Introduction

It is night and the vacant cavern is dim, chilly, still. A few animals have arrived before the others, bustling about the immense expanse beneath the cavern roof sixty feet above. From time to time a cry echoes through the chamber and the flurry of activity increases. And then, all at once, a herd of two thousand shuffles in.

It is a highly territorial species and each animal seeks out its rightful station in the cavern. Those of highest status roost farthest in; others withdraw to murky corners near the entrance. Outside, they had cooed and preened, dominated and submitted, but all that is finished now. It is time to nest. Deep in the brain, structures as ancient as a brontosaurus announce, "It is safe here. You can relax. But do not sleep, for something is about to happen." Pulse rates drop, blood pressure slackens, breathing lightens.

The cavern visitors are a species of tool users, and when a group of a hundred more enter—individuals with distinctive black and white coloration—they carry oddly shaped wooden boxes and metal tubes to the front of the chamber, where they sit together. Abruptly, the dominant male struts in, climbs to a position above all others, and performs a triumph display. His arrival is greeted by much hooting and clatter.

Then silence. In two thousand brains the frontal lobes take command: there is to be no coughing, no spitting, no loud yawning, and for that matter no vocalizing or fighting or mating. The cavern darkens, muscles relax, touch receptors quiet, and much of the brain dozes off. But in the
of these two thousand brains, spontaneous neural activity—
a sign of heightened expectation. When the dominant male
penetrates an elaborate display, swinging his forelimbs to and
fro in cascades. It has begun.

Glorious sound. Sound of a kind little encountered outside the
church, a sound that is pure and enduring. Patterns ascend to
be inaudible, then fold into themselves and melt away as even grander
sound soar. A wall of a hundred sounds hurls toward eager ears, rico-
cheting about the cavern roof and muffled by 150 tons of flesh below.
Tones, thousands of minute reverberations, tones rain down upon the
audience from all sides, funneling into ears to climb from vibrating air to
trembling membrane to oscillating bone to pulsating fluid to surging
decrochemical discharges that spurt like fountains toward an expectant brain.

Some of the animals are left unquiet; a few have even fallen asleep.
Many covertly vocalize in communication with themselves. But most are
overpowered by the sound. At first it conveys circumspect pleasure. Then
delight. Then amazement. Then elation. For something is emerging from
the patterns, something between the tones that is unheard yet is as sub-
stantial as any sound. Voices hurl together; bass tones rise above a furious
sweep of treble; the sound lowers its horns and charges. Deep within,
there's a tightening, a verging, a sensation of release from gravity's pull.
Ectasy.

Ecstasy. Ex—outside, stas is for “standing.” Sounds that leave you
standing outside yourself. Sounds like those that called Ulysses to the Sirens'rocks.
Sounds whose potency lies beyond pleasure and even beyond beauty.
Sounds that reveal to us truths we have always known yet won't
be able to recount when the last echo has subsided.

But how? How can music make sense to an ear and brain evolved for
detecting the approaching lion or tracking the unsuspecting gazelle? The
sense of hearing is 300 million years old. Complex music has existed only
one hundred-thousandth as long. What is it that our brains have learned
do to themselves in so short a time? What makes a distant oboe's wail
beautiful? Why is one chord “happy,” another “sad,” another “anguished”? How can sounds that are a feast to some ears be a sickening meal?

Why are some individuals ravaged by music and others indifferent?
And how is it that of billions of brains that have known and enjoyed
music, only a handful have been able to invent the music of ecstasy?

Such questions are hardly new. You'll find them asked in Plato, in
Nietzsche. But it’s only in the last century or so that scientists have
become interested in the brain's role in music. First came acoustics, the science of sound;
then psychoacoustics, the study of how minds perceive sound; then musicology, a vast
discipline scrutinizing every aspect of musical perception and performance.

In parallel, brain science has inched along, the
psychologist's tortured mind against the scientist’s keen mind. Slowly, grudgingly,
a knot of billions of nerve cells has given up some of its secrets. Today, scientists can watch as an ear dances in time to a waltz, and they can
observe parts of the cerebral cortex “light up” as Mozart saunters through.

Over ten chapters we'll venture from trembling air to quavering con-
sciousness. Our journey begins quietly—indeed, soundlessly—in the
muddy depths of Jurassic seas. It ends in the equally muddy depths of
modern music. What lies between is unfailingly fascinating. We begin
with two background chapters on how the characteristics of musical sound
and musical hearing limit what music can become. Then come three chap-
ters about how such sounds are combined into the basic devices by which
melody, harmony, and rhythm work their magic, focusing on how such
devices arise from properties of the human brain. With this accomplished,
the next three chapters can consider how a brain assembles musical devices
into vast hierarchies of sound as it composes, performs, and listens to music.

Only then, in the last two chapters, can we turn to the questions that haunt
us most: how it is that music takes hold of us, rattle us to the core, and
somehow speaks to us in a way that words cannot. Unavoidably, the question
arises: who, or what, is it that is moved by these sounds? There is more
at stake than a pretty tune. Again and again we will come up against
cutting-edge issues in musicology and neuroscience alike, issues that are
beginning to yield a new conception of the human mind. We begin ...

