Musical Sound

An Introduction to the Physics of Music

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Acknowledgments

In registering indebtedness in connection with a book, one faces the question of how far back to go. Science and music have always constituted the two most important facets of my life, and the list of people and circumstances that made this possible, encouraged it, and contributed to it is too long to enumerate. Turning to more specific influences, my direct interest in the science of musical sound arose when I was asked to teach, at the University of Oregon, a one-term course, by then well established mainly due to the efforts of a colleague of mine, Kwangjai Park, called The Physics of Sound and Music, catering to a substantial extent to students in the university's distinguished School of Music.

As my decision matured to write a textbook for such a course and for the many music-lovers "at large," I was greatly encouraged by the ready cooperation of Sidney Solomon, of Publishers Creative Services, with whom I had a happy association in connection with my previous book on a quite different subject.

Three members of my family also played a very substantial role in this book. My sister, Edith Moravcsik, professor of linguistics at the University of Wisconsin in Milwaukee, volunteered to be a guinea pig on whom I could try out the manuscript. Not at all a natural scientist but an avid music lover, she went over the book with a fine tooth comb and made a long list of suggestions which

were incorporated in the final version. My wife Francesca, a landscape architect, took time out to prepare the illustrations from the sketches drawn by me, a born antitalent in drawing. Finally, my daughter, Julia was not only instrumental in preparing the manuscript and the index but also made stylistic and other suggestions which improved the book.

Various earlier versions of the manuscript were also used by students in several of my courses on this subject, and their complaints and praises were also a beneficial influence. In a similar vein, I hope that complaints and praises from the readers of this book will be forthcoming in order to continue to improve it in subsequent editions.

MICHAEL J. MORAVCSIK
Eugene, Oregon

Foreword

WHAT IS MUSIC?

Where does it come from?

What does it do?

What does it mean to us?

Why does music belong to human life?

These are the main questions that have provoked—and continue to provoke—the huge literature around that sublime form of art. The more answers are attempted, the more questions are raised.

Arriving, through manifold and complicated channels, to an axiom like statement, it can be said that music represents, mirrors, sublimates the three basic fields of human emotion and intellect: love (sensuous and spiritual), by melody; work (activity) through rhythm; community, (togetherness, brotherhood) with harmony.*

*Responding to possible arguments.

Music can depict, of course, all the above also in the negative: hatred, conflict, and anarchy—but it does so only to point out contrasts. Its goal always is to lead human thinking and feeling into positive channels so as to bring light and freedom.

Mozart—whose intuitive musicianship is unequalled—wrote once to his father: "Music shall never offend." How right he is. Real music always is a source of consolation and hope to those who understand and feel it, no matter how hard it can be to arrive at that platform. Music *gives* abundantly, but also *demands* from both its makers and receivers.

The finality of this postulate could make us think, that with it we have reached the ground.

But we have not.

Not by far.

The next question is right at hand: How does this representation take place? By what means is music capable of penetrating such depths of human existence?

Through sound, of course.

We all know that.

But what is sound?

Yes—what is it? That infinite variety of voices that reach our consciousness through our ears, that our brain digests or rejects, that surrounds us constantly, day and night—including silence, which is a sound also—and what is that sparsely selected group that we call musical sounds—a small number of sounds, a number slowly mounting through the centuries, now about two hundred - two hundred!—taken out at random—random? What random?—out of the billions that float around, to make our art of music with them--what is all that? How does it come about?

With this question we have arrived at the book of Prof. Moravetik, which these lines are to introduce.

As a musician who is active in the creative as well as in the performing realms of music, I have read this book, slowly and carefully, often re-reading a paragraph or a sentence, not only with interest but with mounting fascination.

Its contents were only fractionally included in my early education. Much was entirely new to me, although I know of the existence of all that information. The *terrain* was familiar, but only that.

I had the feeling of entering the cellar of the house in which I live and know intimately, from the ground floor upward. Not that I wasn't in that cellar before. But when I went down there, it was only for a few moments and with a definite purpose, to bring up a suitcase, a bottle of wine, or whatever I needed among the multitude of objects stored in that subterranean territority, dark and slightly mysterious and distant. I have never "wandered around" in that cellar before.

