Music, Evolution

& the Harmony of Souls

ALAN HARVEY

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To Paulien, Christopher and Peter;

To all the brilliant, dedicated, and hard-working scholars and researchers who have devoted their time and energies to the precious study of music, and whose data form the basis for this book;

To my wise mentors in human biology, Charles Oxnard and the late Len Freedman, and to my early guide to the wonders of neuroscience, the late Dr Geoff Henry;

To everyone who has shared with me the joy of creating and making music;

And to some of those special few who have enriched my life beyond measure, and whose music and souls accompanied me as I wrestled with this ambition: Nick Drake, The Beatles, Edward Elgar, Sergei Rachmaninov, Jean Sibelius, Jackson Browne, Franz Schubert, Antonín Dvořák, Karla Bonoff, Bonnie Raitt, and the incomparable Sandy Denny.

Foreword

Do you know that our soul is composed of harmony?
—Leonardo da Vinci[1]

This is a book about the importance of music in human evolution and its continued relevance to modern-day human society. How, from our very beginning as a species, musical communication has acted as a necessary counterweight to our other, newly evolved communication system—language,[2] and why music continues to be an essential part of the cognitive well-being of each of us and our society in the twenty-first century. It is about why music should form a core element of our children's education, and why music should gain traction as an important therapeutic tool in clinical practice and rehabilitation. I hope this book is of interest to all sorts of people, including clinicians, psychologists, allied health professionals, anthropologists, teachers, and musicians—anyone at all interested in who we are, where we came from, and how our species has grown from several thousand to seven billion members in perhaps less than 5,000 generations … all of us still linked by the universality that is music.

The usual disclaimer—this book is inevitably incomplete! In attempting to accomplish such a broad and ambitious enterprise, I have had to explore a diverse but extraordinarily rich literature. I have found myself immersed in many disparate topics such as anthropology, brain imaging, sociobiology, linguistics, neurogenetics, neonatal communication, mechanisms of evolution, auditory processing of complex sounds, and so on. I have sometimes felt like the great Sir David Attenborough or the Australian naturalist Harry Butler, turning over rock after rock and discovering dauntingly complex layers of life under each one. Each time I mined the literature of a topic I uncovered what often seemed to be a never-ending constellation of new facts, new hypotheses, new controversies. I could have gone on forever, or at least until my body ceased to allow it. Perhaps that, and the fear of saying something daft, is why this book has taken so many years to write! But if you keep turning more and more rocks over, day after day, you never get to see the horizon. Perhaps it has ever been thus. To quote Sir Isaac Newton: "but to myself I seem to have been only like a boy playing on the sea-shore, and diverting myself in now and then finding a smoother pebble or a prettier shell than ordinary, whilst the great ocean of truth lay all undiscovered before me."[3]

Harvard Professor David Haig wrote in an essay devoted to discussing Richard Dawkins' concept of memes (units of ideas, of culture, passed from one person to another, within and across generations) that: "Many ideas have competed for inclusion during the course of writing. … The final version contains the ideas that have grabbed my attention. It has sometimes seemed that they are using me for their ends. What fraction of these ideas are my own and what fraction borrowed from others? The web of intellectual influence is complex and it is unclear whether I ever have a truly original idea."[4] I know how he feels. I first started thinking about writing this book at the end of the last century, several years after fortuitously coming across two (for me at least) explosive books while browsing in the music section of a well-known bookshop on Tottenham Court Road in London. These books were Critchley and Henson's *Music and the Brain*[5] and Anthony Storr's *Music and the Mind*.[6] In 2008, I wrote what was essentially a précis of this book for *Music Forum*, a publication of the Music Council of Australia, and a chapter entitled "Evolution, music and neurotherapy" in a book about the modern-day relevance of evolutionary theory to our species.[7] After that, I even got as far as discussions with a couple of publishers, but I continued to prioritize lab work, grant writing, neurotrauma research, and doctoral teaching—the denouement has been far too long in coming!

During this protracted gestation period, an ever-increasing number of erudite, insightful, and informative books and reviews have been published that address many of the issues I have written about in *Music, Evolution, and the Harmony of Souls*. At times, a new book or substantial scientific review on any, or all, of the topics of music, evolution, and/or language have made me lose heart. But I have tried to make this new book different from any other, for example by not focusing quite so much on the rudiments of music and analysis of modern-day musical styles. "Distinctions between the surface complexity of different musical styles and techniques do not tell us anything useful about the expressive purposes and power of music, or about the intellectual organization involved with its creation. Music is too deeply concerned with human feelings and experiences in society."[8] Rather, the emphasis is more on the evolution of modern humans, how humans may have evolved their unique cognitive architecture, how music is processed in our brains, and why two complementary but distinct communication systems—language and music—remain a human universal. In this way, by laying out my ideas about the evolutionary importance of music as a driver of cooperative and interactive behavior throughout human existence, I wish to create the foundation for a primary aim of this book: what this evolutionary imperative means to twenty-first century humanity and beyond, from cultural, social, educational, and medical/neurological perspectives. I hope to convince the reader that music is not just serious and wondrous stuff, but that it needs to become more widely accepted in our community as a mainstream educational and therapeutic tool.

I am accustomed to generating my own data, and have sometimes been hesitant when writing and talking about data and ideas that have been generated by others … but as someone suggested to me, I should perhaps think of myself as an investigative reporter or maker of a tapestry, hopefully seeing new patterns and links that those inside their own work may not always see. I hope I have done justice to these dedicated researchers and scholars, and do not annoy them by my wandering into their chosen and well-tilled fields of interest. And I also obviously hope that readers of this book appreciate the approach that I have taken. In any case, and I trust the authors and editors of other recent books and articles will agree, the more frequently the message about the seminal importance of music in contemporary human life is broadcast, the better for us all. I want this book to be a "good news" story about how music, from our very beginning, has played such an important role in fostering prosocial, cooperative behaviors, and why music remains a core element of our makeup.

I am a neuroscientist by training, and having taught and researched the subject for many years I appreciate how difficult it is for others to wade through and remember the complex terminologies, and appreciate the brain's three-dimensional architecture and connectivity. Pictures and diagrams can help a great deal, and I am enormously grateful to my friend and talented artist Martin Thompson for generously giving of his time to interpret my rough sketches and create the figures that grace this book. I also thank The University of Western Australia for approving two periods of sabbatical during which much of the book was written.

