

2

The causes of tinnitus and hyperacusis

The question, ‘What exactly is causing my tinnitus?’ is on the lips of everyone who is distressed by their experiences. In this chapter, we attempt to answer it by describing our model of tinnitus and hyperacusis, which is built on many ideas put forward by people working in this field. We draw, in particular, on the work of Richard Hallam, Ronald Hinchcliffe, Pawel Jastreboff and Jonathan Hazell.

Many theories have attempted to explain tinnitus and hyperacusis. Most focus on defects within the ear, especially the inner ear. Such theories, however, do not explain tinnitus and hyperacusis very effectively. If tinnitus were due simply to damage to the inner ear, how could we explain the fact that many people with tinnitus have normal hearing? Conversely, there are many people with hearing loss who do not have any tinnitus whatsoever.

Hyperacusis is even more difficult to explain in terms of inner ear damage. If the ear is damaged and less information is passing to the brain, how can sounds seem too loud? Common sense would suggest that we would be *less* bothered by sound if our ears were not working properly than more so.

Clearly there must be an explanation and this explanation is, in fact, quite straightforward: the ears are only *part* of the auditory system. To understand tinnitus and hyperacusis, we must consider more of the auditory system and incorporate an understanding of the hearing pathways within the brain – the so-called central auditory system.

Ear anatomy

If you were to look at a diagram of the auditory system in a biology textbook or an encyclopaedia, you would most likely see a diagrammatic representation of the ear rather like that shown in Figure 2.1.

The fleshy outer part of the ear is known as the pinna. This connects, via the ear canal, or external auditory meatus, to the eardrum, or tympanic membrane. The pinna, ear canal and eardrum together constitute the *external ear*.

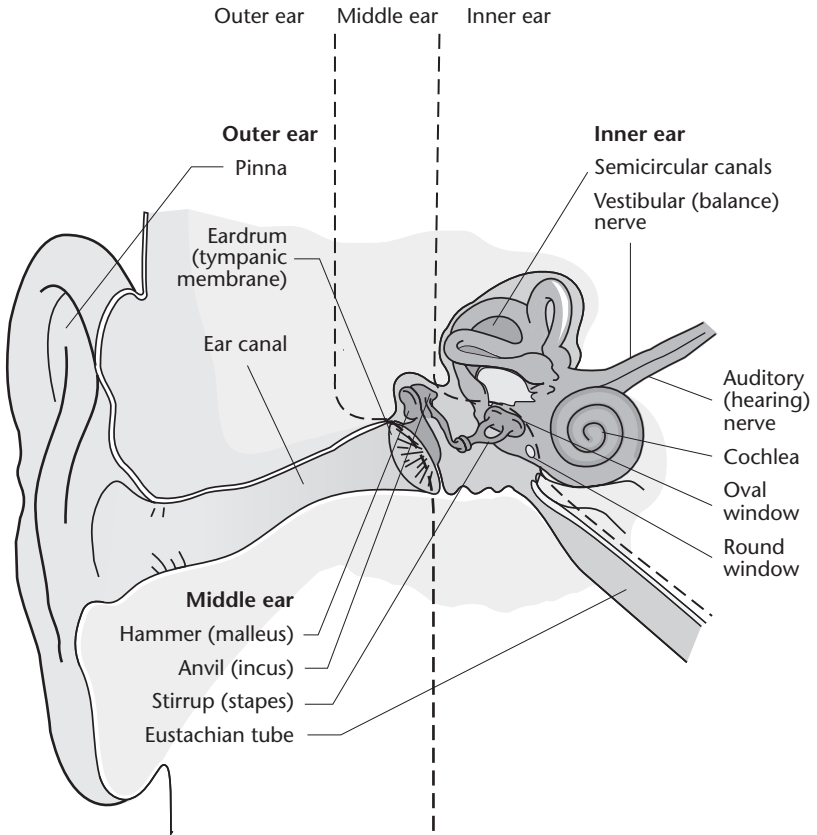


Figure 2.1 The outer, middle and inner parts of the ear

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The eardrum is attached to a tiny bone, called the hammer, or malleus. The malleus is attached to another bone, the anvil or incus, which in turn is attached to a third bone, the stirrup or stapes. These three bones are collectively known as the ossicles and conduct sound vibrations from the tympanic membrane. The ossicles are sited in a small air-filled chamber that obtains its air via a tube called the Eustachian tube that opens at the back of the nose.

