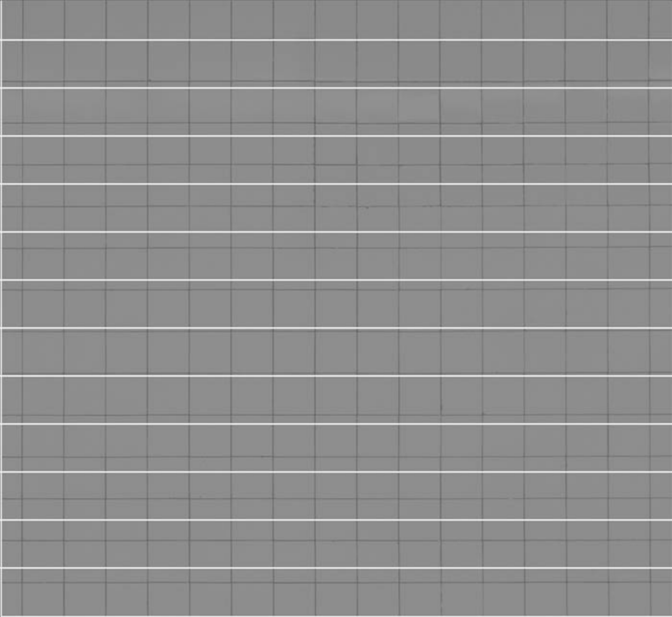

Sound Ideas

Aden Evens

Music, Machines, and Experience

Sound Ideas

Edited by

Sandra Buckley

Michael Hardt

Brian Massumi

Theory out of Bounds

27 **Sound Ideas: Music, Machines, and Experience** Aden Evens
26 **Signs of Danger: Waste, Trauma, and Nuclear Threat** Peter C. van Wyck
25 **Trust** Alphonso Lingis
24 **Wetwares: Experiments in Postvital Living** Richard Doyle
23 **Neuropolitics: Thinking, Culture, Speed** William E. Connolly
22 **Globalizing AIDS** Cindy Patton
21 **Modernity at Sea: Melville, Marx, Conrad in Crisis** Cesare Casarino
20 **Means without End: Notes on Politics** Giorgio Agamben
19 **The Invention of Modern Science** Isabelle Stengers
18 **Methodologies of the Oppressed** Chela Sandoval
17 **Proust and Signs: The Complete Text** Gilles Deleuze
16 **Deleuze: The Clamor of Being** Alain Badiou
15 **Insurgencies: Constituent Power and the Modern State** Antonio Negri
14 **When Pain Strikes** Bill Burns, Cathy Busby, and Kim Sawchuk, editors
13 **Critical Environments: Postmodern Theory and the Pragmatics of the "Outside"** Cary Wolfe
12 **The Metamorphoses of the Body** José Gil
11 **The New Spinoza** Warren Montag and Ted Stolze, editors
10 **Power and Invention: Situating Science** Isabelle Stengers
9 **Arrow of Chaos: Romanticism and Postmodernity** Ira Livingston
8 **Becoming-Woman** Camilla Griggers
7 **A Potential Politics: Radical Thought in Italy** Paolo Virno and Michael Hardt, editors
6 **Capital Times: Tales from the Conquest of Time** Éric Alliez
5 **The Year of Passages** Réda Bensmaïa
4 **Labor of Dionysus: A Critique of the State-Form** Michael Hardt and Antonio Negri
3 **Bad Aboriginal Art: Tradition, Media, and Technological Horizons** Eric Michaels
2 **The Cinematic Body** Steven Shaviro
1 **The Coming Community** Giorgio Agamben

Sound Ideas

Music, Machines, and Experience

Aden Evens

Theory out of Bounds *Volume 27*

MINNESOTA

University of Minnesota Press

Minneapolis • London

An earlier version of chapter 1 was originally published as “Sound Ideas,”
Canadian Review of Comparative Literature 24, no. 3 (September 1977; special edition edited by Brian Massumi),
and reprinted in Brian Massumi, ed., *A Shock to Thought: Expression after Deleuze and Guattari*
(New York: Routledge, 2002). The first half of chapter 3 resembles a previously published essay,
“The Question Concerning the Digital,” *difference*s 14, no. 2 (Summer 2003; special edition,
More on Humanism, edited by Elizabeth Weed and Ellen Rooney); published by Duke University Press.