In attempting the task of writing this book, I am especially grateful to those who gave of their precious time to exchange ideas and/or who read drafts of parts of the manuscript, suggesting corrections and pointing out errors and omissions. I should also acknowledge the book by Nat Shapiro, *An Encyclopedia of Quotations About Music*[1], a wonderful source of quotations and comments that drives home the unrivalled impact that music has always had on our species. The creative process was painfully slow—I took to measuring progress based on the size of the bulldog clip needed to hold the manuscript together, and friends and colleagues provided constant nagging and jocular quips about my seemingly always hypothetical deadlines. I am grateful to them all, and I acknowledge their helpful advice during the writing of this book—here they are in no particular order except alphabetical: Nicholas Bannan, Avinash Bharadwaj, Stuart Bunt, Jim Chisholm, Geoff Cooper, Jane Davidson, Len Freedman, Stuart Hodgetts, John Jory, Debra Judge, Colette Moses, Charles Oxnard, Rob Patuzzi, Don Robertson, Jennifer Rodger, Linc Schmitt, and Terry-ann White. I am especially grateful to Nicholas Bannan, Len Freedman, Silvana Gaudieri, Cyril Greuter, Stuart Hodgetts, Carmen Lawrence, Concetta Morrone, Charles Oxnard, and Don Robertson, who read and critiqued various draft chapters, and a grand bouquet to Danii Baron-Heeris for helping to organize and proof my bibliography. Of course any oversights or errors that remain are my sole, reprehensible responsibility.

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Chapter 1

Introduction: What is Music? What is this Book About?

The senseless happiness of music engulfed me like a golden bath; it's a happiness that never depends on the objective, only the subjective, and perhaps it has a more profound link with the humanness of things because it's altogether senseless: the strenuous production of certain nonsensical sounds—that are no good for anything—for no explicable reasonable purpose.

—Josef Škvorecký, *The Bass Saxophone*, Picador

"he sensed as much as saw the men in the room begin to loosen, not moving, not swaying, certainly not dancing but some reassembling taking place as the melancholic music completed its work upon them and reduced them to essential men—the dirge played out was for each of them alone even as it sang of their brothers, of their others, of all mankind around them and all those come before and all following."

—Jeffrey Lent, *Lost Nation*, Grove Press

Musicologists and anthropologists tell us that all human cultures and social groups on the face of this earth participate in, and respond to, music and dance.[1,2] Music seems to be a "specific biological competence,"[3] and from the earliest age we humans are responsive to its charms. While it is true that in the twenty-first century there are now many different types of music and many different modes and scales, played on many different types of musical instruments, they all appear to be governed by the same physical laws of fundamentals, overtones, and harmonics when producing sound—the so-called harmonic series. Unlike the spoken word, "the use of fixed and discrete pitches seems to be fundamental and unique to music."[4] In his recent book about the prehistory of music, Iain Morley nicely summarizes what he believes is the common ground that links all musical forms: "musical behaviours amongst all humans involve the encoding of sounds into pitches (usually between three and seven) which are unequally separated across the scale, including the perfect fifth, favouring consonance and harmony over dissonance, and organizing sequences of sounds so that they have a deliberate temporal relationship to each other."[5] And we shall see that music's universality extends beyond the structural components of pitch and rhythm, extending to cross-cultural roles in "facilitating group coordination and cohesion."[6]

Most of us are aware of the complex and often strong emotional impact that music can have on us, and almost everybody enjoys or appreciates some form of music. There are, of course, notable exceptions to this; for example, the neurologist and author Oliver

Sacks tells us that the author Vladimir Nabokov thought music a sequence of arbitrary, irritating sounds.[7] I also enjoy the quote by US President Ulysses S. Grant, who apparently said: “I know only two tunes; one of them is “Yankee Doodle” and the other isn’t.”[8] As discussed in Chapter 2, such individuals may in fact have had a condition known as amusia, possessing underlying differences in brain circuitry, perhaps akin to those with color blindness. Nonetheless, despite these exceptions, music has been a source of wonder to the human species for many thousands of years, certainly for at least as long as musical instruments have been made—which at the last count was about 45,000 years. Music has the mysterious power to coalesce the past, present, and future into singular moments of transcendence—or as the influential ethnomusicologist and sociologist John Blacking put it, music has the power “to create another world of virtual time.”[1] When I listen to a piece of classical music I love, for example, I can sometimes conjure up thoughts about the composer; his/her inspiration during the act of creation; the first musicians to play the work; the conductor and musicians who performed the recording; my own experience and emotional responses to this particular piece; and how the music will echo on into the future, affecting other listeners’ hearts and minds.

A brief survey of Nat Shapiro’s uniformly excellent and enlightening *Encyclopedia of Quotations about Music*[8] quickly reveals just how many of the famous and wise have commented on and proffered opinions about music, and have marveled at, and been inspired by, its beauty and power. Why does music allow us to glimpse beauty and the infinite, transcend time and space, and generate such moods and physical emotional responses? Confucius, in 500 BC, said that “music produces a kind of pleasure which human nature cannot do without”; Aristotle pondered: “Why do rhythms and melodies which are mere sounds resemble dispositions, while tastes do not, nor yet colours or smells?”; Martin Luther wrote that: “music is the art of the prophets, the only art that can calm the agitations of the soul; it is one of the most magnificent and delightful presents God has given us”; and according to Samuel Johnson, “it is the only sensual pleasure without vice.”[8] Charles Darwin and the English philosopher and theorist Herbert Spencer fought a long battle over the evolutionary origins of music and language.[9] Darwin thought music was “of the least use to man in reference to his daily habits of life,” that it was mysterious and preceded speech, and that “man possessed these faculties at a very remote period.”[10] Herbert Spencer, however, thought that music was the language of passion derived from speech: “a physiological phenomenon, arising through an exaggeration of the emotional characteristics of human speech.”[11] To Spencer we owe one of the better statements about the impact of music on our species: “Music must rank as the highest of the fine arts—as the one which, more than any other, ministers to human welfare.”[12]

Dictionaries tend to define music in more prosaic ways. For example, the *Oxford English Dictionary* describes music as “that one of the fine arts which is concerned with the combination of sounds with a view to beauty of form and the expression of emotions.” The *Chambers 20th Century Dictionary* on my office bookshelf defines it as “the art of expression in sound, in melody, and harmony, including both composition and execution; sometimes specially of instrumental performance to the exclusion of singing." These are useful definitions, but in some ways I confess I prefer Aldous Huxley's: "after silence, that which comes nearest to expressing the inexpressible is music,"[13] or Leonard Bernstein's poetic and limitless description: "Music ... can name the unnameable and communicate the unknowable."[14] As the nineteenth-century classical composer Felix Mendelssohn wrote in a letter, in response to a question about the meanings of some of his *Songs Without Words*: "There is so much talk about music, and yet so little is said. For my part, I believe that words do not suffice for such a purpose, and if I found they did suffice I would finally have nothing more to do with music" (letter to Marc-André Souchay, 1842—quoted in Morgenstern[15]).

