John Naylor

NOW HEAR THIS!

A Book About Sound

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John Naylor
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Sue and her keen ears

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Introduction

I have to begin with a confession: I am not by nature a listener. I seldom pay heed to sounds with the same degree of interest and attention as I do to sights. I like to stand and stare, but all too often I fail to linger and listen. At least, such was the situation before I set about writing this book. I now realise that for most of my life I have invariably ignored the vast majority of sounds I have heard in the mistaken belief that they are inconsequential, uninteresting or irritating.

Now, well past middle age, and almost certainly soon in need of hearing aids I am increasingly aware that I no longer hear high frequencies, the very frequencies that give sounds the clarity and bite which are essential to comprehending clearly what is being said to me.[1] So having belatedly resolved to make up for lost time and listen to the world as attentively as I look at it, I now find myself in a race to make the most of what remains of the hearing I took for granted in my youth before my acoustic compass is reduced to murmurs and mumbles.

This book is the product of that decision. It is aimed squarely at anyone with an interest in science and the natural world but who is as unaware of their soundscape as I once was. There are six chapters dealing with the subjective aspects of hearing and listening; the history of some of the key events and discoveries that have led to our present knowledge about the nature of

[1] Since writing these words, I have been fitted with hearing aids, much to the relief of my family and friends.

sound; the nature of sound considered both as a physical phenomenon and as a sensation; the workings of the hearing system and how it has evolved in vertebrates; the passage of sound in air and in water; the many ways sounds interact with the environment and the effects of those interactions on what we hear; explanations of a host of sounds and acoustic effects, ranging from the commonplace to the unusual. The footnotes that pepper the text supply annotations to the core text—for no book is entire of itself. My research has been based on primary sources, expert advice and, wherever possible, first hand personal experience of the sounds I write about.

Compared to sight hearing is a hugely underrated sense, not least because we unconsciously assume that the world discloses itself to us most fully by means of light. We seldom pay heed to sounds with the same degree of interest and attention as we do to sights. In almost every situation we are usually far more aware of what we see than what we hear. By habitually ignoring or paying scant attention to sounds we pass up the opportunity to engage more closely with our soundscape, something that will increase our knowledge and awareness of the world at large, not to mention missing out on the unexpected sensuous and intellectual delights that are the true reward of active listening.

A book about sound must also be book about listening. It is only as one learns what to listen for that one begins to engage more fully with one's soundscape because hearing goes well beyond mere sensation. It is a creative act that melds raw auditory sensations with expectation, motive, memory and knowledge to forge a rounded experience of one's sonic environment. Descriptions and explanations of how particular sounds are produced, propagated and altered in a given situation greatly helps here, but is never the whole story, for sounds have psychological and physiological aspects that physical science does not address. The sensations that characterise sound, such as loudness and pitch, are not replicas of the physical vibrations that stimulate them, though that is something very few of us are aware of.

In thrall to the stark and reassuring certainties of physics, during my thirty years of teaching the subject I blithely assumed that there is little more to any sound than complex vibrations within a medium and their interactions with the objects they encounter. I considered that hearing was merely a useful though minor adjunct to those facts. What need for ears when there are mathematical formulas and scientific instruments with which to analyse and make sense of the vibrations we experience as sound? I took it for granted that physics could, and did, tell me everything worth knowing about sound and hearing. How wrong I was. I now realise that although there can be no sound without vibrations to stimulate the hearing system, sounds and the vibrations

that give rise to them are worlds apart. One is a visceral, flesh and blood sensation, the other a noiseless physical event.

It was only when I realised the difference that I freed myself from the mistaken assumption that sound is a special form of acoustic vibration. In fact, there is no such thing as a sound wave, there are only vibrations of the medium in which we find ourselves. *All* vibrations of air and water are in principle audible to humans as long as they satisfy two conditions: first that they are sufficiently energetic to cause the eardrum to vibrate and second that they fall between 20 Hz and 20,000 Hz.

And so one of the least expected and most salutary lessons I learned while writing this book is that sound is a product of the auditory cortex: it's all in the mind. In the absence of ears the world would be utterly silent. It hadn't occurred to me that there were no sounds before there were ears, merely feeble, fleeting vibrations that pulsed within the primeval seas that were home to the earliest forms of animal life. The evolution of the ear in its various forms was driven by improving the chances of survival brought about by being able to detect those vibrations because they proved to be an invaluable and often irreplaceable source of information about events in a creature's environment that are out of sight, events that to this day can be a matter of life or death. Within the murky, muddy waters of lakes and rivers and in the sunless depths of seas within which the ear first evolved, hearing was, and still is, a far more useful sense than vision. But to be aware of these vibrations it is necessary to convert them into something palpable, namely sensations that we experience as sound.

Nor did it occur to me to wonder why human hearing is limited to a narrow range of vibrations that lie between 20 Hz and 20,000 Hz, or why the majority of mammals hear vibrations far beyond the upper limit of that range. In fact, the range of vibrations that a given species hears has been determined as much by biology and the environment that a creature inhabits as it has by the physical properties of waves. You will find an explanation for these things in Chap. 3, in which the science of vibrations audible to the human ear is dealt with, and where several pages are devoted to the evolution and the biological purpose of the hearing system. In that chapter you will also learn that there are several illuminating similarities and differences between hearing and vision, hardly surprising given that they both rely on waves that have many properties in common.

Something else dawned on me as I was writing this book: all of us have a vast store of aural knowledge about the world and its workings that we not aware of having made any effort to acquire. We are able to locate the source of a sound with our eyes closed, estimate the relative size of an empty

space just from its acoustic qualities, identify a host of events merely from their sounds, and distinguish a hard surface from a soft one simply from the sound of the impact when tapping them lightly. Nor can we recall ever having learned to make sense of the most complex of all sounds, those of speech. Our ears have been beavering away in the background since the day we were born, learning to identify and interpret sounds, seemingly with little active participation on our part. As long as one's ears are in working order and one is exposed to sounds and voices from birth, they perform the task for which nature has fashioned them: to provide information about one's environment that is both useful and reliable. But as you will discover as you read this book, despite the vast trove of acoustically acquired knowledge you already possess, there remains an equally large number of sounds and acoustic effects that you encounter daily of which you will not be aware. All it takes to expand your acoustic horizon is a little knowledge and a willingness to pause and listen attentively whenever you hear a sound.

