained pitch in a comfortable range. Gently rotate your head up and down, forward and back. This will cause the timbre and amplitude of the hum to subtly change. Stop this movement at the spot where the hum is loudest and freest feeling. This probably is your point of optimal alignment.

Hearing Loss

Hearing loss is a serious issue for musicians and professional voice users. Even a mild impairment can have dire consequences. If the aural feedback loop is disrupted, the brain has no way accurately to monitor sounds being produced. The result is reduced ability to control intonation, amplitude and timbre, and to project clear diction. Two types of hearing loss may occur: conductive and sensorineural.

Conductive hearing loss is caused by mechanical problems in the outer or middle ear that prevent efficient sound transfer to the inner ear. This could be the result of something as simple as excess earwax. It might also come from an infection of the middle ear or arthritis in the auditory ossicles. The prognosis for persons suffering from this type of hearing loss is usually excellent. Normal or near-normal hearing might be restored through the amplification provided by hearing aids or through corrective surgery.

Sensorineural hearing loss is more pernicious for musicians and can be very difficult to treat successfully. It results from problems in the inner ear, the cochlea or the auditory nerve and is often the result of prolonged exposure to high noise levels, in-