Music is a form of universal communication that, in our culture at least, clearly differs from language and articulate speech, yet as discussed more fully in Chapter 2 (under the heading "Harmony—musical syntax?"), music has a somewhat similar organizational nature to language, with structural principles and processes (a type of syntax) and the possibility of hierarchically embedding phrases within phrases (recursion). In humans, music affects arousal, it entrains neural activity, it has the extraordinary capacity to stimulate our emotions, and it can elicit substantial internal (autonomic) and overt physiological responses.[16] The autonomic nervous system monitors and controls the internal environment of our body, its visceral functions. Everyday examples of autonomic function include control of heart rate and blood pressure, digestion, respiration, and the apparatus of sexual arousal. Most autonomic functions are involuntary but they can often work in conjunction with the somatic nervous system—the part of the nervous system that gives us our sensations of the world around us—and with the brain regions that control voluntary movement. Music seems to have "gold pass" access to this autonomic network. Thus, many physiological changes linked to emotional responses are elicited when listening to favorite pieces of music, including changes in cardiovascular function (eg heart rate and blood pressure), goose bumps, chills, and tears.[17,18,19] Positive internal emotions can include joy, triumph, amazement, and feelings of vitalization, consolation, spirituality, and calmness.[20]

Of course we are all aware that music is intimately linked to movement and dance.[21,22,23] There is an intrinsic, almost unbreakable coupling between perceptual musical experience and the various motor actions that are elicited,[24] and the predictability of time and pitch, seemingly unique in our species, makes communal music-making possible.[25] *Homo sapiens* is the only living species in which individuals co-coordinate movement to a rhythmic pulse—humans have "the ability to follow precise rhythmic patterns so as to permit group singing, drumming and dancing."[26] Darwin suggested that music—including singing and dance, and therefore perhaps the positive selection of fitness attributes and the type of brain which creates and coordinates these activities—was the means by which humans could attract potential mates. Music and sex often seem to belong together; we remember that special song that was playing when we first met an important partner, perhaps our wife or husband, or when we first shared breakfast with a significant other. If most guys who are old enough to have seen the movie "*10*" are like me, then Ravel's "Bolero" is now inextricably linked with the sight of Bo Derek running in slow motion down the beach towards her improbable beau, Dudley Moore.

In addition, and of critical importance, music and dance create or at least facilitate more widespread social interactions that are associated with communal physiological arousal states, which can promote the collective expression and experience of emotion between individuals within a population. Participating individuals are yoked together in mood and activity—in harmony if you like; thus music can promote social cohesion and help to define, as well as separate, social groups.[26,27,28] When two or more people play what one person could play, they are deliberately sharing a social experience where "individuality is community."[1] Some thoughts about how and why music does this will be discussed in detail in Chapter 5, but the capacity for music to bind us together may be its most important evolutionary rationale.

Music (and sometimes dance) also forms a core component of ceremony and ritual. Most cultures and ancient civilizations had (or have) gods dedicated to music, for example Bes and Ihy in ancient Egypt, Apollo in Greek (and Roman) mythology, and the Hindu goddess Saraswati. Some scholars have suggested that early in human history unified, transcendental states induced by chanting and synchronous music-making may have been especially needed to bond groups together during times of conflict with other groups.[29,30] Many of us participate in group musical events, whether this involves singing the national anthem at a football match, singing the club anthem, singing hymns in church, or responding to music at a wedding or a funeral. Whether we ourselves are involved in choirs, karaoke, or rock 'n' roll jam sessions … it doesn't matter; music is embedded in our lives. My colleague Nicholas Bannan has listed some reasons when and why we sing:[31] for personal amusement; for teaching purposes and the social development of children; as a means of recalling information; as an efficient carrier of sound across distances or in noisy environments; for display or entertainment purposes; as a means of communication with animals; to soothe infants; to introduce states of mind appropriate for specific activities; to heighten speech in a ritual or to an audience; as an accompaniment to work; and finally, as a cohesive force in social and political organizations. Singing together in choirs rapidly creates mutually satisfying bonds between strangers, "bypassing the need for personal knowledge of group members gained through prolonged interaction."[32]

Leaders—whether of nations, political parties, armies, or religious denominations—have long understood the power of music to influence the so-called masses, for good or for ill. In the fourteenth century, the organ was called "the devil's bagpipe" and by the fifteenth century most organs had been destroyed in England. Nat Shapiro includes this remarkable excerpt from a 1642 English Act of Parliament: "If any person or persons … commonly called Fiddlers or Minstrels shall be taken playing, fiddling, or making music, in any Inn, Alehouse or Tavern … or shall be taken entreating any person … to hear them play … that every such person shall be adjudged rogues, vagabonds, and sturdy beggars … and be punished as such."[8] Hmm, I remember in the 1970s buskers being turfed out of the London Underground for entertaining the passersby … .

Dictators such as Hitler and Stalin knew the potentially subversive (to their way of thinking) impact of music on a population, hence their control over the types of music that they allowed to be played and the types of music that people were permitted to hear. Hitler banned jazz and would not allow music by Jewish composers such as Mendelssohn to be played, and most Soviet composers in Stalin's era lived anxious, precarious lives. They were expected to write populist, optimistic music deemed suitable by the party propaganda machine. In a speech in November 1935, Stalin said: "Life has improved, comrades. Life has become more joyous," and socialist realism meant that art, including music, had to serve the purposes of the communist state, had to be understood by, and in turn glorify, the achievements of the proletariat. Abstract, expressionist, and/or decadent music was frowned upon, and viewed as a perilous activity. Presumably, music that induced feelings of spirituality or transcendence, anger, disaffection, melancholy, or even lust was just too powerful to be let loose on the masses. Music can inflame passions and revolutionary zeal. Even today, music (and dance) is actively suppressed by certain religious groups and/or political organizations in various parts of the world. Such autocratic suppression is surely a sign of weakness, a symptom of an insecure ideology, depriving the populace of perhaps their most vital social binding agency, music.

Thankfully however, recent history can also provide powerful and heartening examples of the unifying and restorative power of music for humanity. For example, in 1914 the Germans and allies in their respective trenches sang Christmas carols to each other across no man's land, thus beginning the famous Christmas truce of that year. In more modern times, because "music-making is a safe place for people to 'be' together and rebuild trust,"[33] various music-based initiatives have been developed in regions of conflict and extreme social disharmony, such as in the Balkans and in Africa.[33] In the Middle East, the West-Eastern Divan Orchestra—an ensemble of Israelis, Palestinians, and Arabs—was created in 1999 by Daniel Barenboim. In an interview published in July 2012 in *Limelight*, an Australian Broadcasting Corporation magazine, Barenboim responded this way to a comment that the orchestra was created to promote a dialogue between Israel and other countries in the Middle East: "Yes, but our project is not a political one.... It's a project between Israelis and Palestinians and other Arabs, but still it's not political, because it doesn't have a political line. We believe it's exactly the opposite: that the Israeli and Palestinian conflict is not a political conflict. This isn't a conflict between two nations; it's a conflict between two peoples who are deeply convinced that they have the right to live on the same piece of land. This is a human problem. And therefore it cannot be solved militarily; it cannot be saved politically; it can only be solved with human understanding and with the acceptance of the rights of the other. That's what we in the orchestra strive to practise, and it provides us with an alternative way of thinking. But, you know, it's like many things—alternative medicine takes much longer than antibiotics." We shall come back to the therapeutic power of music and Barenboim's alternative medicine analogy in a couple of pages.