From sound... Philosophers ask whether a falling tree makes a sound
when no one is present to hear it. No one? A tree crashes in the ears of
crickets and frogs and snakes and owls and hedgehogs and bats and bobcats. But it crashes differently for each; for the philosophers have a point: sound (as opposed to vibration) is something that a mind does. To understand how this is so, we'll look at the tortuous evolution of the ear and at nature's vast diversity of ear designs. We'll see how primitive parts of the brain first make sense of sounds. And we'll find out what our own ears can and cannot perceive, and what happens to them through age and disease.

...TO TONE... Musical sound rarely occurs naturally, and beautiful musical sound occurs more rarely still. This chapter explains the structure of musical sounds, examines how our brains process them differently from ordinary sounds, and explores the mystery of beauty in musical timbre. Along the way, we'll see how musical instruments have evolved to meet particular requirements of our auditory systems. We'll delve into psychophysics to see the limits and the irregularities of musical perception. And we'll take a first look at the brain's auditory cortex, where music first enters the realm of conscious experience.

...TO MELODY... Music begins only when tones are arranged in a sequence. But if melody is music's most basic experience, it is not a simple one. Every dimension of music is present in a "simple" melody: rhythm, harmony, dynamics. In this chapter, we'll see how scales combine with rhythms to make melodies. We'll ponder how children develop a knack for melody, and whether certain features of melody are built into our brains. Ultimately, we'll take on a question that has puzzled composers for centuries: Why are some melodies so haunting and others not?

...TO HARMONY... To our ears, music has a certain inevitability as it progresses from chord to chord and key to key. Break the rules of harmony, and music is jarring, even painful. It would seem that we have tailored music to our brain's nature. But it is a learned inevitability that we experience, for the harmonic systems of distant cultures can sound just as inevitable to other peoples even though such sounds clash in our ears. This chapter explores how our harmonic system works and describes its centuries-long evolution. We'll investigate how the brain processes harmonic relations, the biological basis for consonance and dissonance, and the usefulness of alternative harmonies. We'll also take a look at the mysterious phenomenon of absolute pitch and its effects on music perception.

...TO RHYTHM... When feet start tapping, people say that music's "got rhythm." But there's much more to rhythm than regular beat. This chapter explores the two basic kinds of rhythm and the many ways we respond to them. We'll look at theories of how the brain gives rise to the sensation of rhythm, the relation of rhythm to physical movement, its development in childhood, and the limits of rhythmic perception. Along the way, we'll ponder whether some kinds of music have "got rhythm" more than others.

...TO COMPOSITION... Combine a highly evolved ear, high-tech instruments, and a powerful harmonic system, and you may still have nothing more than the racket of teenagers jamming in a garage. Good music requires good composition. Yet great composers are even rarer than great painters or writers. Exactly what is a brain up to when it creates original music, and why is it so difficult a task? For nearly two centuries, scientists (and pseudoscientists) have measured the skulls and brains of great composers, sometimes raiding graveyards to do so. Researchers have interviewed composers about how they work, studied their personalities, and followed the progress of child prodigies. Musical imagery and musical memory are central to these studies, and they are the focus of this chapter as we stalk the Muse's lair in the brain.

...TO PERFORMANCE... Nothing is quite so demanding of a brain as musical performance, which involves the choreography of hundreds of muscles, eyes moving across instrument and score, ears following every nuance, written symbols decoded and interpreted, several kinds of memory churning, emotions summoned and deployed, whole passages planned and administered, everything reciprocating to elicit a particular style, and all this without the various activities colliding. It's no wonder that it takes so long to learn an instrument well and that truly great musicians are so rare.
In this chapter we'll consider the brain at work during performance, what it can and cannot do, and how things go wrong. We'll contemplate the notion of musical talent and why some musicians get no better while others never stop improving.

...TO LISTENING... For every musical style there is a style of musical expectation. Various cultures, social strata, and personality types make different demands of music. Some people use music as a stimulant, others as a tranquilizer; some seek intensity and beauty, others distraction and clamor; some demand symbolism of the world about them, others delight in pure abstraction. This chapter looks at the many ways that people use and regard music, and how various emphases on rhythm, melody, harmony, words, and symbols engage the brain differently. We'll focus on the brain's ability to attend and anticipate, and on how experience tailors our ears to particular musical genres.

...TO UNDERSTANDING... While many people believe that music is a universal language, cognitive scientists argue over whether music is a language at all. If music has meaning, then what does it refer to? Does music have a grammar? What is its vocabulary? In asking whether music functions like language, we'll consider whether the distribution of musical skill in the brain parallels those for spoken language. Along the way, we'll take a close look at various kinds of amusia, the loss of musical ability through brain damage.

...TO ECSTASY When music transports us to the threshold of ecstasy, we behave almost like drug addicts as we listen again and again. What's happening in music that drives us right out of our skins? Why is some music "emotional" and some music "intellectual"? And how is it that sound can give us pleasure we seem to feel in our bodies? This chapter regards musical knowers and musical known in light of modern theories of emotion and pleasure. You may leave this chapter with new ideas not only of what music is, but of what you are.