An exasperating human problem!

HI-FI SOUND... BUT

It is ironic that, at the very time when we are most excited about a new era of high-quality sound in the home, we are putting at risk the very organs we need to hear that sound. So look after your ears; they're the only ones you'll ever have!

IT HAS TAKEN ABOUT 100 YEARS OF THE ART OF AUDIO reproduction to progress from the primitive phonograph of Thomas Alva Edison to the cause of all the present excitement—the laser-read compact disc. But for all of that time—and longer—we have been working on the gradual destruction of our ears. Years ago, we blasted them with noisy machinery, pneumatic drills, and rivet guns. Now we have more fashionable methods.*

As if it isn't enough to have ears grow old and sluggish with age, we hasten the process with rock bands and hi-fi headphones—both capable of creating a sound-pressure level, where it matters, of 120 dB or more.

And, if ears have grown old and sluggish, whether naturally or prematurely, of what possible interest are those tiny whisps of sound, now exposed by the elimination of recording noise? Both may lie below the threshold of our hearing!

And what of the rich overtones on the strings and the oboe? Overtones? What overtones?

No Instant Cures

What makes the loss of hearing seem worse is that ears are not like eyes. One can suffer with hypermetropia (long sight), myopia (short sight), presbyopia (loss of lens flexibility), or astigmatism (misshapen lens); and yet retain virtually normal vision with the aid of contact lenses or spectacles.

But that very common effect—progressive loss of aural sensitivity—whether natural or aggravated, general or concentrated at the higher frequencies, is normally incurable and irreversible. Nor, can all or partial loss of hearing be compensated by artificial aids, at least not to high-fidelity listening standards.

The inherent limitations of diminished hearing and of practical electronic aids make it impossible to recover the frequency response, dynamic range, distortion levels, and directional perception of normal hearing. Artificial aids may restore communication, but that's about all. If and when implants are devised to bypass the faulty functions, the position may be more hopeful; but, in the meantime, guard the hearing you have as long as you can!

Inside the Ear

Figure 1 illustrates the physical structure of a human ear. It comprises three distinct sections; the *outer ear*, the *middle ear* and the *inner* ear.

The *outer ear* comprises three main components, of which the most obvious is the outer appendage, known as the *auricle* or *pinna*. Apart from its usefulness in supporting spectacles, the *auricle* or *pinna* modifies sound wavefronts entering the second component of the *outer ear*, the *ear canal*. The brain can ultimately interpret the modified sound wavefronts as supplementary clues to the source of individual sounds. (Some engineering types would refer to the *auricle* as a sound wave phase-shifter!)

The *ear canal* is a fleshy tube which attains dimensions giving it a broad resonance effect which more than doubles the subjective intensity of sounds in the region 2000 to 5500 Hz—the frequency range which we hear best. At the inner end of the *ear canal* is a tough, flexible membrane

*Original project appeared in Electronics Australia, June, 1983 Edition, and appears here by permission.

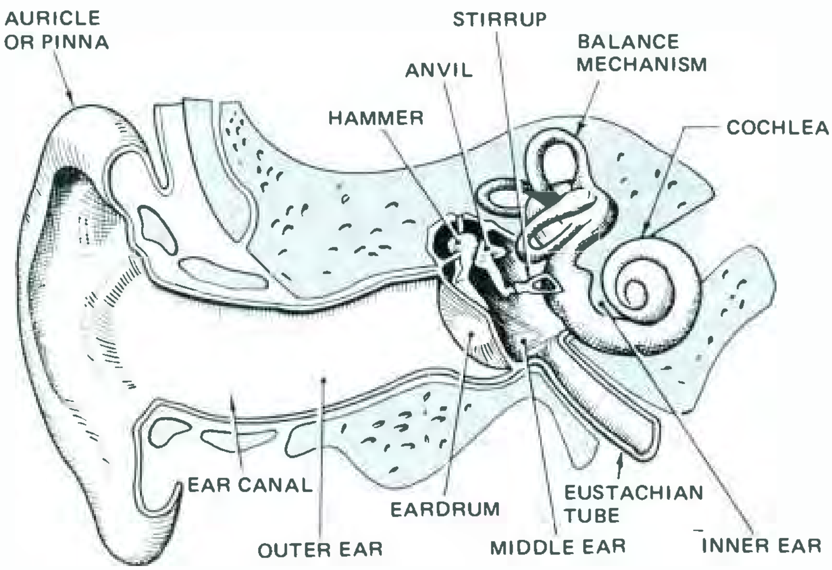

FIG. 1—ILLUSTRATING the structure of the human ear. While part of a remarkable human sense, it is nevertheless vulnerable to age, infection, and physical damage.