Published by the University of Minnesota Press
111 Third Avenue South, Suite 290
Minneapolis, MN 55401-2520
http://www.upress.umn.edu

LIBRARY OF CONGRESS CATALOGING-IN-PUBLICATION DATA
Evens, Aden.
Sound ideas : music, machines, and experience / Aden Evens.
p. cm. — (Theory out of bounds ; v. 27)
Includes bibliographical references (p.) and index.
ISBN 0-8166-4536-1 (hc : alk. paper) — ISBN 0-8166-4537-X (pb : alk. paper)
1. Music—Philosophy and aesthetics. 2. Music and technology.
I. Title. II. Series.
ML3800.E87 2005
780'.1—dc22
2005002025

Printed in the United States of America on acid-free paper

12 11 10 09 08 07 06 05 10 9 8 7 6 5 4 3 2 1

For my dad, who loves music and thinking.
Technology, not so much.

This page intentionally left blank

Contents

Preface ix

Acknowledgments xvii

Chapter 1. **Sound and Noise** 1

Chapter 2. **Sound and Time** 26

Chapter 3. **Sound and Digits** 62

Chapter 4. **Making Music** 126

Notes 175

Works Cited 193

Index 197

This page intentionally left blank

Preface

A GUY from whom I was ordering a sandwich noticed the book I was carrying. "Why write about music?" he asked. "Music is for grooving. You can't say anything about it that makes any difference."

In spite of its anti-intellectual motivation, I found myself agreeing with this claim frequently over the course of writing this book. Music resists theorization at every step. As a form of art that is set in time, that takes its time, a piece of music does not sit still to be observed. One cannot subject sound to a persistent observation; rather, one can only listen and then, maybe, listen again. Music is apprehended in chunks of time. Partly because sound is dynamic, Western intellectual traditions show a marked preference for vision as the figure of knowledge. We articulate more effectively the fixed image than the dynamic sound.

Traditional studies of music surmount this difficulty by a variety of routes. First, musicology—centered on European art music—tends to focus on the *score*, the written representation of a piece of music. The score offers itself to the focused gaze of the musicologist, and its abstract representations can be read and analyzed using the practiced techniques of textual interpretation. Second, the burgeoning discipline of cultural studies examines music in a culture and so emphasizes cultural artifacts and cultural dynamics in its study. Both of these fields yield much of interest, but both suffer from the same "oversight." For neither musicology nor cultural studies listens to the material specificity of music; neither discipline attends enough to music as *sound.*

There are plenty of exceptions. Ethnomusicology, crossing musicology and cultural studies, makes contact with the aural as it moves between disciplines from musical structure to musical culture. Even disciplinary musicology and cultural studies heed the sound of music, its concrete experience, especially when they are unable to employ their usual techniques. Confronted, for example, with improvisatory music, which has no score, musicologists pursue less familiar methods of analysis, furthering consideration of the sound.

This book takes a different path to the music: phenomenology. *Phenomenology* usually refers to a lineage within the history of philosophy, drawn together by a commitment to the study of the world as it is experienced. Other philosophies may search for what lies behind phenomena, the way things *really* are, but phenomenology resolutely studies things as they seem. Likewise, this book takes as its primary object human experience, *the experience of music.* Of course, history, culture, and structure are highly relevant to this analysis, each an intimate dimension of experience, as are plenty of other disciplines, and this work turns frequently to concepts from science and engineering. Such a panoply of ideas reaches across disciplines, connected here through specific musical instruments, traditions, composers, and pieces. These examples usually enter the discourse as something like case studies, where the case under scrutiny is exemplary of broader aspects of the experience of music.

If this book sets out to study in general the experience of music, it takes this notion in a broad sense. That is, within the purview of this study are all those ways in which human beings experience music. Not only do we listen to, compose, and perform music, but we also *learn* to play it, purchase it, share it with friends, record it, catalog it, write about it, dance to it, and study it. Music sets a mood (for shopping, for drinking, for thinking); music marks and measures ritual; music incorporates subcultures; music is protest, anthem, jingle, game, and prayer. Music plays so many roles that it is hard for a phenomenologist to know where to begin. However, the common element throughout our experiences of music is *sound;* without an adequate understanding of the nature of sound, any study of music rests on shaky foundations. To provide such an essential grounding, this book draws heavily from acoustics, psychoacoustics, and music theory. These technical symbolizations of the sciences of sound are not offered as background information but because they constitute a crucial dimension of the ontology of music. That is, the formulas that scientists use to describe the operation of sound and hearing are not abstractions only tangentially related to the actual happening of sound but must be understood, sometimes despite the scientists' own interpretations, as descriptive of sound as heard. This study thus forges a connection between the formal symbolisms (of acoustics, musicology, and other sound-oriented scientific disciplines) and the affect of music, music as experienced.