The ability to acquire reliable knowledge of the world through our ears alone is all the more remarkable given that the acoustic world lacks the permanence of the visual world. By and large a landscape doesn't change significantly from one moment to the next. You can return days or weeks later and find it is more of less as you last left it. But given the transient nature of most sounds, if you don't make a point of listening when the opportunity arises, you may not get a second chance. That transience may be why we often find it difficult to describe a sound in terms of its acoustic qualities alone. In any case, we are usually uninterested in its acoustic qualities; it's the source we find relevant because that tells us something about what is going on in our surroundings. So when we talk about sounds we invariably refer to their sources rather than to their acoustic qualities.

We seldom hear sounds in their pristine state, however. They are almost always altered by their passage through the medium in which they are heard and their interactions with the environment in which we hear them. Indeed, these modifications are sometimes far more interesting than the original sound.[2] So if you are to fully understand why you hear sounds in the form in which they reach your ears, knowing the effect of these interactions on a given sound is as important as knowing how that sound was produced in the

[2] This is even truer of light, by the way: sunlight is invisible until it interacts with matter, making environments visible in all their variety and complexity and creating eye catching sky colours, rainbows and mirages. In fact, considered purely as sources, sounds are infinitely varied in comparison to lights. Every sound is due to a unique event whereas during daylight there is but one source of light: the sun. At night the only natural sources of light are stars, lightning, fire, luminous creatures such as fireflies and phosphorescent organisms. Moonlight is reflected sunlight, as is the light of planets.

first place. The nature and effects of those interactions on what we hear are the subjects of Chaps. 4 and 5.

Yet when all is said and done, information about specific sounds and acoustic effects is of little value if you don't listen to them, which is why you will find suggestions and advice in every chapter of how to improve your chances of hearing them. Knowing which features of a particular sound to listen for will influence and alter the way you listen and, consequently, what you hear, a virtuous circle of aurality. If this book achieves anything I hope it will be to encourage you to listen to all sounds, no matter how unwelcome and unpleasant, with greater attention, interest and understanding than hitherto—and thereby be enthralled and entertained and enlightened by the experience.

I don't, however, have much to say about the undesirable effects of sound beyond sketching out a brief history of noise to show that unwanted sounds have posed a problem ever since humans made an appearance on Earth. Interesting and important though the physiological and psychological effects of noise on people and animals are, they are subjects that are well catered for in numerous books, journals and blogs. In any case, I want to encourage you to listen attentively to sounds however intrusive or disagreeable they may be. Not that I advocate that you should tolerate such sounds any longer than is necessary to make sense of them. It's that one of the consequences of living in a noisy environment, as so many of us do these days is that we allow ourselves to become functionally deaf. We don't go out of our way to listen to ambient sounds unless we have a particular reason to do so.

To avoid overwhelming you with dry, matter-of-fact descriptions and explanations, necessary though these sometimes are, I have provided accounts of how some of the unusual sounds and acoustic effects that you will be reading about were discovered. It will put you in the shoes of the men and women who made these discoveries, enabling you to understand the challenges of hearing and making sense of unfamiliar acoustic phenomena.

The history of these discoveries serves another purpose. We usually ignore the distinctive acoustic qualities of most sounds even when they are in principle audible. John Ruskin, the influential 19th century art critic, pointed out "The first great mistake that people make … is the supposition that they must see a thing if it be before their eyes."[3] Substitute 'hear' for 'see' and 'within earshot' for 'before their eyes' and you have the reason why most of the unusual sounds and their modifications that you will come across in this book were either unknown, ignored or misunderstood until someone

[3] Ruskin, J. (1908) Modern Painters, vol 1. George Allen & Sons, p 54.

realised that what they had heard was in some way out of the ordinary or unexpected and required explanation. If nothing else, finding out how and why they made their discoveries teaches us that if we don't make a point of listening, we will hear only noise.

Although Chap. 2 is specifically devoted to the history of acoustics, in every chapter you will find accounts of how we have come to our present knowledge of sound in general and of specific sounds in particular. Arguably, the science of acoustics began with Pythagoras' attempt to discover the basis of musical harmony, an issue that is yet to be settled, if indeed such a thing is possible. In the following centuries the natural philosophers of ancient Greece established several facts about sound, such as that it travels much more slowly than light and that all sounds, whatever their pitch, must travel at the same speed. They also surmised that sound requires a medium, though proof of this was delayed until the scientific revolution of the 17th century during which air pumps capable of producing a vacuum were invented. That century also saw the development of precise measurements and mathematical theories about the nature of sound and how it propagates, which in turn paved the way to the first satisfactory account of light as a wave in the early decades of the 19th century.

The scientific investigation of sound was never conducted in isolation from the wider scientific investigation of nature. The important role that sound played in the development of modern science is all too often ignored in books about the history of science. It took a couple of thousand years before the innermost secrets of light were finally laid bare (i.e. the wave-particle model c.1900 AD), with considerable help along the way from what was known about sound. But the essential nature of sound—that it involves matter in motion—was known to the ancient Greeks c.300 BC.

But until the turn of the 20th century, almost all scientific research into sound and hearing was based on the assumption that only simple sounds that have an identifiable frequency are worth investigating. Complex, dissonant sounds composed of a broad range of unrelated frequencies, such as those due to natural or mechanical events, were lumped together as noise and, on the whole, ignored by scientists in the belief that nothing very useful could be discovered from such sounds. This view owed as much to cultural preconceptions as it did to the limitations of the scientific apparatus and laboratory techniques of the day. Symphonic music was considered to be the highest expression of European culture, so scientific research into sound focused on investigating those aspects of sound that underpin music. It was only with the invention of electrical devices such as the loudspeaker and microphone towards the end of the 19th century that noise began to interest scientists.