Two of the ossicles, the malleus and stapes, are attached to tiny muscles, the tensor tympani and stapedius respectively. These muscles are occasionally associated with specific forms of tinnitus and may also give rise to a sensation of fullness or blockage in the ears (see page 32).

10 Defining the problem

The air-filled space, the three ossicles and the two small muscles constitute the *middle ear*.

The smallest of the ossicles, the stapes, conducts sound into the *inner ear*. This part of the ear is subdivided into the cochlea, which deals with hearing, and the vestibular apparatus, which deals with balance. Sound energy entering the cochlea causes a membrane to vibrate and different parts of this membrane vibrate according to the frequency of the incoming sound. Rows of cells, called hair cells, sit on this membrane. These cells have small rods of muscle protein projecting from their surfaces, which look like hairs under high-powered microscopes and so give the cells their name.

There are two groups of hair cells: inner hair cells and outer hair cells. The vibration of the membrane moves the protein rods of the inner hair cells and this mechanical energy is changed to electrical impulses by the cells. Small nerve fibres underneath the hair cells collect these electrical impulses and convey them to the brain.

Central auditory anatomy

The central auditory system is composed of several structures, some of which have imposing titles such as the inferior colliculus and the medial geniculate body. The names and anatomical descriptions of these structures are not very important in the context of this book. What it is much more important are the functions that the central auditory system performs, which are shown in the form of a flow diagram in Figure 2.2.

The first process is one of recognizing information and making decisions about which sounds must be attended to and which ones can be

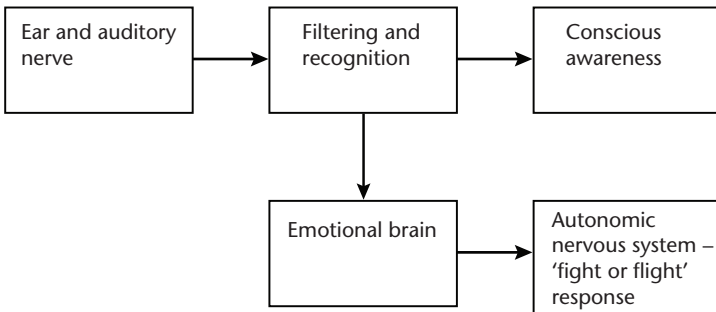


Figure 2.2 The various functional elements of the central auditory system and how they work together

safely ignored. You could consider the auditory brain as having a series of filters, with the purpose of identifying important information and prioritizing it and downgrading unimportant sounds. This is something we all do in everyday life. For example, you can be standing in a busy party with lots of people talking around you, yet if one person mentions your name you will instantly focus in on their conversation. Conversely, you may be so busy doing a task that your friends or family say you are ignoring them or are in a little world of your own.

This ability to either concentrate on sound or block it out is crucial to an understanding of tinnitus. Sound information that is allowed through the filter network is passed to part of the brain called the auditory cortex, which is where we become consciously aware of that sound.

The filtering network can also pass this information to other parts of the brain, particularly the limbic system, which deals with emotions. That is why, if you hear a sudden, unexpected sound, such as a creaking floorboard in the house at night, you may become anxious. The emotional pathways in the brain can, in turn, activate other systems, particularly the sympathetic section of the autonomic nervous system. This is the body's 'fight or flight' response mechanism, the adrenaline centre (see Chapter 8). Thus, not only do you feel anxious but you also become more alert and your pulse starts to quicken, your blood pressure goes up and you breathe slightly faster. If the cause of the creaking floorboard is an intruder, these responses are helpful and may save your life.