LO-FI EARS

By Neville Williams

called the *eardrum*, which seals off the *outer ear* from the *middle ear*. The *eardrum* vibrates in sympathy with the incident sound pressure waves and transfers the vibrations to the smallest bones in the body. The three bones, the *hammer*, *anvil* and *stirrup*, pass the vibrations on to the *inner ear*, an organ which has to do with both hearing and our sense of body balance.

As the ultimate destination of the sonic energy, the *cochlea* is nature's own microphone transducer, turning sonic information into nerve impulses. A tapered, convoluted, fluid-filled tube (Figs. 1 and 2), it is divided along its length into two compartments by the *basilar* membrane.

Sonic impulses are transferred from the *stirrup* (or *stapes*) to a small, bony, oval-shaped piston at the large end of the *cochlea*—the *oval window*. The impulses travel through the liquid in one compartment to the small end of the *cochlea*, then pass through a small aperture and back along the second compartment to the larger end. Here they encounter the so-called *round window*, which reflects the sonic energy back the way it came, much as an object will reflect wave energy in water or a radar waveguide.

Electrical Sensors

The interaction of the initial and reflected sonic wavefronts sets up standing-wave effects in the *cochlea* liquid, causing physical ripples in the central *basilar* membrane. Those ripples trigger responses from an array of something like 24,000 nerve ends distributed along and within the *cochlea*. In its own mysterious way, the human brain is able to translate the resulting electrical nerve signals—digital rather than analog in character—into separately identifiable signals, each with its own pitch, intensity, and phase.

It is, in fact, easy to become quite carried away when extolling the virtues of human ears in prime condition by stating that:

—Our ears are so discriminating that we need thousands of dollars worth of audio equipment to provide the same listening satisfaction as when hearing the real thing.

—The human hearing apparatus—the ear, auditory nerves, and hearing centers in the brain—make up one of the most discriminating mechanisms in the world of nature.

—Many people can detect changes in pitch of only one part in 1000, and even an untrained ear can tell the difference when the same note on the musical scale is played on two different kinds of instrument.

—We can hear a mosquito buzzing outside the window screen and the next instant listen to a jet aircraft roar overhead. The difference in intensity of those two sounds is a ratio of about 1 to 10,000,000,000. (Try that span of voltage on your multimeter.)

—The human ear is capable of hearing sounds within a frequency range of about 20 Hz to 20,000 Hz... and so on.

Our ear possesses an *automatic volume control* mechanism. A sudden loud bang causes a reflex action in two tiny muscles located in the *inner ear*. One—the *tensor tympani*—contracts and stiffens the *eardrum*, so that it cannot vibrate as freely as it would otherwise. The other—the *stapedius muscle*—immobilizes the *stirrup*-shaped *stapes*, preventing it from delivering excessive input to the *inner ear*.

Much has been written, too, about the ability of the human auditory system to concentrate on one particular sound source in a noisy environment, on one speaker in a restaurant, one instrument in a group. Indeed, there are occasions

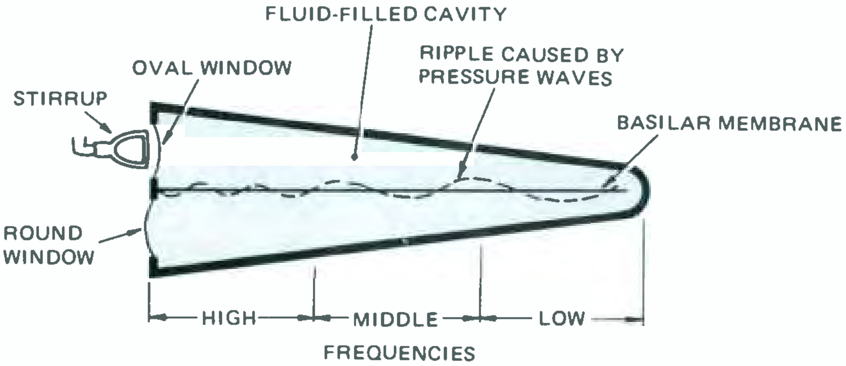

FIG. 2—FED with sonic impulses via the "*stirrup*', the *cochlea* is nature's counterpart of the microphone, transforming physical vibration into electro-chemical nerve impulses. Loss of aural acuity usually occurs first at the higher frequencies.

the auditory system may reject all sound, turning it into a sonic blur that does not disturb concentration—or something even more remote that does not disturb sleep.