Indeed, making scientific sense of noise became a matter of life and death during the two World Wars, as we shall see in Chaps. 4 and 5.

So much for an overview of what you will find between the covers of this book. Now down to business. If you've picked up the book because its subject matter is of interest to you but, like me, you've hitherto taken your ears for granted, you may find it worthwhile priming the pump and, rather than diving straight into Chap. 1, spend some time listening to the soundscape you find yourself in and even making a few noises of your own.

So here is a suggestion: put the book down and take a break. Make yourself a cup of tea (or coffee) and listen to the attendant sounds as if you were hearing them for the first time.

Finished? What did you hear as you filled the kettle from the tap and as it heated up until it began to boil? And what of the sound as you poured water from the kettle into the cup? Did it change as the cup filled up? What of the sound as you stirred the drink with a spoon? If you made instant coffee you might have noticed a change in pitch as you stirred. And how would you describe these sounds to someone else: in terms of their acoustic qualities or the events or things that are their source?

There will, of course, have been many other sounds as you made the cup of tea, ambient sounds that had nothing to do with tea-making. How aware of them were you and can you recall them? I ask only to make the point that to consciously experience sounds you have to make a point of listening attentively, which is the overriding theme of this book.

Alternatively go for a walk and make a point of listening as attentively as you can. Sound walks, as such walks are known, are very popular these days and I shall have more to say about them in Chap. 1.

A final word of advice. The descriptions and explanations of sounds that you will here is only a first step. The real goal is to listen to them. This is not just a matter of being in the right place at the right time, it also helps to know what it is that one should be listening for. Written descriptions of the acoustic qualities of a particular sound is helpful, but these usually have to be heard several times before one can be confident of identifying them without difficulty. Persistence is the key, as I have learned. And when listening be prepared to hear out every sound from the moment you become aware of it until it finally fades away: linger and listen.

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1

Just Listening

Abstract The chapter deals with the subjective experience of hearing and introduces themes and topics that are taken up in later chapters. It opens with a brief history of the universal human aversion to sounds that are loud, intrusive or unpleasant and explores their psychological and physiological consequences before going on to argue that if one is willing to listen attentively one discovers not only that every sound is interesting, but also that they are frequently an irreplaceable source of information about the world.

A Brief History of Noise

In the realm of the senses we unthinkingly consider sight to be first among equals, so much so that we give little thought to the broader picture, that we have a multitude of senses on which we rely for an awareness of our body and the surroundings in which it finds itself. Though the exact number remains an open question, the idea that we have just five is a legacy from ancient Greece, and a gross underestimate.[1] But however many senses we may have,

[1] Quite apart from vision, hearing, smell, taste and touch, there is the vestibular system that is essential to keep track of head movements and prevent one from falling over (and is located in a cavity within the skull adjacent to the system responsible for hearing). And touch consists of several distinct senses that are separately responsible for sensations of warmth, hardness and pain. In total we may have as many as 21 senses. Interestingly, the Greek quintet of five senses (sight, hearing, taste, smell and touch) is also found in Chinese and Indian natural philosophy.

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only two of them are capable of perceiving the world in detail well beyond arms' reach: sight and hearing.

On the face of it, however, we appear to have far less control over what we hear than what we see. You can avert your gaze from anything that distracts, disgusts or dismays you and direct it at what is of interest or importance. You can close your eyes or turn your back on what you don't want to see, but short of blocking your ears with your fingers there is no equivalent action that will enable you to avoid sounds you don't want to hear.[2] Unlike eyes, ears are more or less permanently open to the world. Indeed, if eyes are scouts that probe and search our surroundings, ears are watchful sentinels that warn of dangers and opportunities that are out of sight Friedrich Nietzsche, the German philosopher and a master of the mordant aphorism, considered the ear to be the organ of fear that evolved to warn us of dangers in the darkness of night.[3]

The price we pay for having such a vigilant sense is that all too often we must endure sounds over which we have no control, sounds that are unpleasant or intrusive and which may be loud enough to damage our hearing. Perhaps this is why there is a specific word for sounds that we would rather not hear—noise—but no comparable collective noun for their visual equivalents, for sights that we find distracting or distressing. And you don't need to be told that we live in a noisy world. Nor that it's becoming noisier, that there are fewer places where one can get away from the host of loud, disagreeable, unwanted sounds due to overflying aircraft and road traffic, not to mention sirens, chainsaws, mowers, strimmers, leaf-blowers and the like that contribute to the all too often aggravating soundscapes of our towns and cities, and which have long since encroached on all but the most remote rural landscapes.

Not that there ever was a time when the world was entirely free of noise, especially noises of which other people were, and continue to be, the source. For noise is more often than not shorthand for any sound that we would rather not hear, either because it is loud or unpleasant or because we find it intrusive. Unwanted sounds can interrupt one's train of thought, cause distress because the source is beyond one's control or prevent one from hearing clearly sounds one wishes to hear. Even sounds that in one context one finds enjoyable or soothing, say a favourite piece of music or a gentle tinkling of a fountain, can be distracting or aggravating in another.

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[2] Low frequency sound can reach the inner ear by bone conduction through the skull, so sticking your fingers in your ears won't prevent you hearing the bass notes emitted by a source of sound.

[3] Nietzsche F. (1997) Daybreak, Thoughts On The Prejudices Of Morality (trans: Hollingdale R.J.). CUP, aphorism 250, p. 143.