This example demonstrates the fact that one of the major functions of your auditory system is to alert you and warn you about danger. Of course, it is not just for that – it also enables sophisticated communica-

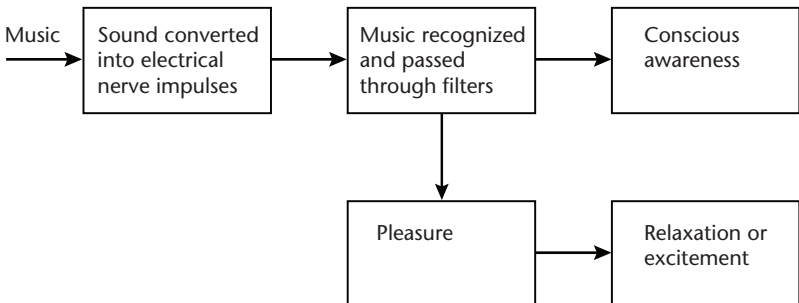


Figure 2.3 How the central auditory system processes sound, enabling us to enjoy music

12 Defining the problem

tion via speech and produces many enjoyable sensations. Figure 2.3 (on the previous page) shows the process that takes place in the auditory system that enables us to enjoy listening to a favourite piece of music.

What the anatomy tells us about how tinnitus develops

To understand how tinnitus develops, we now need to consider research done in the early 1950s by two American researchers, Morris Heller and Moe Bergman.

They placed 80 people who did not have tinnitus, one at a time, in a soundproofed room and told them to listen carefully. They determined that approximately 94 per cent of these people experienced a sound sensation such as hissing, ringing or buzzing when listening hard in silence.

This research was conducted well by the standards of the time, but did attract some subsequent criticism. Interestingly, a recent repeat of the experiment obtained similar results.

Whatever their views on the methodology, the research caused scientists to consider the idea that tinnitus-like sensations are present just below the level of awareness in almost everyone. This is probably due to the healthy, random firing of the auditory nerve at rest or else we could say that it is still busy even when there is no outside sound – it acts ‘spontaneously’.

So why do people who do not have tinnitus not normally constantly hear these sounds? Because the filtering network regards them as unimportant and blocks them in a process known as *habituation*. Figure 2.4 shows this random electrical activity being filtered out.

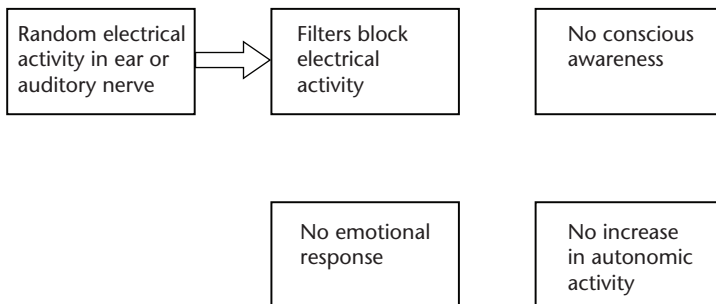


Figure 2.4 The filtering mechanism of the central auditory system working correctly and preventing awareness of random electrical activity

Sometimes this filtering process goes awry and we become briefly aware of a sound sensation. Most people probably experience this for a few seconds at a time. Every now and then, the filtering process can allow the ‘spontaneous’ neuronal activity through for longer periods. This results in a conscious awareness of sound that can also stimulate the emotional pathways in the brain, which, in turn, can produce an autonomic, fight or flight response (see Figure 2.5).

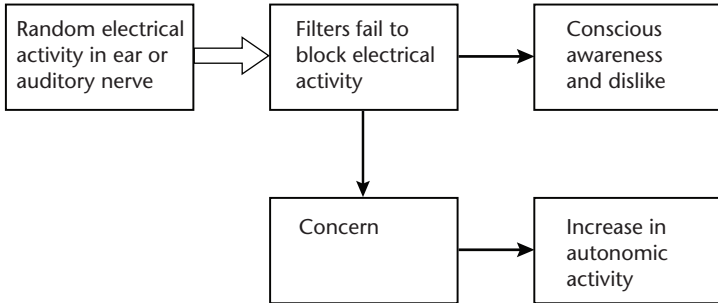


Figure 2.5 The filtering mechanism of the central auditory system can fail and allow random electrical activity to reach other parts of the central auditory system

This increased autonomic activity makes our senses, including our hearing, more acute. Consequently, we notice the spontaneous neuronal activity more. The more we notice the activity, the greater the emotional response to it, resulting in a vicious circle within the central