If the aforementioned diverse impacts of music were not already sufficient to impress upon the reader the importance of music to modern-day *Homo sapiens*, there is more.

In the educational field, researchers have shown that music structures time and provides mnemonic frameworks that help learning and memory. Many of us can remember the lyrics of songs for example, but may not remember much, if any, prose. Somehow attaching words to music makes the words easier to remember, something of critical importance and usefulness as we get older. And the benefits of music extend well beyond the musical domain. As discussed in detail in Chapter 7, music education increases verbal skills, enhances general cognitive and perceptual abilities, and facilitates a child's overall social development.

Yet, when peering into the dim shadows of our past and thinking about music in the context of human evolution, reasons for the transcendental power of music and its universality remain elusive and controversial. Yes, music makes our bodies move, and yes, it hooks into emotional circuitry within our brains, involving a complex group of interconnected cortical structures that are given the collective name of the "limbic system," a term first coined in the nineteenth century by the French physician Paul Broca (who also gave his name to the specific part of the brain long thought to be the motor speech area). But, as the eminent English psychiatrist Anthony Storr wrote in his excellent book *Music and the Mind*,[34] music is not usually propositional—it does not put forward any testable hypotheses; it promulgates no doctrines and preaches no gospels. Music does not convey information in the same way as language or speech. As described in the writings of Cambridge scholar and musician Ian Cross, music has no immediate or evident efficacy—it "neither ploughs, sows, weaves nor feeds."[35] According to the philosopher Schopenhauer (quoted in Storr[34]), music is "a copy of the will itself, music speaks of essence, the inner spirit." Such properties don't feed or clothe a family! So at its most basic and fundamental level, what exactly is music for? Why do humans make music and respond to it, and why does music remain such an important part of our lives—an integral component of our social architecture? Why is it, again quoting Anthony Storr, "a permanent part of our mental furniture?"

In his book *How the Mind Works*,[36] Steven Pinker suggests that music is merely auditory cheesecake, "a biologically pointless challenge," a "cocktail of recreational drugs" that aurally activates and stimulates our pleasure circuits. Is it secondary? An accidental by-product? What Stephen Jay Gould and Richard Lewontin called a "spandrel"? A spandrel is a space next to or between arches that may be filled in with beautiful ornamentation, but which has no structural relevance. Recent functional imaging studies of the human brain do indeed show that pleasure and reward centers in the brain are stimulated when we listen to pleasurable music. This is discussed in more detail in Chapter 5. But the essential point to make here is that drugs and addictions are usually, in the long run, debilitating to the individual. As David Huron suggests, what he terms non-adaptive pleasure-seeking behaviors, such as drug use, are not usually conducive to ongoing reproductive success: "poor health and neglect of offspring are infallible ways of reducing the probability that one's genes will be present in a future gene pool."[37] Drugs often lead to isolation and introspection, and if too many members of the population indulge there will almost certainly be a loss of social order and cohesion. Even when opening the gates of perception, drug-induced hallucinations cannot be shared, even with an identical twin.... It seems to me that music, and with it dance, are the very antithesis of this. This is surely *not* what music was, or is, about.

Unravelling the evolutionary relevance of music to our species is the key; despite all of the writing and theorizing, and the centuries of scholastic endeavor, most in agreement that music has a weird and wonderful power over our species, there remains a lack of consensus as to exactly why humans, seemingly throughout their history, have responded so positively to music. Many questions remain. Is there a broader context of music? What, if any, adaptive advantages did music give to *Homo sapiens* from an evolutionary perspective as our founders migrated out of East Africa to rapidly colonize the world? What collection of circuitries and abilities was needed to generate and underpin what we define as human musical behavior? Our numbers increased perhaps by a thousand fold between 60,000–70,000 and 10,000 years ago, and increased yet a further thousand fold after the transition from hunter-gatherer to farmer. Why does music continue to remain important to all human cultures, thousands of generations after the founders of our species evolved?

Finally, there is the thorny question of the relationship between music and language. The modern human brain is clearly wired to deal with both forms of communication, in a sensory-perceptual as well as motor capacity, but how do these forms interact? From an evolutionary point of view, did music come before language, did language come before music—or was there some common progenitor that somehow separated into two distinct yet still overlapping strands when *Homo sapiens* evolved, with both types of communication retained? If this was the case, then why were both retained? Why were both communication systems needed? Was music an important ingredient in the phenotypic recipe that contributed to the survival of our newly evolved species? Why are we the all-speaking, all-singing, all-dancing creatures of our planet?

In this book, in suggesting possible answers to these questions, I will take you on a wide-ranging journey that encompasses anthropology and archaeology, genetics, neuroscience and behavior, brain imaging, neurology, and modern-day neurotherapies. Bringing these various strands together I hope to convince you that music (and with it, dance) was there at our beginning, in our founder population, and is a unique and special communication system that continues to promote the collective expression and experience of emotions. Music fosters cooperation and social cohesion. Our recognition of, and emotional responses to, consonance (tones that sound good together, for example octaves or fifths) and dissonance (tones that are slightly different and that interfere with each other, causing an unpleasant sound that we find difficult to resolve), to pleasant and unpleasant music, seems to be universal and expressed even in very young infants,[38,39,40,41] although exposure to music increases our appreciation of consonance and "harmonicity."[42] Music, or perhaps the elements in any type of vocalization that signal emotion or emphasis of some kind,[43,44] may be an important way of helping to bond with infants prior to the ontogeny of articulate speech, and "happy voice quality"—irrespective of whether speech or singing is involved—is the most important element in gaining an infant's attention.[45] Excitingly, responses to music appear to be independent of our cultural upbringing.[46] Modern neuroscience research confirms that the appreciation and processing of music has a real and consistent structural foundation in the human brain. As each decade passes, we learn more and more about how such music-related circuits differ from, or overlap with, other pathways involved in cognitive and emotional processing. Of particular importance is the realization that brain areas associated with positive responses to music are closely aligned to networks associated with reward behaviors and acts of social cooperation/altruism, consistent with earlier ethnomusicological descriptions of music as "a product of the behaviour of human groups."[1]