Indeed, to judge from the ancient Mesopotamian tale of Atra-hasis, humans have always had a deep-rooted aversion to unwanted sounds because, long ago, people believed that even the gods detested noise above all else. In this story, which almost certainly predates by several centuries or more the 2nd millennium BC clay tablets on which it first was inscribed, we learn that the storm god and chief deity, Enlil, found the din made by the first humans so unbearable that he decreed that their number should be drastically curtailed. First he visited a drought on them, followed by a plague and finally a famine. But after each disaster the survivors quickly restored their number and became as noisy as before. Exasperated, Enlil concluded that the only solution was to do away with humans altogether by drowning them all in a great flood. One of the gods, Ea, considered the punishment to be unjust and secretly warned Atra-hasis of the impending catastrophe, advising him to build a huge vessel and fill it with artisans and animals, which he did.[4]

Enlil was enraged when he discovered that he had been betrayed, but was eventually persuaded by Ea to spare Atra-hasis and his companions on condition that, to keep their numbers down, henceforth man born of woman shall be mortal. The story of this great flood and its survivors reappears in the Epic of Gilgamesh, a rip-roaring, eponymous saga which dates from the turn of the 2nd millennium BC, though the name of the ark-builder and survivor is now Uta-napishti. After the flood has abated, Uta-napishti and his wife are granted immortality on condition that henceforth they live apart from their fellow men and women. It is the account of the flood in that epic that the Jewish authors of the book of Genesis drew upon for the story of Noah and the flood, though they attributed the punishment to mankind's wickedness rather than to disturbing God's peace of mind.

The Epic of Gilgamesh has been patiently pieced together by scholars over several decades from hundreds of clay tablets, the first of which were recovered in 1850 by an English archaeologist and his Assyrian assistant from the ruins of the royal library of the last great king of Assyria, Ashurbanipal (668–627 B.C.), at Nineveh, in what is now northern Iraq.[5] Nineveh, which was founded several thousand years before the reign of Ashurbanipal, was perhaps the first true city. And of all environments, the hustle and bustle of commerce, manufacture and street life makes the soundscape of cities potentially the most varied, and to sensitive ears, the most gruelling of any. Cities are also

[4] Finkel, I. (2014) The Ark Before Noah: Decoding the Story of the Flood. Hodder & Stoughton.

[5] The Epic of Gilgamesh (trans: George, A.). Penguin Books, 1999. See the introduction for an account of the discovery and translation of the cuneiform tablets.

home to poets, philosophers, historians and diarists who have often chronicled life lived within earshot of inconsiderate neighbours, bustling streets and busy workshops.

Writing about life in Rome at the turn of the second century, AD, the Roman poet, Juvenal claimed that the city was so noisy that "Tis frequent here, for want of sleep, to die …What house secure from noise the poor can keep, When even the rich can scarce afford to sleep?"[6] Even the Stoic philosopher, Seneca the Younger, writing a generation before Juvenal, admitted in a letter to a friend that the noises from the gym above which he had rooms (grunting weightlifters, swimmers splashing about in the pool, cries of hawkers peddling their wares), and from the street (trundling carriages, artisans at work, more hawkers), to which, as a Stoic, he claimed he should be indifferent, eventually got the better of him. He moved lodgings.[7]

To judge from "The Statutes of the Streets of this City, against Noysances" drawn up to control inconsiderate neighbours and busy workshops, intrusive noises were an inescapable fact of life in late sixteenthcentury London. Rule 30 required that "No man shall after the hour of nine at the Night, keep any rule whereby any such suddaine outcry be made in the still of the Night, as making any affray, or beating hys Wife, or servant, or singing, or reviling in his house, to the Disturbance of his neighbours." And trades that employed hammers were covered by rule 25, which ordered that "No hammar man, (such) as a Smith, a Pewter, a Founder, and all Artificers making sound, shall not worke after the houre of nyne in the night, nor afore of four in the Morninge." Enforcing these rules was another matter, because the authorities seldom acted upon complaints.[8]

London's "hammar men" paid a heavy price for practicing their trade, one that all metal workers since antiquity have paid, because repeated exposure to loud sounds progressively kills off the tiny hair cells that convert external vibrations into auditory sensations within the inner ear. Hair cells do not regenerate, so their destruction leads to irreversible hearing loss and even to profound deafness. This was particularly true of blacksmiths and coppersmiths because iron and copper are harder to work than softer metals such as silver or gold and so require more forceful blows to fashion them into shape. And it isn't just loudness that harms hearing. The high frequency sounds that are produced when a stiff metal sheet is struck are particularly

[6] Juvenal, Satires III, 375–380. In: The Satires of Decimus Junius Juvenalis (1693) Translated into English Verse. By Mr. Dryden, and Several Other Eminent Hands. Printed for Jacob Tonson, London.

[7] Seneca the Younger, Epistles to Luculius, LVI. https://en.wikisource.org/wiki/Moral_letters_to_Lucilius/Letter_56 (accessed 06/08/2021).

[8] City of London (1677) The Laws Of The Market. Printed by Andrew Clark, Printer to the Honourable City of London.

damaging, so hearing impairment in metal workers typically begins with the loss of sensitivity to high frequencies.

Worse was to come. During the early stages of the Industrial revolution, which began during the second half of the eighteenth century, small, muscle-fueled workshops and forges were replaced by relentless and impersonal steam-driven machines housed in large, regimented factories. The noise of the machinery within these factories was often so loud that workers could not hear themselves speak, and occupational deafness was no longer confined to the "hammar men". Weaving mills, in particular, were notoriously noisy, and the level of sound due to the machinery was such that workers were very unlikely to survive life on the shop floor with their hearing intact.

Surprisingly, the link between loud sounds and deafness was not fully recognised until well into the nineteenth century, possibly because workers usually died before the full effects of their occupation on their hearing reached its inevitable denouement. Even as late as 1831, while acknowledging that blacksmiths eventually lose their hearing due to the sound of constant hammering, a physician might be just as likely to ascribe his patient's deafness to "cold air, variable climate, nasal polyps, tonsillitis, fever, bladder infections, measles, catarrh."[9] Nevertheless, the ancient Greeks may have been aware of the link between loud sounds and deafness. Aristotle implies as much in a passing reference to metal workers of his day. Commenting on the claim that mortals are unable to hear the Music of the Spheres—the sound that Pythagoreans claimed was made by the planets as they move through the sky—he wrote that it "is just what happens to coppersmiths, who are so accustomed to the noise of the smithy that it makes no difference to them."[10] Knowing what we now know, it is not unreasonable to conclude that the reason Greek coppersmiths tolerated the sound of constant hammering is that it had rendered them partially deaf and so were unable to hear the worst of it.