And there's the matter of audio-signal phase—the subject of much discussion and argument in recent years. Human hearing is amazingly sensitive to phase, runs the argument, and much of that indefinable satisfaction which is either apparent or not apparent in hi-fi sound reproducion is traceable to phase discrepancies in the system. So we've had a spate of linear-phase loudspeakers and now, linear-phase phono cartridges.

There Are Problems

In truth, your ears may not perform as described above because the keen edge of your hearing has been perceptibly blunted—purely as a function of age. Also, if your ears have been subjected to protracted periods of very high-level sound, whether in the context of entertainment or employment, there is a strong chance that they will exhibit losses additional to those due to aging.

In respect to aging, a broad rule of thumb suggests that, if a young child is credited with the ability to hear sounds up to 20,000 Hz, the child will exhibit a loss of treble response at the rate of about 2000 Hz per decade. On that basis, one can draw up a table correlating age with the upper limit of hearing. The assumption is that the aural response will be rolling off through the nominated frequency with a fairly pronounced cutoff beyond it. (See Table 1.) There is a difference between the sexes. It is noted that females retained a generally better high-frequency response than males.

TABLE 2—NOISE LEVEL TABLE

Injurious Range	
140 dB	Jet engine at 25 yards
130 dB	Rivet gun—pain threshold
120 dB	Propeller airliner, 50 yards
Danger Zone	
110 dB	Pneumatic rock drill—non-OSHA approved
100 dB	Metalworking shop
90 dB	heavy transport truck
Normal Range	
60 dB	Ordinary conversation, 3 feet
50 dB	Low conversation, 3 feet
40 dB	Soft background music
30 dB	Whisper at 3 feet
20 dB	Quiet country dwelling
10 dB	Rustling leaf
0 dB	Threshold of hearing

TABLE 1—AGE TAKES ITS TOLL!

Age in Years	Upper Limit of Hearing
10	18,000 Hz
20	16,000 Hz
30	14,000 Hz
40	12,000 Hz
50	10,000 Hz
60	8,000 Hz
70	6,000 Hz
80	4,000 Hz

Familiar Format

Purely to present the information described in the previous paragraph in a more readily recognizable form, the usual frequency-response hearing format in Figs. 3 and 4 have been modified. The curves ignore the expectedly superior hearing of children and take, as reference, clinically normal 20-year-old female ears. The derived curves involve a certain amount of free-hand extrapolation, but they still can be taken as being well *in the ballpark* for typical age/hearing loss relationship.

Two points are obvious from the family of curves in Figs. 3 and 4. One is a ready explanation of why aging grandparents may frequently find it necessary *to beg your pardon*. To them, speech is quite muffled. The other is that, beyond about age 50, your audio amplifier system is beginning to sound

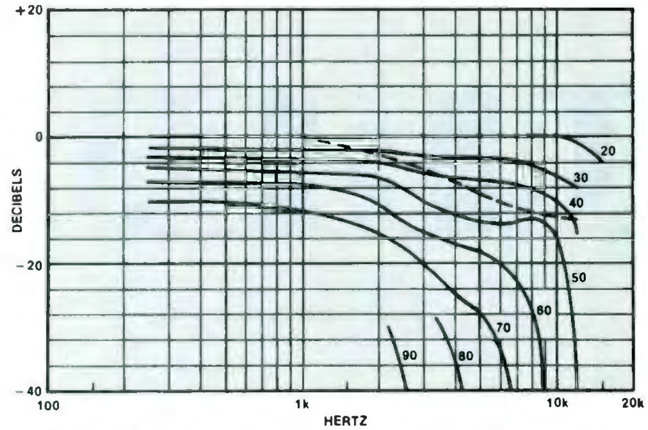

FIG. 3—WITH CLINICALLY-NORMAL HEARING of 20-year-old females referenced to 0 dB, those curves give some idea of the gradual loss of hearing acuity with advancing age, the loss being particularly apparent at high frequencies.

much as it would to a young person in his/her twenties, with the tone control turned to minimum treble. To a 70-year old, the tone control may not appear to have much effect at all.

Well then, does the compact disc, or any other improved audio system coming down the pike, represent a waste of time and money to the 50-and-over group—the people who can best afford the equipment?

Fortunately not, for reasons about which we still have to speculate.

A difference in frequency response, as such, may not be all that apparent to the 50-and-overs. But the clean, hard transients can still be obvious by contrast to what they have been accustomed to current audio systems.

And the reduction in harmonic distortion can certainly be evident as an uncanny clarity, which is missing in the audio program if the contact disc has been remastered from a tape.