The commitment to the technical dimensions of sound and hearing leads directly to another emphasis of this book. Sound, especially musical sound, does not generally arise spontaneously but is generated through certain techniques and by using certain technologies. The materiality of music weds it to technology, which enables its production and dissemination. The experience of music thus demands a *technical* understanding of musical technologies. The nonexpert will find accounts of the relevant notions from these technical disciplines, but their definitions and conclusions are not to be taken for granted. Each chapter includes at least some technical analysis, but especially chapter 3, which deals with Fourier series and digital signal processing. Technical explanations, of technologies and their scientific bases, are not provided merely for the edification of the reader but appear in the service of claims that are ultimately theoretical (philosophical, ethical, aesthetic, musicological, cultural, historical, etc.) as well as technical. Theorists are too often reluctant to study technical arcania, having abandoned once and for all the symbols and formulas of mathematics back in college. Rather than avoiding these discourses, this book deploys technical terms as concepts, dragging their symbolic apparatuses along with them. Scientific approaches to sound and music are critiqued at the level of their formal representations. Philosophical questions are pursued in the minutiae of engineering and physics. In general, formal symbolic manipulations are integrated into theoretical discourse.

In other words, the technical details do not so much support as constitute (a part of) this book's theory of music. They are essential to the claims made herein. The formal symbolic explanations given in this book assume almost no prior knowledge of the math or science explained—which is not to say that the explanations are somehow completely clear but only that this book is not specifically for experts. Inevitably, simplifications are made. After all, there is no such thing as a complete account of a phenomenon. Here, simplifications arise for two further reasons. First, considerations of space and consideration of the reader demand a navigable rhetoric. Second, simplifications serve the argument by emphasizing certain features that are most philosophically relevant.

As for this latter category of simplifications, they range from innocent to contestable to malicious. They are points at which the text breaks from science to connect to other experience. Experts will notice not so much falsehoods in the formulas but technical concepts applied in novel domains where they are unfamiliar, bent out of shape, or ambiguous. Such polysemy is a frequent rhetorical device in this book. A given term has a number of different but related meanings. Their amalgam is not a simple sum. For example, *noise* refers to many things, a semantic wealth that has been exploited in numerous works on music and sound: noise can be any difference between an input signal and the corresponding output signal; or it can be a background level of sonic energy in a room or in a machine; or it can be any unwanted, annoying, or unexpected sound; or it can be the constant vibration of the air at a given point in space; or it can refer to any sound whatsoever. The conflation of these definitions yields an original concept of noise. Similarly, time is understood simultaneously at different dimensions or different levels: time as tempo, time on the clock, time as lived duration, time as anticipation or memory, time as a variation of air pressure, etc. Further polysemies abound: grain, digit, compression, contraction, intuition, instrument, medium. Each of these terms is multiplied and then gathered back into itself, a crowd of meanings under a single denomination. Productive ambiguity connects disparate disciplines: physics crushed into ethics, phenomenology tied to aesthetics, computer science approaches musicology. Such polysemy might just be a bad pun were the argument not phenomenologically verifiable, if it didn't ring true, as it were. I call on the reader to search her own experience, not to take me at my word but actively to forge her own connections, reasons, and supports, and seek her own examples to augment those provided in the text.