And in an early eighteenth century treatise on industrial injuries by an Italian physician, Bernardino Ramazzini wrote that Venetian coppersmiths become increasingly deaf during their working life "To begin with, the ears are injured by that perpetual din … so that workers of this class become hard of hearing and, if they grow old at this work, completely deaf."[11] He made

[9] Fosbroke, J. (1831) "Practical observations on the pathology and treatment of deafness. The Lancet, Vol. 16, No. 398, p 69–72.

[10] Aristotle, 350BC, On the Heavens, Book 2, Sect. 9. http://classics.mit.edu/Aristotle/heavens.2.ii.html (accessed 15/03/2020).

[11] Ramazzini, B. (1940) Diseases of Workers Translated from the Latin text De morbis artificum of 1713 by Wilmer Cave Wright. Chicago University Press, p 438.

no mention of other trades in which hearing is damaged by loud noise such as stonemasons, blacksmiths and military gunners.

The loudest and most injurious industrial sounds were those produced in the manufacture of boilers, the *sine qua non* of the steam engines of the nineteenth and twentieth century. Indeed, hearing loss was so common among boilermakers that occupational deafness of industrial workers became known as "boilermaker's disease". The worst affected were the riveters' mates who worked inside the boiler. Although boilermakers knew that their hearing was impaired, many of them insisted that they could hear perfectly well as long as they were in a noisy environment. They seemed not to realise that this was because they had to shout loudly to be heard above the din. When their hearing was tested, they were invariable found to be partially deaf.[12]

But even if you haven't spent your working life bashing bits of metal, your hearing will almost certainly deteriorate. Hearing loss is, alas, an inevitable consequence of aging. The condition is known as presbycusis and is due to irreversible damage of the hair cells within the inner ear responsible for hearing high frequencies.[13] But presbycousis usually occurs so gradually that one becomes aware of the problem only when one finds oneself constantly having to ask people to speak up or repeat what they have just said, adding irritably: "don't mumble". The inability to hear high frequencies makes it difficult for a listener to distinguish clearly sibilant consonants such as /s/ from /z/, in which high frequencies are prominent.[14] This can result in confusing one word for another, e.g. 'fifty' and 'sixty'. Presbycusis makes it difficult for English speakers to distinguish the singular from the plural form of English words because the sibilant /s/ at the end of the plural form can't be heard distinctly.[15] As we shall see in chapter three, the link between presbycusis and the loss of sensitivity to high frequency sounds was not clearly established until the early years of the nineteenth century.

It is also possible to lose one's hearing through illness, injury or poison. Hearing loss in an adult can result from illnesses such as scarlet fever and measles, and, occasionally, head injuries. And as if that were not enough, some people become partially deaf because the tiny bones in their middle

[12] Schartz, H. (2011) Making Noise: From Babel to the Big Bang & Beyond. Zone Books – MIT, p 366–67.

[13] The deterioration of vision with age due to loss of elasticity of the lens within the eye, which leads to long sightedness, is known as presbyopia.

[14] See this for yourself with an audio spectrometer such as SpectumView, an app for iOS. Alternately voice each of the consonants into the app and notice that their spectra are (a) similar and (b) higher frequencies are prominent. The spectra of consonants /v/ and /f/ are even more similar. To see the audio spectrum clearly, prolong the utterance of the consonant to allow the spectrometer to reveal the constituent frequencies clearly.

[15] Foley, H.J., Matlin, M.W. (2010) Sensation and Perception. Routledge, p 394.

ear fuse together, which prevents them efficiently transmitting vibrations of the eardrum to the inner ear. The condition is known as otosclerosis and it is the commonest cause of deafness in young adults. Alarmingly, some of the drugs that have been used to treat these conditions, such as quinine or the antibiotic streptomycin, are now known to damage the inner ear and the auditory nerves.

Otosclerosis is probably what put paid to Ludwig van Beethoven's hearing. He became aware of problems with his hearing when he was 30 years old and living in Vienna. He had already been suffering from ringing and buzzing in his ears (i.e. tinnitus) for a few years. Most of the doctors he consulted concluded that his ears were blocked up with wax and that in time they would clear. Given the state of medical science at the time, it is not surprising that the remedies they suggested proved useless. Among these was bathing in the Danube. Eventually he was advised to leave Vienna for a quiet village not far from the city. He was joined there by a friend, Ferdinand Ries. During a walk in the countryside, Ries drew Beethoven's attention to a shepherd playing his pipe, but Beethoven, to his great dismay, couldn't hear a thing.[16] Perhaps this was the moment when he first realised that his hearing was not going to improve. It continued to deteriorate and in 1816 he resorted an ear trumpet. A year later he was reduced to using pencil and paper to conduct conversations. And by 1823 he was completely deaf. Only someone with most determined and uncompromising character could have composed his greatest symphonies while being unable to hear clearly, or indeed at all in the case of his final and possibly his greatest symphony, the 9th. The autopsy following his death was inconclusive regarding the cause or causes of his deafness. A later analysis of his hair revealed high levels of lead, a metal now known to be otoxic and which can cause otosclerosis.