In close association with the evolution of the modern sentient mind, I will propose that music was an essential attribute of our early ancestors. It acted as a counterweight to the new and evolving sense of self, to the emerging sense of vulnerability in all of us as we began to appreciate our mortality—a realization that grew along with the evolution of the modern brain and newly acquired language capability. In arguing the case, and noting the inevitable danger of "spinning untestable 'just so' stories" that cannot be proved or disproved,[25] I hope to persuade you that music remains just as essential to *Homo sapiens* now in the twenty-first century as it was perhaps 80,000 years ago. Music can be a source of joy and excitement, a bringer of tranquility and enlightenment, and a vehicle for reconciliation and unification. It is important for both social and cognitive development in children. Music is cathartic. It helps sustain our health and overall sense of mental well-being, our sense of community, and our sense of belonging, and it has potentially great power as a therapeutic tool. To quote a great title of an earlier essay by Ian Cross: "Is music the most important thing we ever did?"[47]

Back in November 1997, I gave a talk on the basic principles described in this book at a local meeting known as the Western Australian Neuroscience Colloquium. The next day I listened to a talk by an eminent Australian neurologist about "the clinician's approach to neurodegenerative diseases" and was surprised to discover that music, and in particular a patient's cognitive and affective reactions to music, did not normally form part of the clinician's armamentarium, and was not used to help decipher mood and emotional responsiveness in patients. Today, in the minds of most people, music therapy remains a branch of "alternative" medicine. In recent times the phrase "nonpharmacological" rather than "alternative" therapy has gained currency in some quarters and is perhaps an improved descriptor, but it still implies something outside the mainstream.

Any brief online search will show how music therapy, especially in the treatment of chronic pain or anxiety, is so often grouped together with other so-called alternative medical treatments such as acupuncture, hypnotherapy, aromatherapy, balneotherapy (treatment of disease by bathing), thermotherapy, magnetic therapy, homeopathy, relaxation methods, massage, prayer/meditation/yoga, lifestyle or dietary changes, herbal treatment (eg green teas), vitamins, "ethnomedicine" (eg treatment with garlic, lime juice), reflexology, hydrotherapy, and pet therapy.[48,49,50,51,52,53] I am sure that champions of any of these "alternative" therapies wish that their favorite treatments were accorded more conventional clinical status. I am convinced that this is the status that should be afforded to music therapy, with its beneficial effects on the mental and physical health of the great majority of the human species.

By compiling this story and putting musical processing fairly and squarely into an overarching evolutionary, neuroscientific, and sociological context, I hope to convince you that music should be recognized as being less specifically “arty”—less “alternative”—and should be recognized as being central to human cultural and intellectual experience. My hope is that this book is of interest to a wide range of readers from different backgrounds, all interested in why music is a human universal, its possible role in our recent evolutionary history, and why music: (i) remains important for the welfare of human society in the twenty-first century, (ii) is an essential element in early education, and (iii) should be viewed as a proven and reliable therapeutic tool for use by neurologists, neuropsychologists, and rehabilitation specialists when treating neurologically and/or physically challenged patients. But before addressing these twenty-first century “big picture” issues, we must first consider how and where music is processed in our brains, and after that when and how *Homo sapiens* evolved, and why our species continues to possess two interrelated but distinguishable communication systems: music and language.

Chapter 2

How the Brain Processes Music

It is essential to understand our brains in some detail if we are to assess correctly our place in this vast and complicated universe we see all around us.

—Francis Crick, *What Mad Pursuit: A Personal View of Scientific Discovery*

It is worth restating that in modern humans, at least in our culture, language—usually but not necessarily communicated via the spoken word—is regarded as the major and universal form of communication between individuals. It is a unique attribute of *Homo sapiens*. But then so is musicality; why is music also a universal form of communication? Is music merely an accidental by-product of evolution, just a hang-over from our forebears, or is it, in partnership with language, an essential part of our cognitive and emotional makeup?

To address this core question, we need first to understand the extent to which music and language differ from each other. How do modern-day musicologists and linguists define and describe the various intrinsic properties of our two communication streams? Of course the phenomenon of music, like language, has a number of essential psychological and physiological elements—creation (mind/imagination), performance (motor), and perception (sensory). Broken down into its basic constituents, music contains pitch changes, tonal relationships, melodic contour and harmony, changes in volume, and changes in stress/emphasis. There is also what is termed "timbre," or the particular sound quality of tones. Music has beat, meter, and rhythm. It has a regular pulse that invariably elicits involuntary or voluntary movements in the listener. As most of us appreciate, music is inextricably and universally linked to physical movement and dance, especially in a social context. It is particularly revealing that some societies do not have a word that distinguishes between music-making, singing, and dancing, even ceremony—it is all one and the same.[1] This music–movement alliance is clearly an important evolutionary relationship, something that is discussed in more detail later in this chapter. Finally, music also has a hierarchical structure, with various rules and constraints, which requires the processing and prediction of phrases and extended musical sequences, and with that comes the need for efficient and reliable classification, recognition, and memory systems.

While music has the well-known capacity to affect human emotions, human language also has what are termed "prosodic elements." These include pitch range and variation, voice quality, loudness, and rhythm of delivery that convey information about the emotional state of the speaker or that color an utterance in some way (for example, whether what is spoken is a question or a command, praise or sarcasm, threat or plea). But language also supports literal and scientific content; it is a primary medium through which we store, catalog, and transmit data and knowledge.[2] Language has grammar (nouns, verbs, adjectives, etc) and a complex set of hierarchical principles (syntax, recursion) that underpin the construction and arrangement of words (the lexicon) into meaningful sentences, clauses, and phrases. These underlying rules seem to be instinctive in us,[3] and are learned by each individual in order to be able to produce meaningful sentences and recognize that a particular combination of words is grammatical and makes sense: "Comprehending a sentence involves identifying the structural relations among its words and phrases. By assigning grammatical functions and thematic roles to different arguments of the verb, syntactic structure of a sentence indicates who is doing what to whom."[4] Remarkably, language is not exclusively the domain of speech and audition. Thus the congenitally deaf, who have a morphologically normal volume of auditory-related cortical areas with typical asymmetry between left and right temporal lobes,[5] also possess the virtual cognitive architecture that enables them to babble with their hands as infants, eventually learn to use signing, lip-reading, and so on, in adulthood, and apparently communicate via "standard" language networks in the brain.

Language is propositional; it is referential in that meaningful interpretation requires additional knowledge or experience—sometimes termed "external referents." Language is expandable in content and facilitates the virtual creation and manipulation of symbols, the meaning and relevance of which vary depending on context. It permits intuitive reasoning and the expression of thoughts and ideas, and facilitates planning and choice-making. Language contains past, present, future, and conditional constructions (was, is, will, may, might, should, could) that allow descriptions, and a shared appreciation, of time and its possibilities. It is not necessarily representative of anything real and can be used to convey information about objects or occurrences that are not necessarily "here and now." As my late friend and esteemed colleague Dr Len Freedman once said to me: "language both defines and defies time." For many scholars, and this is a key point, the creation of language in *Homo sapiens* must have been intimately associated with the evolution of the modern mind.