Along with polysemy, there is a second methodological emphasis, an insistent focus on the limit case. Sound and music are consistently examined at certain extremes or thresholds. Sometimes it is a limit of subtlety, other times a limit of sensibility, materiality, ideality, expression, etc. The resolve here is to read the norm from the extreme rather than vice versa. The force that moves in sound is the imperceptible, while the extreme of imperceptibility is the very basis of perception. It is a matter of determining the essential by way of the inessential, seeing the static and fixed as traces of the dynamic and variable. Chapter 4, for example, investigates the process of making-music by focusing on musical genius, the exceptional moment of music-making. Eventually, this exceptional moment shows its essential affinity with the ordinary; every act of music-making has as its impetus and inspiration the exceptional. Chapter 1 discovers sound's sense in the part that cannot be heard, the subtle noise that gets buried under the heard music, pushing the music ahead without itself being sensed. Chapter 2 hearkens to innuendo, the hint or nod, that directs attention but does not rise to articulation. Chapter 3 probes the limits of the digital, searching for that moment of failure that rarely impresses itself within the banality of everyday computer use. Each of these investigations takes place at the limit, but that limit ultimately informs what it delimits.

It is at this limit that the phenomenology that characterizes the method of this book meets the ontology, aesthetics, and ethics that are its central issue. And this is the point about the limit. The limit or threshold is the dynamic reference, the force or meeting of forces where territory is contested, won, granted, and lost. Disciplinary methods are adequate to the relative stasis within a given territory. They describe a pattern of behavior but do not account for its generation. It is not only a rhetorical maneuver but also an ethical commitment to search for the ordinary by way of the extraordinary, to heed the limit case as the inscrutable source of the forces that shape sound. It is precisely where measurement fails, where standard explanations fall apart that we must discover the dynamic forces that give rise to those standards.

The emphasis on the dynamic limit already alters the founding question of music studies. The question is not *What is music?* but, rather, *What is musical? What is music?* has been particularly popular throughout the past century, as all the arts called their own statuses, ontological, aesthetic, and epistemological, into question. Though productive in its progress, the ultimate result of this intense questioning has been to void the question itself of most of its force. That is, it now appears arbitrary to draw a line between music and some other kind of sound, and to define the activity of music is to shed little light on its nature. As such, *the musical* is a more worthy quest, for it refers not to the territory of music but to the *limit* at which sound becomes musical. The notion of the musical invokes not only the ontological question of whether or not something is music but also the aesthetic question of music's quality or value. The musical is the limit that makes music music, but it also makes some music better than other music. The musical is what we listen for in music, what we attempt to engender in music, what we long to hear, what is satisfying about music. Moreover, the notion of the musical need not confine itself to music but may well be tied to other arts and other subjects and activities.

Of particular interest is the intersection of musicality and technology. *What happens when the digital meets the musical?* This question is motivated not only by the prevalence of digital technologies in all aspects of the experience of music during the past twenty years but also by a more general concern about the role of the digital in human existence at the outset of the twenty-first century. Computers are everywhere, occupying an increasing percentage of our time, our visual field, and our aural experience. Microchips are even more widespread, and the digital is becoming the default mode of operating on the world in countless areas of endeavor. This book begins with a deep suspicion about the effects of digital technology, a suspicion that computers and other digital devices have an influence that has not yet been apprehended and articulated. In addition to a thorough investigation of the effects of digital technologies on music reception and production, half of one chapter is devoted specifically to the question of the digital in general, its repercussions and limitations.

In addition, the digital is a pervasive concern of this text partly because of its intriguing relationship to the limit. On the one hand, the digital is all limit, defining its edges as clearly as possible, and defining itself exclusively in terms of those hard edges. A 0 or 1 is nothing but a threshold, a limit that divides it from its opposite number. The digital operates effectively on a smooth, consistent territory, to which it can apply its metrics or measures regularly and without interference. On the other hand, the digital deals only poorly with the ambiguity of the limit. For the limit is dynamic, and so resists digital territorialization, refusing to conform to the binary logic that is the sole tool of the digital. The digital is particularly ill-equipped to deal with the limit case, the ambiguity of the border, because its own borders have no ambiguity: *on* or *off* but not in-between.

Already this book demonstrates its resolute multidisciplinarity. No single disciplinary approach is finally chosen, and the book remains a gathering of ideas, neither comprehensive nor wholly consistent. There are undoubtedly omissions and digressions. Nevertheless, there are a number of persistent themes, questions that direct the investigation. Musicality and its relationship to digital technologies are two such themes. Another theme is time, which, it has been said, is the stuff of which music is made; any search for meaning in music cannot but address its ways of incorporating history and of pointing ahead of itself, toward the *not yet.* A multidisciplinary approach to music must also confront the divisions of high culture, mass culture, and marginal culture, as each of these has a unique relationship to music that calls the others into question. Sometimes this book strays widely from these themes, but they return persistently as a motivating force in each chapter.