Beethoven lost his hearing over several years, but a serious injury to the head can sometimes deafen one in the blink of an eye. Disconcertingly, a sudden and total loss of hearing is not always immediately evident to the sufferer. John Kitto, a nineteenth century British missionary, lost his hearing aged 12 following a fall from a roof. He was concussed and didn't regain consciousness for 2 weeks. "I was very slow in learning that my hearing was entirely gone. The unusual stillness of all things was grateful to me in my utter exhaustion [which] I ascribed to the unusual care and success of my friends in preserving silence around me. I saw them talking indeed to one another, and thought that, out of regard to my feeble condition, they spoke in whispers, because I heard them not. The truth was revealed to me when

[16] Wegeler, F. and Ries, F. (1848/1988) Beethoven Remembered: The Biographical Notes of Franz Wegeler and Ferdinand Ries, (trans: Noonan, F.). Andre Deutsch Ltd.

[I asked for a book I wished to read]. And I was answered by signs which I could not comprehend. 'Why do you not speak', I cried, 'pray let me have the book.' [But instead of speaking to him, someone wrote an answer on a slate.] But, I said in great astonishment, 'Why do you write to me, why not speak? Speak, speak.' The answer was written on the slate: 'You are deaf'."[17]

Another occupation where hearing was and continues to be at risk is soldiery. The blast that accompanies the exit of a musket ball or bullet from the muzzle of a rifle damages the hearing of the shooter, a condition known a "shooter's ear". The problem would have been evident as long ago as the sixteenth century, when firearms were first introduced to the battlefield. Ambroise Paré, who served with the French army as a battlefield surgeon in the sixteenth century, found that cannon fire often left gunners permanently deaf.[18] But it was only following the American Civil War (1861–65), in which at least one third of the surviving combatants were found to have suffered loss of hearing to a greater or lesser extent, that deafness was recognised to be a service-related injury.

Hearing loss, however, is arguably among the least of a soldier's worries when on active service. Long lasting psychological trauma due to the stress of combat, which in addition to the prospect of being maimed or killed includes the shock and noise of battle, afflicted combatants long before it was properly recognised. Herodotus, the Greek historian, writing about the battle of Marathon which took place in 490BC recounted how "An Athenian, Epizelus, son of Cuphagoras, while fighting in the medley, and behaving valiantly, was deprived of sight, though wounded in no part of his body, nor struck from a distance; and he continued to be blind from that time for the remainder of his life."[19] There are countless similar cases in accounts of battles throughout the ages.[20] But it is only since the advent of the modern artillery shell during the early years of the nineteenth century that the nerve-shattering sound of exploding shells became an inescapable feature of the battlefield soundscape, and which undoubtedly contributed to what became known as "shell shock" during the First World War. It was experienced in all armies during that war, hence "kriegsneurose" in German and "névrose

[17] Kitto J. (1845) The Lost Senses, Series 1, Deafness. Charles Knight & Co, p 11–12.

[18] Schacht, J., (2008) Auditory Pathology: When Hearing Is Out Of Balance. In: Schacht, J., Popper, A. N., Fay, R.R. (eds) Auditory Trauma, Protection, and Repair. Springer, p 1.

[19] Herodotus, (1899) The Histories of Herodotus With a Critical and Biographical Introduction by Basil L. Gildersleeve (trans Cary, H.). D. Appleton and Company, Book VI, p 357.

[20] Crocq, M.-A., Crocq, L. (2000) From Shell shock and war neurosis to posttraumatic stress disorder: a history of psychotraumatology. Dialogues in Clinical Neuroscience, Vol 2, No 1, p 47–55.

de guerre" in French.[21] Following the huge number of cases of traumatised American soldiers during the Vietnam War, which ended in 1975, the condition has been known as "post traumatic stress disorder" or P.T.S.D.

Although the "hammar men" of earlier years had ceased to ply their trade in London's residential districts by the nineteenth century, the streets still rang with intrusive sounds. Alongside the harsh, unpleasant sounds of iron-rimmed carriage wheels on cobbled streets, London's chattering classes objected to the legions of street musicians and the all too often incomprehensible cries of a multitude of itinerant street traders. Charles Babbage, the wealthy and notoriously irascible mathematician who designed the first, albeit entirely mechanical, computer, was prepared to stand his ground, though much good it did him. His particular *bête noire* were street musicians, especially organ grinders. He used his political contacts to lobby against them and as a result of his campaign became a target for people who took an uncharitable delight in provoking him. When he left his house, he wrote, "the crowd of young children, urged on by their parents, and backed at a judicious distance by a set of vagabonds, forms quite a noisy mob, following me as I pass along, and shouting out rather uncomplimentary epithets."[22]

For the best part of a year, Babbage kept a tally of the number of times he had been disturbed by organ grinders—165 occasions from August 1860 to May 1861—and appended it to the letter of support he wrote to Michael Bass, an M.P. who was campaigning to make the parliamentary statute that regulated noise more effective. Bass's amendment required the police to enforce an existing bylaw that allowed householders to ask street musicians to move on, something that the police had hitherto been reluctant to do. The bill was enacted in 1864, much to the relief of several hundreds of "professors and practitioners of one or other of the arts and sciences", Bass claimed.[23]

As the administrative and commercial centre of the wealthiest nation on Earth, nineteenth century London grew to become the most populous conurbation in the world. The city expanded as houses and buildings were erected to accommodate the huge increase in its population and the demands of industry and commerce, adding the sounds of their construction to the city's already stressful soundscape. Charles Dickens, another of Bass's supporters, complained that a "speculative builder, who is running up terraces, crescents, and gardens by the score in the suburb where I dwell, has erected a range of workshops at the bottom of my garden, where all his carpentry and joinery is

[21] Hendy D. (2013) Noise: A Human History of Sound And Listening. Profile Books, p 269–81.

[22] Babbage, C. (1864) Passages From The Life Of A Philosopher. Longman, Roberts, & Green, p 349.