The biologist and cognitive scientist Tecumseh Fitch has put forward some possible design features that characterize and distinguish music from language.[6] Based on the early work of Charles Hockett, who argued that there are 13 design features of language (and only the human language possesses all 13), Fitch suggests that music—specifically vocal music—is "speech minus meaning." The lack of referentiality and semantic meaning in music gives it special "affective and aesthetic power" that can have different connotations to different individuals.

There is considerable evidence in support of the proposal that the basic circuits needed to learn language are innately wired—are "a distinct piece of the biological makeup of our brains"[3]; however, these networks require social and cultural experience and training during critical periods of early life in order to develop them to their full potential, as evidenced by the rare occasions when human infants are raised by non-humans. The extraordinary tale of the two Indian girls discovered in the 1920s who were raised by wolves in the Bengal jungle is a classic case in point.[7] These so-called feral children did not, even when eventually reunited with humans, acquire many human characteristics, including articulate speech, although one surviving girl was eventually able to generate some words, but apparently not sentences or conversation. This disquieting human story is not unlike the maternal and social deprivation studies on baby rhesus monkeys carried out by the psychologist Harry Harlow and colleagues in the late 1950s/early 1960s. He found that early and sustained deprivation caused profound and long-term physiological and behavioral dysfunction in animal subjects.[8]

Perhaps the clearest example of how refinement of an innate neurological potential requires appropriate environmental input at the appropriate time comes from the primary visual cortex. In animals like us, with frontally placed eyes, each eye is in a different position in the head and thus views the world from a slightly different perspective. The visual cortex can combine these images from the two eyes, and by comparing the two inputs, generates a binocular three-dimensional reconstruction of the outside world—giving us the perception of depth, or stereopsis. But this remarkable facility cannot be harnessed if early visual experiences are abnormal. If, during the first four to five years of life, a child's eyes are misaligned relative to each other (squint), then the signals to the visual cortex are desynchronized and binocular processing is not established. If the eyes are subsequently aligned correctly, but after this critical developmental period, it is then too late and stereoscopic depth perception is permanently lost. The potential circuitry was there, but the input triggers were not. So, too, does effective and appropriate maturation of language circuits also require early experience, and the same appears to be true for many aspects of music-making. Importantly, as discussed in Chapter 7 on music and education, early musical training has diverse developmental and cognitive benefits that extend well beyond the purely musical domain.

Given that the sensory aspects of both music and speech require a sophisticated hearing apparatus and involve extraordinarily complex auditory processing within the brain, it is important to present a brief introduction to human auditory pathways, from the ear to the cerebral cortex. I will describe the essential elements of this sensory pathway and what is currently understood about the processing of complex sounds. I will then go on to describe what is known about where and how music is processed in the brain of *Homo sapiens*, and briefly compare this neural architecture with what is known about the processing of speech and language. Differences will be emphasized at this point, but we shall see in Chapter 4 that the circuits involved in the processing of music and language are not entirely separate, providing intriguing clues about the possible evolutionary antecedent of these two human communication streams.

The brain—an overview

At the most basic level, the human brain above the level of the spinal cord is divided into a number of major regions, from back to front—hindbrain, midbrain, and forebrain.

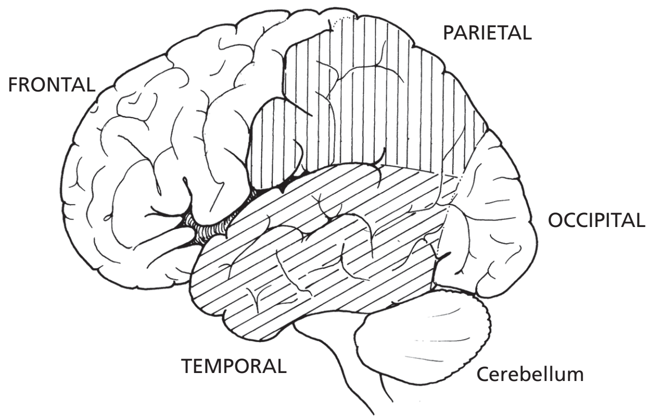

Figure 2.1 The major lobes (frontal, parietal, temporal, and occipital) of the human cerebral cortex and their approximate boundaries. The cingulate lobe/cortex can only be seen on the medial aspect of each cerebral hemisphere (see Figures 4.2 and 5.1).
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Many important aspects of auditory (sound) processing are carried out in specific parts of the hind- and midbrain, as well as in part of a major sensory relay station, the thalamus, which is located deep in the forebrain below the cerebral cortex. The nerve cells (neurons) in this part of the thalamus then send information on to a number of auditory processing areas in a lobe of the overlying cerebral cortex, called the temporal lobe (Figure 2.1). These small sensory areas of the superior temporal cortex are involved in the initial processing of sound, and transmit information on to so-called higher level cortical regions involved in music and language processing, as well as to regions concerned with affective/emotional responses and motor control. Beyond auditory cortex there are also interactions with complex multimodal cortical regions that are the presumed repository of higher cognitive and social functions, including the long-term storage and recollection of autobiographical memories, assorted facts, and other types of stored knowledge.

The nervous systems of our body contain different types of cells, essentially divided into two major classes: neurons and glia (the latter from the Greek word meaning "glue"). All these cells have typical—what is termed "eukaryotic"—features, which include a nucleus containing the genetic code within chromosomes, cytoplasm, and intracellular organelles such as mitochondria, Golgi apparatus, and endoplasmic reticulum, all necessary for maintaining the long-term health of each cell. The central nervous system (CNS, brain, and spinal cord) comprises a huge range of neuronal types, defined morphologically by the size and shape of their cell bodies and the three-dimensional shape of their cellular processes (dendrites or axons—see below). Neurons also differ in the chemicals they contain and in the complement of receptors and various ion channels located on their membrane surface. This in turn influences how they receive and respond to information exchanged with other nerve cells. Neurons are the obviously electrically excitable cells in the brain; they process and then transmit signals either locally or over long distances, from one brain region to another. Neuronal dendrites are generally the receivers of information (the antennae if you like) from other cells, whereas a neuron's output signal (action potential or nerve impulse) is initiated close to the cell body and is then propagated along the axon to influence the activity of another neuron or a target such as a gland or muscle. Anatomically, large aggregations of neurons into clusters or layers are called "gray matter" because these regions have a dark(ish) appearance when viewed postmortem.

Neurons communicate with each other and with other targets via tiny structures called synapses. At these sites, there is a small gap (cleft) separating the presynaptic side from the postsynaptic side. Neuroactive molecules (neurotransmitters or neuromodulators) are released from the presynaptic terminal and diffuse across the cleft to either increase or decrease the electrical excitability of the postsynaptic cell. Each neuron can receive many thousands of synaptic inputs, these inputs terminating on either the dendrites or the cell body itself. At any given time the physiological state of the neuron will be affected by different combinations of excitatory or inhibitory inputs, and by how these active inputs are spatially distributed around the cell. Whether or not a given neuron then generates its own action potential depends on whether the overall integrated drive to that neuron is sufficient to excite the cell. If inhibition prevails, the neuron is silent for that period of time.