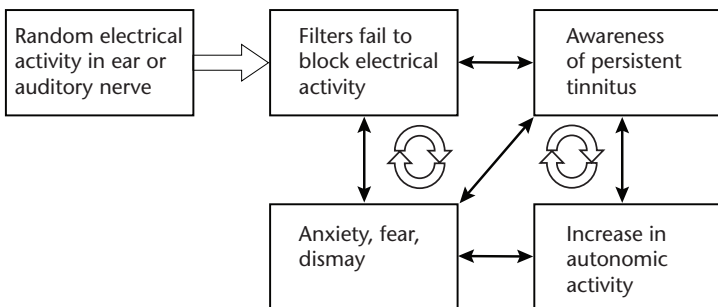


Figure 2.6 The various parts of the central auditory system stimulate other areas, producing positive feedback loops or vicious circles that become synergistic. For example, increased anxiety about sounds causes increased awareness of them and vice versa. The curved arrows show the vicious circles of tinnitus

14 Defining the problem

auditory system. Actually, there are so many interconnections between the various components of the auditory system that the process probably results in the setting up of several vicious circles. If these continue, we become persistently aware of the neuronal activity and tinnitus has arrived (see Figure 2.6, on the previous page).

Once the vicious circles have been set up in the central auditory system, the role of the ear becomes less important. Activation of the emotional pathways in the brain produces the changes in the mood, arousal and thought and behavioural processes that are discussed in Chapter 6.

What causes the filtering mechanism to malfunction?

One possible factor is a hearing loss. This contributes because, as the brain compensates for a hearing loss, it increases sensitivity to sounds that can be heard and, as a consequence, the filters may open wider to allow more information through. Unfortunately, this sometimes allows the spontaneous, random, electrical activity through as well as the important sound information.

Another factor is some kind of emotional shock. Even people whose ears have remained unchanged but have experienced an emotional shock can experience tinnitus as a result. This is because there is increased activity in the emotional brain and this opens the filters. Indeed, many people with tinnitus link the onset of their problem to a life event such as an illness, a bereavement, work or family issues, a car crash or similar.

Finally, there are people who do not seem to have had a hearing change or an emotional upset. It seems that there can be a normal temporary glitch in the filtering mechanism, but, rather than returning to normal, it persists.

Discovering the full picture

It is possible, of course, to experience more than one of these causes – someone with an existing hearing problem may experience an emotional upset, for example, and these two factors together caused the onset of tinnitus.

One helpful tool for understanding the cause of tinnitus is to make a distinction between the *ignition* site of tinnitus, which may be in the inner ear, auditory nerve, emotional brain or other area of the nervous system, and the processes that *promote* the tinnitus into the awareness of the person and *keep* it there.

Tinnitus can be influenced by non-auditory pathways

It used to be assumed that tinnitus was a condition related purely to the auditory system, but, in the early 1990s, some fascinating research was undertaken by Dr Robert Levine, a neurologist working in Boston, USA.

Dr Levine noted that nearly two-thirds of his patients with tinnitus said that it temporarily changed when they made certain movements, such as clenching their teeth, bracing their necks or making a forced smile. In the main, these things increased the intensity of their tinnitus. Furthermore, in people without tinnitus, these movements brought on temporary tinnitus. This phenomenon might be related to the ability that some mammals have to move their ears to help localize sounds, cats being a good example. The brains of these animals have areas that integrate information about the position of their ears and their hearing. Humans have retained this ability, though, as we no longer move our ears in this fashion, the function is vestigial and we do not notice it – that is, until such head and neck muscle movements turn the intensity up, resulting in tinnitus.

More about habituation

As we learned earlier, our brains automatically prioritize the information we receive from our immediate environment, so much of the sensory input coming in does not reach our consciousness. For instance, when you get dressed, your clothing touches your skin, triggering the sensory nerves, which send a myriad nerve impulses to your brain. The brain registers that you have got dressed and then promptly ignores the nerve impulses from the skin. While the clothes are touching the skin, the nerve impulses continue to reach the brain, but you do not continue to pay attention to this information. Regarding sound and hearing, consider a situation where you visit friends who live next to a primary school or a motorway. You might ask them, ‘How do you live here with all that noise?’ and they will probably reply, ‘We don’t hear it any more.’

The process by which your brain filters away continuous, background and non-threatening input from your senses, including your auditory system, is known as habituation. This is normal and helpful. In fact, if you were not able to do this, you would be bombarded and bewildered by an array of sensations.