[23] Bass, M. (1864) Street Music in the Metropolis. John Murray, p 41.

done…He has set up a circular saw—twenty circular saws, I should say. They are sawing my heart in twain. I shudder at the shrill, ceaseless whirr. I can hear the innocent planks screaming as the merciless teeth eat into their very marrow."[24]

Unable to bear the noise of the saw a moment longer, "I rush to the front of the house, desperate; but there, oddly enough, I experience no nervous discomfort when I hear the costermonger crying his "fine savoys", his turnips and his carrots. I shudder not, when the donkey-man who sells fish expatiates in prolonged bawl on the virtues of his fresh cod and "fine cheap soles." The sweep is rather a melodious person than otherwise, with an excellent baritone voice. The four o'clock muffin-woman, with her tinkling bell, fills me with comfort and joy. I could tolerate the milkman if he cried his wares in an honest and rational fashion; but the man who comes at three o'clock utters a cacophonous cry sounding like "Yahoop;" and the milkwoman, who is due a three-thirty—she is presumably of Welsh extraction, and has a pair of legs like the balustrades in the background of a carte de visite—puts her arms akimbo, and in accents as gruff as those of a corporal-major in the Life Guards, says "Cuckoo!" Now, "yahoo" and "cuckoo!" have nothing, I surmise in common with "Milk O!" I am waiting for "afternoon cresses!" a pretty innocent noise, when I am driven to the back of my residence again by the diabolical screech of the knife-grinder's wheel-as dire an infliction in its way as the circular saw. The wretch with the wheel—he will be Ixion [tied to a rotating, fiery wheel as punishment by Zeus] I hope one day—who infests my neighbourhood, is an orator, forsooth; and instead of succinctly delivering himself of his message to the community launches into a long round running, "Ave you hany knives, scissors, razors, penknives, table himplements to grind, or heven humbrellas to mend O!" and a murrain [i.e. a plague] on him!".[25]

These street sounds, about which anyone who has not had to live with them day in and day out may feel a somewhat misplaced nostalgia, are absent from the cities of post-industrial nations. But in their place we city dwellers must endure the sounds of overflying planes, the occasional hovering police helicopter, assorted vehicles hurtling around neighbourhood roads, the wailing sirens of assorted emergency services, and inconsiderate builders who invariably insist that they cannot work without loud music.[26] And in place of the screech of the knife grinder's wheel, one has all too often to put up the

[24] Dickens, C. (1871) Noises. In: All the Year Round, 159, Dec 16, p 56–57.

[25] Dickens, C. (1871) Noises. In: All the Year Round, 159, Dec 16, p 56–57.

[26] The most egregious example of builders and radios I have come across was a man laying paving stones which he cut with a petrol powered stone-cutting saw while his radio was on full blast. Mindful of his hearing he was, of course, wearing ear defenders.

devilish cacophony of a neighbour's assortment of power tools such as electric lawnmowers, strimmers and leaf-blowers.

In short, it appears that intrusive sounds are an unavoidable feature of any soundscape that involves human activity: *Homo clamosus* seems inseparable from *Homo sapiens*. It has probably always been like that, even before there were settled communities. It seems unlikely that a snoring sleeper, a bawling infant or a barking dog would not have tested the patience of our prehistoric nomadic ancestors just as much as it does ours. We have the same hearing system as they did, and like them we can't avert or close our ears as we can our eyes.

As far as we know, however, it was not until there were settled communities in which people lived cheek-by-jowl that attempts were made to control noise with rules and regulations. These emerged piecemeal and were usually based on circumstances in which particular sounds were considered to be a nuisance, as we can deduce from the "The Statutes of the Streets of this City, against Noysances". But any attempt to formulate an all-encompassing, objective definition of noise that can be used to formulate laws to control or limit all unwanted sounds seems doomed to fail. Consider a 1931 proposal by George Kaye, a British physicist, that noise should be considered as sound out of place due to "[its] excessive loudness, its composition, its persistency or frequency of occurrence (or alternatively, its intermittency), its unexpectedness, untimeliness or unfamiliarity, its redundancy, inappropriateness, or unreasonableness, its suggestion of intimidation, arrogance, malice, or thoughtlessness."[27] Such a broad definition means that apart from loudness and composition, which are measurable qualities and therefore a source of objective evidence, noise remains for most of us what it has it always has been, largely in the ear of the beholder; noise needs a listener.[28] In fact, noise legislation, where exists, usually lays down only the maximum permissible loudness to which workers should be exposed and is intended to prevent their hearing being damaged.[29] All other noise issues are dealt with through laws that limit nuisance, whatever its nature.

Nevertheless, as we all know from personal experience, there are sounds such as the proverbial scraping of fingernails on a blackboard, that make one wince and clamp one's hands over one's ears regardless of circumstances.[30]

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[27] Kaye, G.W.C. (1931) The Measurement of Noise. Proc. Of the Royal Institution of Great Britain, 26, p 435–88.

[28] Hegarty, P (2007), Noise/Music: A History. Bloomsbury, p 3.

[29] UK noise legislation limits worker's average daily exposure to noise between 80 and 85 dB. The decibel scale is logarithmic, so 85 dB is almost twice as loud as 8 dB.

[30] Has anyone heard fingernails on a blackboard now that pen and paper have replaced slates and chalk and blackboards have given way to whiteboards?

Such sounds are not merely unwanted, they are inherently disagreeable. And what makes then so is that they are particularly rough and jarring, which makes them exceptionally dissonant. In fact, the vast majority of sounds that we hear are dissonant, i.e. a short-lived jumble of unrelated frequencies of irregular and constantly changing energies. The only exceptions are sounds composed of harmonically related frequencies, sounds that are the bedrock of music and speech as well as of bird-song and animal calls. Harmonic frequencies are also present in the hums and whines of the rapidly beating wings of flying insects such as bees, flies and mosquitos, not forgetting the eponymous hum of hovering hummingbirds. The almost complete absence of naturally occurring musical tones is hugely significant because it holds clues to why and how our hearing system evolved, a subject that we shall take up in chapter three. Suffice it to say here that it is probable that ears first evolved to hear brief, dissonant sounds, not musical tones.

