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THE PHYSICAL BASIS OF MUSIC

PREFACE

The main purpose of the following work is to explain certain physical considerations useful not only to a beginner learning how to play a musical instrument, but also to an accomplished musician trying to gain full technical mastery of an instrument. Some conscious understanding of the facts of physics and physiology, while obviously not necessary, can speed up the learning process for a beginner and may help the good performer to acquire a level of technical skill, accuracy, and endurance unlikely ever to be attained otherwise. In some cases, what a musician can learn in a year of intense but undirected trial–and–error practicing on an instrument, might have been learned in a week of practice guided by this knowledge.

The idea of writing this book has been in my mind for many years, as my own research and experimentation gradually made me aware of more and more of this situation, and notes accumulated for the course which I taught for a number of years at Stanford University and Washington University. But when this loose collection of ideas was finally assembled, it appeared hard to say just what "*the*" purpose of the book is. The fact is that the final result has a number of secondary purposes.

I realized only gradually, from a repeated strange experience, that there is a need not only to explain technical facts; but also to provide young musicians with a general cultural background in the subject. The strange experience was that of making a passing reference in a lecture to something in the history of music, that I thought every literate person must know – only to find that my students, some of whom were already accomplished performing musicians, had no idea what I was talking about. Of course, a single small book can convey only the bare minimum of all the general historical information available in a good library; so we have tried to make this work also a guide to the literature, with extensive references showing where the interested reader may find more – in many cases, vastly more – material than we can include here.

But in the older literature there is also a great deal of misinformation, superstition, and downright error concerning not only the physical facts of musical instruments and technique; but even the simple historical facts concerning which instruments, scales, and styles of music existed in various earlier times. Different contemporary sources contradict each other – even on matters which were within living memory when they were written – and so today we are obliged to decide whom to believe, taking into account every scrap of relevant evidence we can lay our hands on. The further back we go, the more of this we find; before the 18'th Century most writers existed in a kind of dreamlike state, unable to distinguish between a real fact and a figment of the imagination. But a person with scientific training is in a very good position to judge what statements are plausibly true, which are conceivable but highly improbable; and which are manifestly impossible.

Unfortunately, the record does not always improve in modern times. In recent works, understanding of the original very practical reasons why music became associated with mathematics, why the violin has its peculiar shape, and similar matters, has been largely lost and replaced with folklore. Important facts about vibrating systems and acoustics, which were explained clearly and correctly by Lord Rayleigh and Hermann von Helmholtz over 100 years ago, were still not comprehended 40 years ago by the instrument technicians and music teachers who had the most need to know about them, and whose ideas still dominate much of the field today. So we aim to be critical, warning against common fallacies which tend to persist long after the truth is known. We lay the strongest emphasis on things which one cannot find at all – or cannot find explained clearly and correctly – in recently published works.

Music has many different aspects: the historical evolution, the mathematical connections, the very different aesthetic considerations involved in composing and performing, and the unavoidable physical considerations that must be faced in building and playing instruments. We want to say something about each of these so that our main purpose, the last, is seen in better relation to the whole.

Since no author can be intimately familiar with every instrument and every musical tradition, we end up with a very uneven treatment whoever tries to write such a study as this. While I have been playing pianos seriously and studying their inner workings and the physiology of the piano–playing hand for over forty years, and have some slight experience with the clarinet and violin, my total hands–on experience with brasses is probably less than ten minutes; accordingly we devote three Chapters to pianos, and none to brasses.

Fortunately, what I lack here has been supplied admirably by Arthur Benade (1976), another professional physicist[†] who has specialized in just the areas where I am weakest. Practically everything I know about the inner workings of wind instruments has been learned from reading Benade; and so it seemed best to refer the reader to his work rather than attempting to repeat it here. We urge the reader who is seriously interested in this material to obtain also a copy of Benade's work to read in connection with this one.

In other words, the present work is in no sense a competitor of Benade's; it is rather a companion piece, in which the viewpoint is more that of a musician, and we concentrate more on the history and playing of musical instruments (and indulge, in Chapter 7, in musical aesthetic judgments which Benade, no doubt wisely, avoids). Also, compared to Benade's even treatment, ours has a schizoid character; in the main part of a Chapter a musician is talking to musicians, in their language, about physics; in the ending Sections of several Chapters this switches to a physicist talking to physicists, in their language, about music. This is done for the following reason.

A major concern was the question of the proper technical level for this presentation. To make it too technical would defeat our purpose by making it inaccessible to the very people we want most to reach; but to make it too elementary would only perpetuate errors and frustrate those who have enough mathematical training to follow the whole story. In the end we decided that to accomplish our goal it is necessary to give the presentation at both levels simultaneously. Accordingly, at the end of several Chapters there is a "*Mathematical Supplement*" of two or three pages in which we repeat the verbal

[†] It is a sadness to report that Arthur Benade, a former graduate student in physics here at Washington University, died in 1987, so the 1990 edition of his book, revised from his marginal notes, will be the final one.

statements in the much more complete form of the mathematics, at the highest technical level yet attained. Readers without mathematical training may skip these parts; yet they may still gain some useful understanding merely from skimming over them. Equations, like books, do not bite; a musician with no mathematical training has no reason to fear the sight of an equation – particularly when that equation indicates exactly what scientists know about his/her instrument. A little of its meaning will come through; if not the quantitative details, then at least a qualitative feeling for the *kind* of information that is and is not known.

Mathematics is simply an enormously efficient shorthand language; a single equation states simultaneously thousands of quantitative details, which we could not say in words in an entire book. So the Mathematical Supplements are not merely restatements of the text in a more esoteric language; they are vast extensions of the text. One who can read the meaning of the equations can extract from this book far more detailed information than is contained in the words alone; and that information, far from being dull, is often highly interesting – even exciting – to one who did not suspect some of the wonderful things that are happening in musical instruments. Indeed, we fancy that some readers, perceiving this, may be inspired to learn some mathematics for that reason – just as Theodore Steinway did 130 years ago.

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