Chapter 1 investigates how sound becomes sensible—which is to say, how sound makes sense, *and* how it is sensed. This chapter proceeds by a kind of case study, and the case under study is the experience of listening to recorded music. By examining different recording media, comparing CDs to LPs, noise is revealed to play a crucial role in bringing sound to sense.

Chapter 2 examines the way in which music takes time. How does music incorporate a history? How is it materially distributed in time? This chapter refers the most explicitly to musical examples, considering the way in which avant-garde composers of the past century have manipulated time in music.

Chapter 3, the most directly engaged with technology, proceeds in two parts. The first part, “The Question Concerning the Digital,” looks at the nature of the digital in general: what are its threats, what are its limits, how does it work? The second part, “Instrument and Articulation,” calls the first into question by examining certain applications of digital sound processing to find out how the digital is able in these cases to rise to a creative engagement despite the limitations discussed in the first part of the chapter. How do these digital processes escape the inability of the digital to generate the novel?

Chapter 4 looks at making music, with especial regard to the musical instrument. How do musicians relate to their instruments? What does the instrument contribute to the music? How do musicians make music? The discussion of the limitations of digital technology is prolonged in this chapter as the computer is compared to the musical instrument in the hopes of finding ways to make it more creative.

These chapters do not form a progressive argument but rather a series of movements, internally coherent parts that belong together by virtue of their differences as much as their similarities. They are tied to each other by recurring concepts, persistent themes, a phenomenological method, and the book binding. They differ in many regards, but the overarching division of chapters derives from the subject position considered in each case. The first chapter examines the experience of the listener. The second chapter follows the composer. The third looks over the engineer’s shoulder. And the fourth chapter observes the musician at work. These perspectives do not add up to a comprehensive treatment of the meaning of music, and I hope that readers will find the ideas and methods here useful in articulating some other relationships to music that are here elided by the particular focuses of this work. Aurality, too long regarded as unassailable, is beginning to find its place in theoretical discourse, with significant consequences for technological development and artistic production. Walking an ill-defined and discontinuous line at the edges of many disciplines, this book sets out somewhat blindly, calling to peers it cannot yet see, hoping to join this growing body of work that takes sound seriously.

This page intentionally left blank

Acknowledgments

I ACKNOWLEDGE the generous contributions of many people, friends, family, and colleagues. Some of those whose influence has been most explicit are named here.

Daniel Itzkovitz, for his edits, his insight, and his warmth.

Sally Ackerman, for taking care of me and pretty much everything else.

Felix Ackerman and Jules Evens, for being Felix Ackerman and Jules Evens.

All the attendees of the 2001–2002 Pembroke Seminar at Brown University, especially Elizabeth Weed and Mary Ann Doane, for creating the most stimulating and enjoyable institutional setting I have known.

Timothy Murphy, whom I have never met but whose close and critical reading was invaluable in preparing this book.

Brian Massumi, for helping so many times and when no one else would.

And an honorable mention to Mathematica, used to create most of the illustrations in this book—and the smartest computer program ever.

O N E

Sound and Noise

Perfect Sound Forever

—Sony advertising slogan at the introduction of the compact disc

Hearing Contractions

WHAT IS HEARING? To hear is to experience air pressure changing. Waves of pressure propagate from the sound source, causing over time a fluctuation of the air pressure in the surrounding space, pressure rising and falling at each point, now higher, now lower, more compressed, then more rarefied. The wave of pressure travels through the air, into the outer ear, causing the eardrum to fluctuate in step with the air. For a sound to be hearable by human ears, its fluctuation must be relatively rapid: at least fifteen times per second the pressure must rise and fall. The rate of fluctuation is heard as the pitch of the sound: more rapid fluctuation sounds like a higher pitch,[1] slower fluctuation sounds lower. One does not hear air pressure, but one hears it change over time. This point deserves reemphasis: to hear a pitch that does not change is to hear as constant something that is nothing but change, up-and-down motion. To hear is to hear difference.