Dissonant sounds are not necessarily unpleasant, however. All composers of music routinely employ a degree of dissonance to great effect in their compositions.[31] Depending on one's frame of mind, dissonance can be soothing, pleasurable, evocative and fascinating. Who isn't cheered by the gentle chatter of a babbling brook, or soothed by the spellbinding rhythm of wave-driven pebbles grating on a beach, or diverted by the rustle of leaves on a windy day?Even an undeniably vexatious sound such as the prolonged and often alarming roar of a low flying aircraft is full of interest if you are willing to listen attentively. Indeed, as we shall see in later chapters, the different sounds produced by their engines are arguably among the most interesting and instructive of all the mechanical noises that we encounter daily.

But there is no getting away from the fact that dissonance is the major reason why people find some sounds unbearably unpleasant. Dickens claimed that "There can be very little difference of opinion, I should say, as to the repulsiveness of the sounds made by the tearing of calico, the creaking of doors, the passing of a wet finger over silk, the endeavour to remove a glass stopper from a bottle, or the scraping of slate pencil. Concerning sounds the bare thought of which is enough to set your teeth on edge, it is not necessary to say much more."[32]

Dickens may have been afflicted by misophonia or "hatred of sound". This auditory condition makes it difficult for a person to tolerate sounds that the most of us either hardly notice or don't find particularly disagreeable or irritating. Noises such as chewing, slurping, constant sniffing or throat clearing

[31] Ball, P (2010) The Music Instinct: How Music Works And Why We Can't Do Without It. Vintage, p 165–170.

[32] Dickens, C. (1871) Noises. In: All the Year Round, 159, Dec 16, p 56–7.

will trigger a range of emotions from intense annoyance to extreme rage in someone who is misophonic.

Until recently misophonia was not considered to be a medical condition. But a recent study appears to have established that there is a link between an extreme intolerance of particular sounds and an abnormal activation of the limbic system, that part of the brain that deals with the emotional response to sensations. And if there is such a link, then there will always have been people whose excessive reaction to certain sounds has left their acquaintances and families nonplussed.

The nineteenth century appears to have particularly well supplied with misophobics, though perhaps this owes much to the fact that many of them were prepared to record in detail the auditory torments they claimed to suffer daily. Charles Babbage was certainly amongst their number, as were the German philosopher Arthur Schopenhauer ("noise is the true murdered of thought", he wrote, and his least favourite sound was the crack of a drover's whip[33]) and Thomas Carlyle, the notoriously churlish Scottish historian who had an extra floor added to his home to accommodate a sound proof study. It proved to be even more susceptible to unwanted sounds than the room it replaced. Other famous writers known to have found particular sounds distressing include Charles Darwin, Edgar Allen Poe, Anton Chekhov, Marcel Proust, Joseph Pulitzer and Franz Kafka.

Clinical research into misophonia is in its infancy, but there is another form of auditory discomfort known as hyperacousis that is a medically recognised condition and to which misophonia may be related. Hyperacousis causes one to perceive sounds to be louder than they really are. In some sufferers the condition is linked to problems with the vestibular system, the sense organ responsible for orientation and balance, which is located within the bone of the skull next to the inner ear. We shall take a closer look at the vestibular system in chapter three.

To judge from the experience of Jane Carlyle, Thomas's long-suffering wife, in some circumstances an aversion to sound can be contagious. Thomas found the noise of construction of the sound proof study so unbearable that he moved out, leaving Jane in charge of the works. She confided to a friend that "The tumult has been even greater since *Mr C* went than it was before…But now I feel that the noise and dirt and discord with my own senses only and not thro *his* as well, it is amazing how little I care about

[33] Schopenhauer, A. (1893) On Noise. In: Studies in Pessimism (trans: Saunders, T.B.). Swan Sonnenschein & Co, London, p 127–133.

it."[34] If you are neither misophonic nor hyperacoustic and live with someone who is, her words will ring a bell.

But what is it about those sounds that almost everyone finds inherently unpleasant, the ones that set one's teeth on edge?[35] A recent study appears to have found the answer.[36] Volunteers were asked to rank several sounds in terms of how unpleasant they found them. The most disagreeable was found to be that made when the blade of a metal knife is scraped against a glass bottle, a variant on fingernails scraped across a blackboard. Indeed, the study found that with few exceptions, of all the sounds that the volunteers listened to the most disagreeable were due to scraping or grinding. Somewhat unexpectedly, a woman's scream and a baby's cry were rated almost as unpleasant as scraping.

To the selection of unpleasant sounds used in this study I would add a couple of my own. One is a bird's distress call. Interestingly, these distress calls do not vary greatly from one species of bird to another. A recorded version of these calls is played loudly through outdoor speakers at a supermarket near where I live and has succeeded in driving away the starlings that once lingered around the entrance in search of morsels to eat. The other is the shriek of a fox, which sounds like the cry of an infant in extreme agony and which puts me on edge. What all these sounds have in common is that they are largely composed of frequencies to which the human ear happens to be most sensitive, namely those between 2000 and 5000 Hz. Equally important is that their loudness varies too rapidly to be heard distinctly, variations which contribute audible frequencies to the original sound, making the overall sound even more dissonant than it would otherwise be.

As for the most agreeable sounds, the study found that most involve flowing water, either cascading or bubbling gently. And, as if to compensate for its distressing cry, a baby's laughter was considered to be the most pleasurable of all the sounds used in the study. All the agreeable sounds used in the study are dominated by low frequencies and variations in their loudness that can be clearly heard, the very opposite of the characteristics of unpleasant sounds.

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[34] Carlyle, J.W. (1852) letter to John A. Carlyle 27th July 1852.

[35] There is no single word in English for this reaction to unpleasant sounds, though there does seem to be one in Spanish: "grima", which is translated into English as "the creeps".

[36] Kumar, S., Kriegstein, K.v., Friston, K., Griffiths, T.D. (2012) Features versus Feelings: Dissociable Representations of the Acoustic Features and Valence of Aversive Sounds. The Journal of Neuroscience, 32 (41): 14184–14192.