Glial cell types are also diverse. The main cell type is the astrocyte, originally named because it has a star-like appearance. Classically, its role is both structural and functional, especially in the maintenance of a barrier between the bloodstream and the brain, and in providing substrates needed by neurons, and subsequently, in eliminating any breakdown products (metabolites). Astrocytes are now understood to be a heterogeneous population, and we shall in Chapter 3 (under the heading "Chemistry and plasticity") that this traditional "housekeeping" role undoubtedly does not do justice to the physiological importance of astrocytes in the modern human brain. It is also possible that subtle changes in astrocyte function occurred in our ancestors that contributed to the eventual evolution of a thinking, talking, musical *Homo sapiens*. To speed up the transmission of signals in the brain, many axons are insulated with a fatty sheath called myelin, which is produced by another glial cell called the oligodendrocyte. Regions that contain bundles or tracts of large numbers of myelinated axons look white in cut sections of the brain; hence these tracts are called "white matter." Immune responses and reaction to injury and disease involve a third glial type: the microglial cell. Remarkably, these cells originate from the bone marrow and can continue to colonize our central nervous system throughout life, helping to maintain brain health.

In all mammals, the cerebral cortex is the gray matter on the outside of the cerebrum. It is where the cortical neurons are located and is divided into two huge masses in the left and right cerebral hemispheres of the brain. These two halves differ significantly in their functionality and capability. Many parts of the left and right cerebral cortices are interconnected by a massive white matter tract called the corpus callosum, estimated in humans to contain about 100 million axons.[9] The cortex receives axons from, and sends axons to, subcortical structures, and vast and complex association white matter tracts interconnect cerebral cortical regions on the same side of the brain. There have been many estimates of neuronal number in the gray matter of human cerebral cortex, ranging from 16 billion to 23 billion.[10,11] Perhaps surprisingly, the smaller cerebellum (Latin for "little brain"), which is situated at the back of the brain (Figure 2.1) and is involved in motor learning and the coordination and synchronization of movement, contains far more neurons (69 billion) than the cerebral cortex.[10] This is because cerebellar neurons are much more closely packed together and there are far fewer glial cells.

Within each hemisphere, regions of the cerebral cortex can be defined anatomically and functionally. For example, certain areas are involved specifically in sensory processing, such as the primary and secondary auditory cortical areas, primary and secondary visual areas, and areas relating to touch sensation and proprioception (awareness of the position of our limbs) (Figure 2.2). In addition, other areas are involved in the control of movement, and yet another area is specialized for the control of eye movements. Multimodal association cortical areas integrate all this information via complex interconnecting circuitries; other cortical regions are involved in learning and memory, the planning and processing of ideas, as well as in many other higher-level cognitive functions. This functional localization has been acknowledged for some time, but until recently information was obtained primarily through analysis of the effects of injuries such as stroke or trauma. Modern techniques that measure neural activity, such as electroencephalography (EEG; electrodes on the scalp measure voltage changes due to electrical activity in the brain) or magnetoencephalography (MEG; measures magnetic fields produced by electrical currents in the brain) and diverse ways of functionally imaging the living brain, have vastly expanded our knowledge about how the brain works.

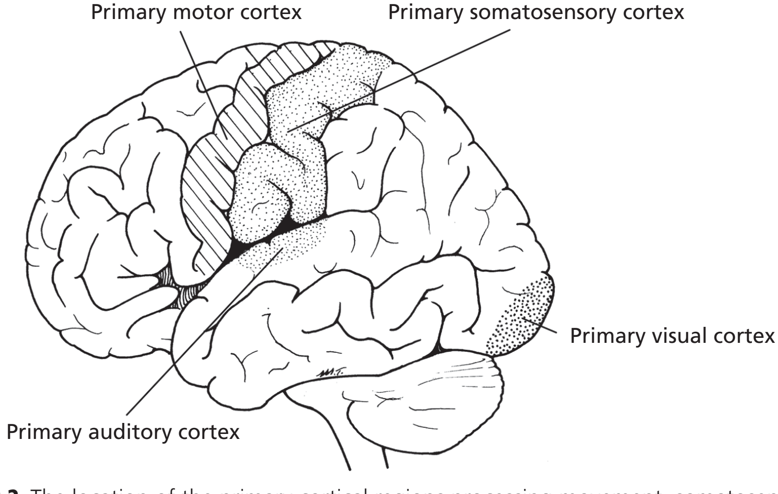

Figure 2.2 The location of the primary cortical regions processing movement, somatosensation (touch, pain, etc), sound, and vision.

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Anatomy and physiology of the human auditory system

Auditory pathways differ from some other sensory pathways in that they involve many synaptic relays as they ascend through various regions of the brainstem on their way, via the thalamus, to cerebral cortex. Ascending pain pathways may also make connections in the brainstem en route to higher centers, whereas the projection from the retina in the eye to visual cortex is more direct and involves only one major relay in the thalamus. Auditory pathways therefore potentially have access to the reticular formation and autonomic brainstem areas, regions that influence the way our bodies physically respond to arousal and emotions. In fact, there is good evidence that autonomic responses can be synchronized with music.[12] It is tempting to speculate that such potential interactions with brainstem circuitries are not accidental and may reflect a long evolutionary history of the potent impact of sound on emotions and affective social behaviors.[13]

The human ear comprises three parts, classically divided into an outer, middle, and inner part (Figure 2.3). The outer or external part is called the pinna or auricle and is mostly made of cartilage. This structure is highly specialized in mammals, and is movable in most species, including many primates, but not in the so-called *Hominidae* (the great apes—chimpanzees, bonobos, gorillas, orangutans, and us!). In each human, the shape of the pinna is subtly different, and our brains seem to adapt to these shape variations in order to best process incoming auditory information. The pinna helps to facilitate sound localization and to resolve so-called front-back ambiguities (the ability to determine whether the sound source is in front or behind).[14] Of course, localization of sound