What hearing contributes to sound, therefore, is a contraction. Hearing takes a series of compressions and rarefactions and contracts them, hears them

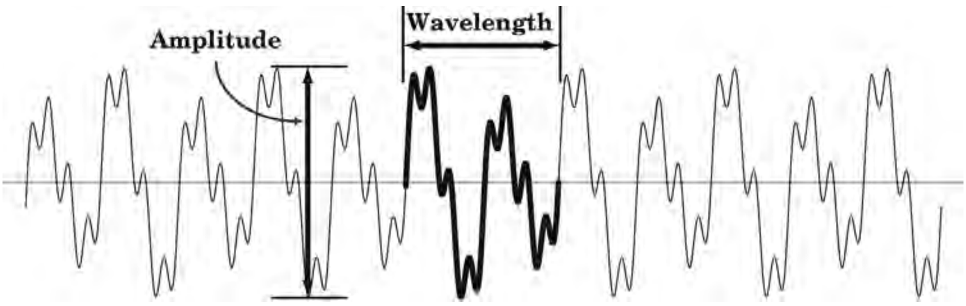

Figure 1. A sound wave. This graph should be understood as a graph of air pressure over time. The *amplitude* of the wave is the difference between the highest and lowest air pressure values. The *wavelength* is the repeating unit, indicated by bold strokes. Five complete wavelengths are depicted here, plus partial wavelengths at the start and end. If this image represented a total duration of one one-hundredth of a second (0.01 seconds), then its frequency would be about five hundred Hertz (500 Hz), a pitch right around the middle of the piano keyboard.

as a single quality, a sound. Or, rather, hearing contracts this wave of compression and rarefaction into a number of qualities that together determine a singular sound. As was noted, pitch corresponds to the rate *(frequency)* at which the wave fluctuates. But pitch is by no means the only characteristic of a sound. A sound's loudness corresponds to the *amplitude* of the pressure wave:[2] a larger change in pressure (measured from the maximum pressure of compression to the minimum pressure of rarefaction) results in a louder sound. Again, difference is perceived as constancy; a difference in pressure is contracted into loudness.

Nor do the contractions stop there. Sound is not born in hearing of only frequency and amplitude. A piano, a violin, and a soprano can each produce a sound of the same pitch and volume, but these three sounds do not sound the same. They differ in their overall character, the aspect of sound called *timbre.* Timbre is a fairly complex concept to analyze. As a first approximation, it can be understood as the shape of the sound wave. The most basic wave shape is a *sinusoid* (referring to any wave shaped like a sine wave), but there are infinitely many other ways to get from peak to valley and back again. (Consider Figure 2.)

Consider a sound wave represented (typically) as a graph of pressure (the *y*-axis) over time (the *x*-axis). The frequency of the wave is a matter of how frequently it repeats, which can be estimated by observing how often it crosses the *x*-axis. The amplitude is a matter of the vertical distance from the peaks to the valleys. Keeping these factors constant, one can imagine any number of different waves

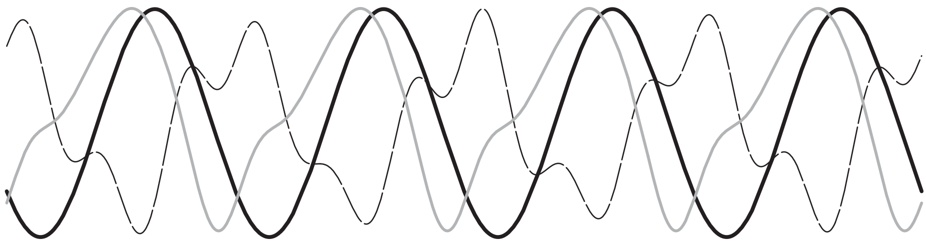

Figure 2. Three sound waves. The thick, solid wave is a sine wave. The other two waves have the same amplitude and wavelength (hence also the same frequency) but different shapes.

that would have the same frequency and amplitude but would trace completely different shapes.

Given the vagueness of the notion of shape, one might guess that timbre would be difficult to deal with precisely. The mathematician Jean Baptiste Joseph Fourier provided a solution to this difficulty, a solution applicable not only to sounds but to any signal that behaves like a wave.[3] The Fourier theorem outlines an operation, called the *Fourier transform*, that takes a wave of any shape and describes it as the sum of a number of sine waves of different frequencies. A sine wave is the simplest regularity: simple harmonic motion, the pattern of motion of an ideal spring bouncing up and down, or a pendulum swinging back and forth, or the vibration of a perfectly crafted tuning fork. A Fourier analysis of each of the sound waves (of the same pitch and volume) from the piano, violin, and soprano would show that they each have, as a most significant component, the same basic sine wave as their *fundamental* frequency. But, the additional sine waves that must be added to that fundamental sine wave to create the timbre of a violin are different from the sine waves that must be added to create the timbre of a soprano or a piano.