Now that I have, I can happily report that I came up again, enriched by an important experience--and intact. The excursion did

not change my musicianship, the information gathered did not alter my musical attitudes, methods, goals, ideals. But I became richer and pleased, contented by having been told these "facts of life" of the art that I am serving—and told in such clear, in such—the word that is on the tip of my pen seems unavoidable—*natural* terms.

The "facts-of-life" analogy that suggested itself, is—I believe—rather apt. Indeed, the knowledge of them, in the realm of sex, where the term is conventionally used, does not have a negative effect upon the spiritual "ingredients" of sex life. Love, passion, exaltation do not suffer from our knowing the "facts-of-life," and the poetry of love does not lose its impact upon those who know these facts.

This book—as its author emphatically states right on the first page—is not intended for scientists. That promise is rigorously fulfilled until the last page is turned.

It is good so.

These kinds of books should exist—and I hope they do—on every subject.

Everybody is ignorant—about something. And it is very important that we should be getting information in the various fields of our ignorance. It is also very important that those who undertake to disseminate needed information take into account that adult laymanship that they undertake to address and not be "blinded" by their own knowledge.

Thus, in the case at hand, it is refreshing that laymen are told in laymen's terms (but attention! what we hold in our hands is by no means a juvenile transcription or a reader's-digest edition) about the sources of music, and only as far as the sound itself is concerned: its origin, its mechanics, its "bodily" existence, and told by an expert scientist who has set his own limits and does not wish to trangress them.

One important qualification must be interpolated here when the author says that his book is for lay readers he means laymen in physics. The reader's relationship to music is not his concern. He obviously would regard musical interest as an asset, but his book is wide open for readers who are not musical but are interested in acoustics for other reasons. (The enormous advances in that field, that are being made in our days, open—among other things—vast

areas of laymanship and dilletantism as well.) It is very possible that someone who picks up this book out of general curiosity only, will end up by reading it as a hi-fi fan or a music-enthusiast. The author's own position is clearly defined, although he does not waste any words about it: it is that of the musically interested scientist. Perhaps there was in his early youth a moment in which he vacillated between a musical or scientific profession, but ever since he made his decision he stands by it and never goes beyond the goals he has set for himself. In his book he does not treat the art of music, but the means, the basic "tools" of that art.

The line is really drawn—and this is for the good. There are no "sour grapes" in this book, because the hand is stretched out only to those it can reach.

An example to the contrary comes to mind. A very eminent colleague of mine, a great and widely esteemed musician—my elder of nearly two decades—wrote a thoughtful, interesting, searching book in which he endeavored to explain the evolution of the art of music on the basis of its physics only. (He came to a pessimistic conclusion.) During a debate, discussing that book with its author, the writer of these lines, then a young man (whose attitude concerning the same problems was—and still is—optimistic) was prompted to exclaim: "But, my dear friend, you have described and discussed every facet of music in your book, omitting only the single one that you were longing to write about—the talent for it!"

Professor Moravcsik did not fall into that trap. His book is not concerned with musical talent, whether creative, recreative, or receptive (let us not underestimate the overall importance of the last mentioned!)—even with music itself he is only concerned as far as the sound it makes.

He well knows, however, that the impact of music is beyond its sound: it is in the region of associations, fantasies, emotions kindled by those sounds in that most mysterious human "organ"—the word is used in want of a better one—the soul—that has no physics.

This region Moravcsik does not enter. But he leads us to its door, and we shall be thankful for that.

—Antal Dorati

Re-introducing
MUSICAL SOUND

THE PHYSICAL and theoretical properties of sound were first systematically studied by Pythagoras and his followers in ancient Greece. It would appear that the valued aspect of such study was the *discovery* of universal ratios, which were assumed applicable to the macro-universe ("music of the spheres") and the micro-universe ("harmony of the soul"). According to historians, the theories and philosophy of the Pythagoreans constituted a religious sect. Pythagoras, Archimedes, Euclid, even Zeno were looking to distill basic truths from the observable universe and to express them in the pure language of mathematical form.* A shift to the concerns of man himself—ethics, morality, love, emotional development, politics, and social issues—became the provenance of the later school of Socrates/Plato.