As for background noise, the difference may not be as obvious as to a younger person but a difference there can be over the low and middle register, where rumble and acoustic feedback betray the mechanical nature of the conventional phono system. All is not lost, by any means! *(Continued on page 94)*

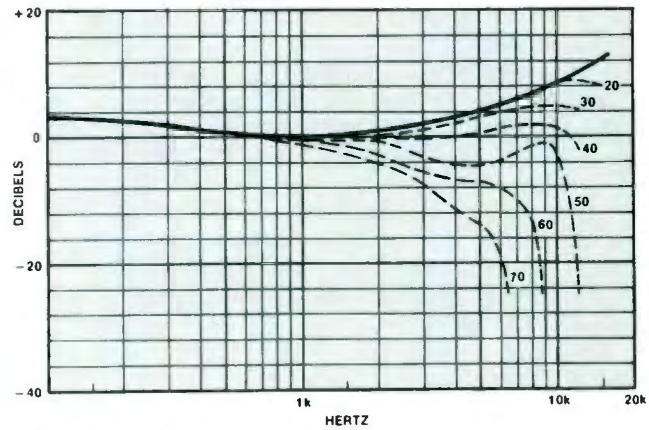

FIG. 4—TAKEN FROM BASF literature, the heavy curve shows the noise-energy distribution of a typically good quality compact cassette tape. High-frequency loss with advancing years renders the hiss level less obvious.

HI-FI SOUNDS, BUT LO-FI EARS

(Contnued from page 32)

Hearing Problems

But—and it is a very significant but—the foregoing figures and remarks apply to people with what has been described as *clinically normal* hearing. While that term has to be very broad in its interpretation, there can be little doubt that a significant number of people suffer from clinically sub-normal hearing.

In some cases, the problem is congenital, in others traceable to trauma of one kind and another. Such problems should logically be referred to a specialist for whatever treatment may be available.

Of more concern, in the context of the present article, is the kind of hearing loss brought about by avoidable situations, of which by far the most important is exposure to prolonged and excessive sound-pressure levels.

The Noise Hazard

The accompanying noise-level figures in Table 2 may prompt the question, "What happened to the automatic-volume-control function," mentioned earlier, and reputed to protect our hearing against exposure to loud noise? The explanation, it would appear, is that the spontaneous tensioning mechanism in the ear can cope with sound-level variations within the *safe* range and perhaps somewhat beyond it; and it can cope with very loud sounds, provided they are infrequent and of short duration. However, when faced with very loud, *sustained* sound, the muscles gradually let go, allowing the high-level impulses to reach the *cochlea*. It is then that the damage occurs, with the hair-like nerve ends for the higher frequencies being particularly vulnerable. Once destroyed, they can never regenerate.

In practical terms, males were at one time more at risk than females, because of their likely exposure to factory noise for much of their adult lives and their possible involvement in noisy activities at other times.

Nowadays, we seem to have learned some lessons in those areas, with noise-abatement programs operating in factories and the more frequent wearing of earmuffs where high noise-level cannot be avoided.

The trouble is that modern technology has now put powerful amplifier systems into everything from rock-music reviews to theaters, cars, and homes. And, with them has come the cult belief that, for sound to turn you on, it has to be at deafening level. How else can it shut out every other stimulus? What's more, if you don't like it that way you must be a bit odd—or old!

As if that's not enough, modern technology has provided us with personal cassette/radio players, and with miniature hi-fi stereo headphones which, if driven hard enough, can deliver sound-pressure levels of 120 dB or more—and that is also in the injurious range (see Table 2).

So, if you really want to add further "decibels down" to the inevitable effects of aging, it is not necessary to take up the trade of a boilermaker or a riveter. Anyone can achieve the same result by spending a few hours a week at a disco, or playing super-loud music at home, or cultivating high-frequency deafness in comparitive isolation with the aid of a powerful headphone stereo system.

What's more, the new deafen-yourself-with-music syndrome is appropriately non-sexist; male and female have equal access to the method. In fact, they often tend to do it in mixed pairs!

Is that all? No, not quite!

According to our medical source, another effective way of turning down your biological tone control is to swim frequently and dive deeply in polluted water. Entering the body through the mouth and nose, bacteria from polluted water can travel up the *eustachian tube* and set up infection in the middle ear. Too many episodes like that can take their own special toll.

And that brings us right back to where we started!

If the blush of youth in your cheeks has given way to the mantle of maturity, you can still anticipate a pleasurable listening experience from quality audio systems—provided you've taken reasonable care of the two bits of audio equipment for which no replacements are available—your ears! But, if you're fortunate enough to be still young, and look forward to the day when even the compact audio disc will be primitive and obsolete, spare a thought for those tiny nerve ends in your ear whicn dislike loud sound so much that rather than listen, they lie down quietly and die! ■