The ingenious Fourier transform takes a signal that might appear utterly chaotic and reveals the regularities within it, breaking it down into a bunch of simple, regular signals. Moreover, the Fourier transform shows that every signal is equivalent to the sum of these very simple regular signals (sine waves); sound is repetition at every turn. Given a signal described as amplitude values over time, the Fourier transform describes this same signal over frequency; that is, it specifies the relative amplitudes of sine waves of various frequencies that would have to be added together to generate the original signal. The significance of this conclusion for acoustics cannot be overstated. Every sound has regularity and is nothing but regularity. Every sound can be decomposed into sine waves and can be regenerated by adding

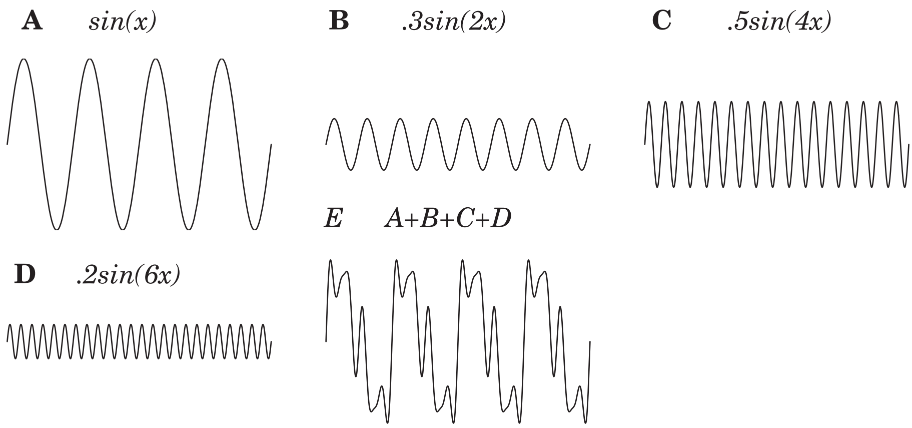

Figure 3. Adding sinusoids. Each of the waves *A*, *B*, *C*, and *D* is a sinusoid. *B* has a lower amplitude than *A* and is double the frequency. *D* has a frequency six times faster than *A*. The sum of all four is a nonsinusoidal wave with a more complex timbre.

together sine waves in the right proportions.[4] This makes possible a mathematically precise account of the shape of a wave and so also offers a rigorous definition of timbre: the timbre of a sound wave is a matter of the relative proportions of sine waves of different frequencies that must be combined to generate that wave. The timbre of a sound is constituted by the regularities that define it.

An individual sine wave has a minimal timbre. Its Fourier transform would reveal that it has only one component, only one sine wave that contributes to it, namely, itself. The sound of a sine wave is thin, without texture, a pure tone with no body behind it. (It sounds vaguely bell-like, but, lacking the harmonics of a bell, it has an unworldly thinness. Pure sine waves are unlikely to occur in nature, so we encounter them primarily in the context of electronic technologies.) In a sine wave, hearing contracts frequency and amplitude into pitch and loudness. In sounds of a more complex timbre, hearing does more contracting. It hears as one sound what Fourier describes as a set of sine waves; it contracts this set of waves into a singular sound of distinctive character, rich texture. Heard, timbre is the contraction of many regularities into a single complex variation, a singular quality.

To summarize this lesson in psychoacoustics: a perceptive body experiences variations in pressure and contracts this wave into sound. The wave, a variation in pressure over time, has discrete characteristics, including frequency, amplitude, and shape (timbre).[5] Each of these is a motion, a change over time. But, in perception, the wave is contracted, and the corresponding characteristics of the sound are a-durational, independent of time. This is not to say that hearing happens instantaneously but that change is perceived as constancy. Pitch, loudness, location, and timbre, though associated with an enduring sound, are in themselves independent of this endurance.[6] Time is contracted into the quality, the character of the perceived sound. One does not hear the motion of an up-and-down but a singular quality of a note, high or low, soft or loud, string, percussion, or woodwind.