Habituation gives great hope that recovery from troublesome tinnitus is possible as the usual reaction of your body to such sounds

16 Defining the problem

is to ignore them. You may find it extremely difficult to believe this, but most people do gradually habituate to their tinnitus. There are two main steps in this process. First, a reduction in agitation, both directly related to tinnitus and any other cause. Second, a change in the meaning of the tinnitus so that, instead of being a sound sensation that the brain gives priority to and must pay attention to, it becomes a background and less meaningful stimulus.

Hyperacusis

As we saw in Chapter 1, hyperacusis is an excessive sensitivity to sound. Other terms for different types of sound sensitivity include phonophobia, misophonia and recruitment. For a tinnitus and hyperacusis specialist, there are subtle differences between these terms, but, due to considerations of space and usefulness, here we will consider them as a single entity – hyperacusis.

Defining problems associated with sound sensitivity is difficult. We all have a limit to the loudness of sound that we can comfortably tolerate. This limit is not fixed, but varies according to the context of the sound and your mood. Thus, a sound that you can usually tolerate with ease can seem unbearably loud when you are tired, stressed or ill. Similarly, most of us have particular sounds that we dislike, such as chalk screeching down a blackboard or the squeal of a London taxi's brakes.

So, when does a normal reaction to sound change and become hyperacusis? The answer is, when it causes significant distress or even pain to the person who is experiencing it.

How does it develop?

There are probably two main mechanisms by which hyperacusis can develop. First, if the emotional brain is overactive, it can react excessively to sound (see Figure 2.7).

Second, if the auditory system is overactive, it can abnormally enhance sound inputs, which, in turn, causes more activity in the emotional brain and autonomic nervous system (see Figure 2.8). As we have already seen, the emotional brain and subconscious parts of the auditory system are overactive in people with tinnitus, so it is not surprising that hyperacusis is more common in people who have tinnitus than those who do not.

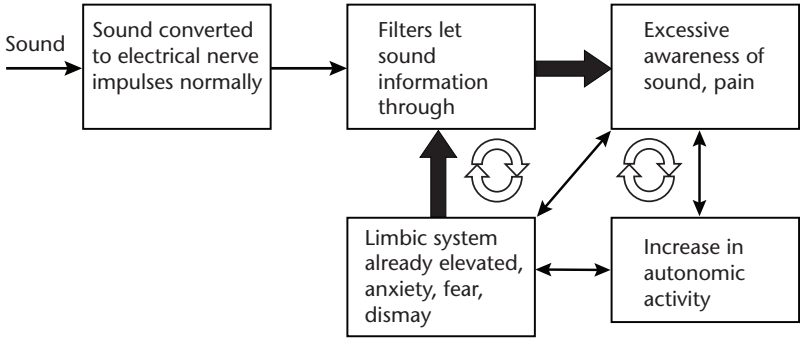


Figure 2.7 Hyperacusis generated by increased activity in the limbic system, causing the filtering network to allow more inputs through to the central auditory system (see the thick black arrows). Vicious circles develop (see curved arrows) – the increased anxiety causes increased auditory awareness, which makes the anxiety worse and so on

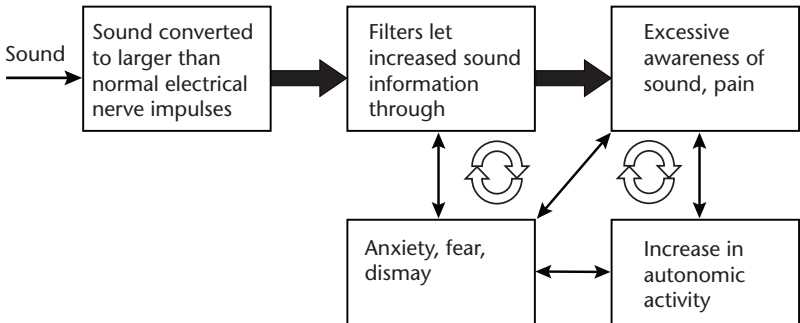


Figure 2.8 Hyperacusis generated by increased activity in the auditory pathways, increasing inputs to the central auditory system to an abnormal level (see the thick black arrows). Vicious circles develop (see curved arrows) – the increased auditory awareness causes increased anxiety, which heightens the awareness and so on

Summary

In this chapter we have presented an overview of what is understood about tinnitus and hyperacusis. This provides you with a framework that enables you to use the information given in the rest of the book, but, if you are interested, we have described some of the mechanisms in more detail in the Appendix.