Foreword

How does a tuner achieve such a precise tuning of a piano or an organ using nothing but his ears? Why does the clarinette, though equal in length to the C flute, play one octave lower? What difference is there between the Pythagorean scale and the tempered scale? How can a series of notes seem to rise indefinitely even though it always repeats the same notes? What are the possibilities offered by digital sound? What are its limitations? How can a compression technology such as MP3 achieve a tenfold reduction of a sound file's size without significantly altering it? What is the very simple principle underlying audio synthesis in Yamaha's famous keyboard, the DX7? These are a few examples of the questions we will try to answer.

The goal of this book is to use these questions to give the reader an overview of the nature of musical sound, from its production by traditional musical instruments to sounds obtained by audio synthesis, without trying to be exhaustive however: this book is not meant as a catalogue, but instead, I hope, as a first step that will enable the reader to move on to more specific areas in this field. Musical sound is addressed from a scientific standpoint, and the succession of causes that lead to a specific type of sound are, as much as possible, described in a simplified but precise manner. The fact, for example, that a particular sound is composed of harmonics (strings, pipes, etc.) or of partials (bells, timpani, etc.) finds its causes in the physical laws that govern the behavior of materials, laws that induce mathematical equations, the nature of which leads to a certain characteristic of the produced sound.

This book is intended for any reader interested in sound and music, and with a basic scientific background: students, teachers, researchers, people who work in a scientific or technical field. It describes and relies on concepts of acoustics, mathematics, psychoacoustics, computer science and signal processing, but only to the extent that this is useful in describing the subject. In order to broaden its reach, it was written in such a way that the reader may understand sound phenomena with simple analytical tools and the smallest possible amount of required knowledge. Those who teach this material will find diverse and motivating study problems, and students will find ideas for different kinds of ' projects ' they may encounter in their undergraduate and graduate studies. In the end, my greatest wish would be to succeed in sharing with the reader the pleasure I find in understanding the basic mechanisms underlying the manifestation and the perception of the sound and music phenomenon.

After an introduction to acoustics, a bit of music theory, and a study of sounds and their representation in chapter 1, we will discuss vibrational modes and the timbre of a few typical instruments in chapter 2, and in chapter 3, we will relate this with the question of scales and tuning systems. After wandering off into psychoacoustics in chapter 4, and using the opportunity to discover a beautiful acoustic illusion, we will discuss several aspects of digital sound in chapters 5 and 6: sampling, compression technology based on the properties of hearing (such as the widely known MP3 format), sound effects (vibrato, reverberation, the Leslie effect) and synthesized sounds, such as for example those produced using the Chowning technique, made popular by DX7 synthesizers.

For further development, each chapter ends with the following:

- study problems, to explore certain themes, or to study them further in depth. For the reader's information, the difficulty and the amount of work required are indicated with stars: (*) means easy, (**) is average and (***) is difficult;

- practical applications meant to be carried out on a computer, where the reader will create different kinds of sounds and play them on a crude synthesizer, experimenting on the phenomena described in the book, as well as put his or her hearing to the test, and practice his or her scales! Practical instructions relevant to these applications are given at the end of the first chapter.

Website. A website is available to illustrate the book. It contains many examples of sounds, as well as the programs used to generate them. It also contains the programs and sound files necessary to perform the practical applications, along with the answers. The address of the website is:

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`www-gmm.insa-toulouse.fr/~guillaum/AM/`

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Throughout the book, it will be referred to simply as the `AM` website.

Reading advice. The chapters were written in a particular, logical order, and the concept and methods developed in a given chapter are assumed to be understood in the chapters that follow. For example, the approach used to go from the wave equation to the Helmholtz equation, which is detailed in chapter 1, will not be explained again when studying the vibrations of sonorous bodies in chapter 2. However, you can also browse through it in any other order, referring if necessary to the previous chapters, and using the cross-references and the index to easily find where a given concept was discussed. Finally, because some phenomena are easier heard than explained, listening to the website's audio examples should shed light on any areas that may still be unclear !

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