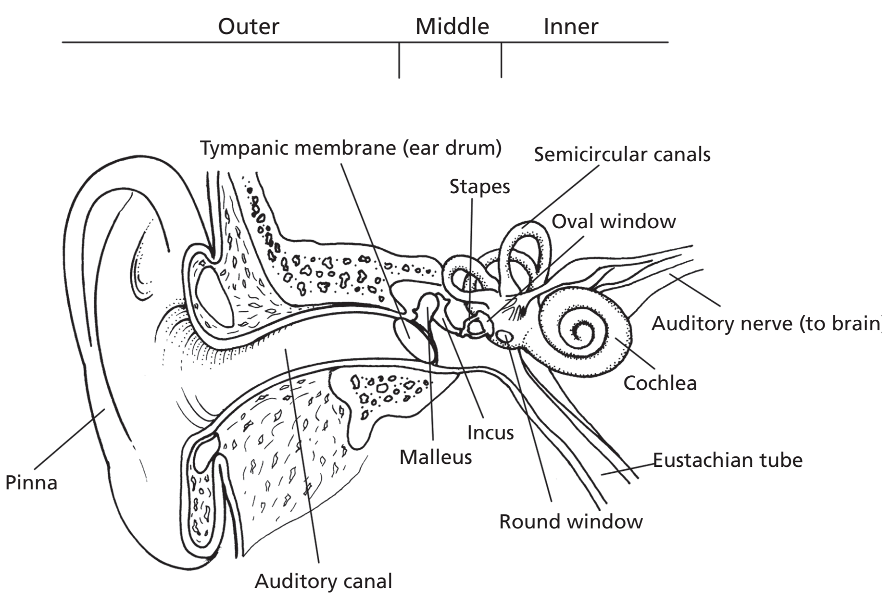

Figure 2.3 The human ear and auditory apparatus.
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is facilitated by turning the head towards that sound, and in the horizontal plane is perceptually achieved by reference to the timing of inputs to the left and right ears, and interaural intensity differences due to head shadowing effects. The pinna is thought to be especially important in localizing sound in the vertical plane and may also be important in aiding the processing of speech.

The auditory canal or external auditory meatus is about 2.5 cm long and leads to the tympanic membrane or ear drum. The canal can amplify certain frequencies of sound. The ear drum, which lies at an angle to the canal and is circular in shape, separates the outer from the middle ear (Figure 2.3). It has elastic properties, and air pressure changes (sound waves) entering the ear cause the drum to vibrate. There is air in the middle ear, and the pressure on either side of the ear drum is usually kept fairly constant because the middle ear is connected to the nose and throat via a tube called the Eustachian tube. When that tube becomes blocked, owing to a heavy cold for example, this equalization of pressure cannot occur, and thus any external pressure changes such as we experience during takeoff or landing in an aircraft can be very uncomfortable!

The middle ear bones, or ossicles, form a hinged chain ("ossicular chain") that transmits vibration or mechanical energy from the eardrum to the inner ear, where the energy is transduced into electrical signals for transmission to the brain. The malleus (hammer) is firmly attached to the ear drum; the incus (anvil) is next, and the stapes (stirrup) is the last in the chain. This small bone then contacts a structure known as the oval window, an opening in the bone that separates the middle ear from the chambers of the inner ear, which in turn are filled with fluid. The area of the stapes footplate on the oval window is about 17 times smaller than the area of the ear drum, and the ossicular chain plays an important role in magnifying the mechanical energy per unit area as the sound energy moves from "floppy" air to the stiffer fluid medium in the inner ear. It has been suggested that these middle ear ossicles may also have eventually become useful in reducing the interference from internally generated sounds such as chewing and crunching.[15]

The inner ear

The inner ear is contained within a labyrinth of bone in a part of the skull called the petrous bone. It consists of a number of specialized structures that encode information about sound (the cochlea) or head position and head movement (the vestibular apparatus) (Figure 2.3). The cochlea is a highly specialized sensory apparatus that transduces mechanical energy into electrical signals. In humans, the cochlea is about 35 mm long and resembles a snail shell (hence its name—of Greek origin) with two and one half-spirals, from base to apex. Along its length, the cochlea is divided into three fluid-filled chambers: the scala vestibuli, cochlea duct (scala media), and scala tympani (Figure 2.4). The first two named ducts are separated by a thin membrane, and the cochlea duct and scala tympani are separated by a complex structure that includes the so-called basilar membrane. On this membrane is the organ of Corti, where the receptors are located and the transduction process begins. The two scala chambers are continuous at the apex of the cochlea (the opening is called the helicotrema), and both contain a clear fluid called

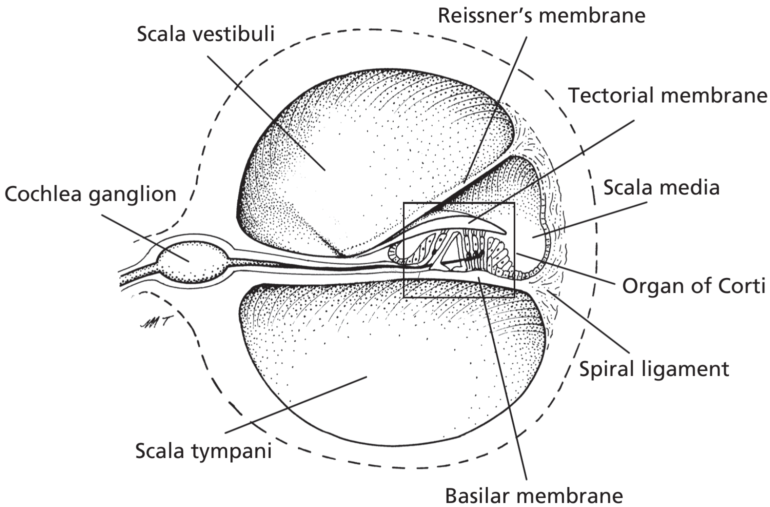

Figure 2.4 A high-power view of a section through the cochlear spiral showing the various fluid-filled chambers, the basilar membrane, and the organ of Corti, containing the receptors needed to transduce vibrational energy into electrical impulses that are subsequently perceived as sounds.

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perilymph. By contrast, the cochlea duct contains a fluid called endolymph that contains a comparatively different concentration of sodium and potassium ions—essential for the ongoing activity of the inner ear receptors. Endolymph is made by specialized cells in a structure known as the stria vascularis.

Vibrations that enter via the oval window travel all around the cochlea until the energy is eventually dissipated back into the middle ear at another membranous window known as the round window. These vibrations cause the basilar membrane to oscillate in a travelling wave towards the helicotrema. The width of this membrane is about ten times wider at the apex than at the base. Anyone who has played a stringed instrument will know that the shorter the string, the higher the note. Similarly, high frequencies preferentially cause the basilar membrane to vibrate at the base, whereas the membrane at the apex is sensitive to low frequencies. This, together with progressive changes in the mass and stiffness of the membrane, results in a place code on the basilar membrane, from high to low. Receptors located at different positions along the length of this membrane, and that are activated by vibrational energy, therefore respond optimally to different characteristic sound frequencies (the number of times a waveform repeats itself per second) (Figure 2.5). This place code is used to assist in the neural coding of frequency and in the formation of frequency maps that are found throughout the various stages of auditory processing all the way up to auditory cortex. This ordered representation of sound frequency is called "tonotopicity." The range of frequencies heard by humans is about 20–20,000 Hz, and not all frequencies are heard with the same degree of sensitivity; there is inter-individual variation, and the