It is useful to remember that the average ancient Greek did not read Aristotle for advice on child-rearing; nor were the musicians who comprised the banquet circuit in Olympia familiar with Pythagoras' monochord. The same could be said for today's average citizen of the entire Western world and the musicians who comprise today's banquet circuits. Indeed, and on their behalf, Dr. Carl Jung noted, "Don't expect to find Chartres Cathedral in a geology book just because it's made of stone."

Sound is a vibration that travels through a medium (air, water, wood, etc.) and is detectable by the ear. Musical

*Zeno of Elea was fond of noting the paradoxes found in nature, common events made impossible by apparently sound logic. This approach is yet another indication of a powerful preoccupation with Nature's Order. (Perhaps Zeno would appreciate the paradox of being explained thus!)

sound is distinguished by its purposeful production that results in an orderly sequence of vibrations. When these vibrations cycle at the rate of 440 times per second, we hear the tone "A." Originating from the bowed string of a violin, the column of air within a flute, or the crystals of a computer's inner circuitry, the quality of the sound will differ markedly; the pitch, however, will be the same so long as the vibrations are of like speed. The various means used to excite these vibrations have each of them their own "voice-prints," or timbres. The "A" sung by opera singer Maria Callas sounded quite different from the "A" sung by rhythm & blues singer Janis Joplin. The string instruments made by Stradivari sound different from those made by Guarneri. In fact, each of Stradivari's instruments has its own particular timbre. It is clear that pitch is but one element of the sonic phenomenon. Timbre is another. In addition, factors such as method of transmission—listening to a symphony orchestra in the large space of a concert hall as opposed to listening through the speakers of a radio—need to be considered. Ultimately, the physical aspects of sound are registered by the human ear and perceived by us not only through physiologic processes, but psychological ones as well.

The principles that underlie most every aspect of our lives are organized into discrete fields of study. Necessarily, there is great overlap. An organ builder must have extensive knowledge in far-ranging areas in order to successfully complete his task. Often, one person will design the organ to be built by others, and fine-tuned by yet a different party. Only then can the organist sit down and play. Only then can all the preliminary work find expression through its intended application. The result is effected by a coordinated team of specialists.

Specialization does have inherent disadvantages. Every field develops jargon. Further, vocabulary is drawn from common speech, becoming suddenly arcane, to wit: "charmed" and "strange," "left-handed" quarks in quantum physics. The reverse holds true, too. In daily life, the words "tone," "note," and "sound" replace one another rather synonymously; in the physics of sound, however, these are discrete terms. The old Beaufort scale indicates wind speed by commonly observed effects: the rustling of leaves indicat-

ing a light breeze. One can also determine the same light breeze through the use of an anemometer. Stradivari clearly understood wood, varnish, acoustics, engineering, and proportion well enough to create string instruments, many of which define beauty. I doubt that he could converse fluently in the disciplines of Helmholtz, Curie, Linnaeus, or Vitruvius on any of the salient specialties involved; but neither could they bring it all together to build a passable fiddle. If we follow this kind of logic to its dead end, "Only God can make a tree."

It is easy to rue the fact of specialization; however, keep in mind that specializing is a phenomenon that happens only when everyone is doing it. Each explores a discrete area; all make use of the resultant data; the whole discipline of science benefits in the process. When Galileo studied the moons of Jupiter he was limited by the quality and size of lenses available for his telescope. Needing better, he improved them as best he could; then it was up to the opticians and those with applied knowledge of the related trades to develop new technologies to meet the demands that Galileo's discoveries occasioned. New discoveries begot new technologies, which begot new discoveries. Today, the Hubble telescope is the latest generation in the series. Imagine all the technologies from all the fields that needed to come together to bear such fruit!

Still, it is unfortunate that so many discrete areas of knowledge are beyond the ken of so many. The sciences are notorious in this respect. Those that exist on the wings of math alone are the most arcane.

The physics of sound has engendered an enormous amount of literature over the past 2,500 years. (A just summation with additional material was written by the great German scientist, Hermann Helmholtz, in 1862, in *On The Sensations of Tone.*) When one considers that the essentials behind such profligate explication involve little more than a half-empty bottle of soda-pop and a length of dental floss, it is clear that there are some basic principles at work that can be explained with physical application, thought, and imagination—i.e., a minimum of math. When sound is deliberately organized and produced we know it as music. Sound and music have fascinated the curious since recorded his-