To avoid one possible confusion, consider the notion of frequency. If a wave has a complex timbre, with many different sine waves of different frequencies contributing to its sound, then what is *the* frequency of that wave? Generally speaking, a wave only has a determinate frequency when one of its component sine waves has a large enough amplitude to dominate the others. Put otherwise, if a wave, represented by a graph, is made of one (possibly complex) element that repeats, then the wave's frequency is just the frequency of the repetition. If there is no single repeating element that constitutes the wave, then the wave has no definite frequency. Percussion instruments, such as cymbals, do not usually produce a specific frequency but combine many frequencies at once, some quickly fading out while others become briefly prominent. The graph of a sound wave produced by a struck cymbal is very chaotic and complex; the only aspect of it readable to the eye is that it starts loud and eventually gets softer. (Bowed cymbals, on the contrary, tend to produce a singing bell-like tone with a clear pitch.) Notes sounded on pitched instruments generally have a specific frequency, a dominant sinusoid component with a frequency corresponding to the pitch of the note.

A further source of potential confusion in this account of acoustics is the overlap among the various technical properties of a wave. In one sense, a wave has only one property (dependent variable), its amplitude: one value, changing over time, describes the entire wave. Sound at a given point in space is nothing but the changing amplitude of the air pressure at that point. (Used in this sense, *amplitude* refers to the instantaneous measurement of air pressure rather than to the difference between the extremes of air pressure.) Frequency is then a secondary property: the rate at which the amplitude changes.

One might rather understand a sound wave to be nothing but timbre. For to describe the shape of the wave is just to describe the wave, to describe it in the totality of its detail. As a reference to shape, timbre captures not only the gross features of the wave, its overall curve, but also every tiny variation, every little blip, every notch or bump in the motion of the air. What physics represents as the sum of sine waves is heard as the character of a sound in all of its specificity, the middle C of a Steinway and not a Bösendorfer, the bowing technique of Yo-Yo Ma and no other. The "sound" of a sound is its timbre, which contracts its multilayered complexity

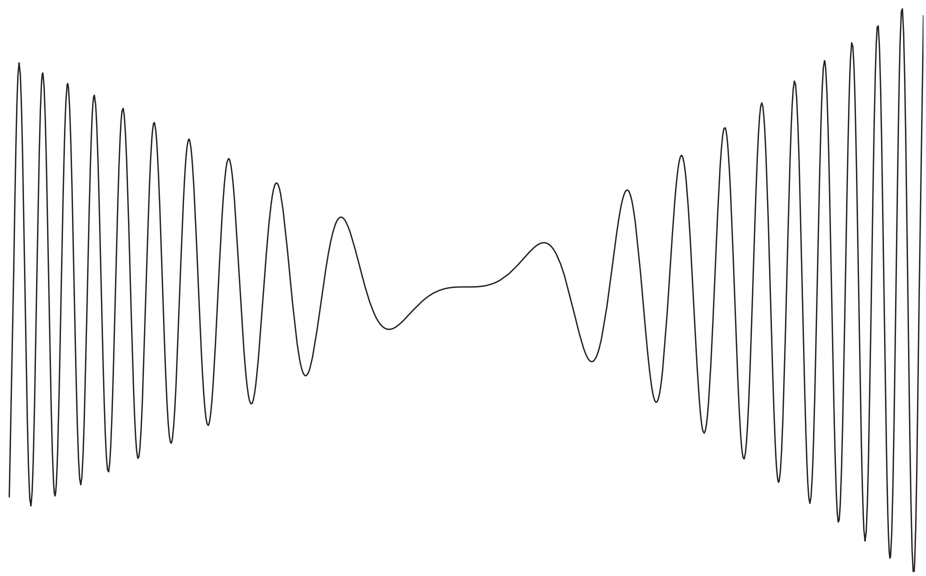

Figure 4. No definite frequency. This wave has no single repeating element and so has no specific frequency. It starts louder and higher in pitch, then gets softer and lower, then louder and higher again.

into a distinctive quality; tones added together, tones subtracted or shifted in place, bursts of tone, slow undulations of tone, but always the sum of sinusoids. It is both a matter of the regular and the irregular, for what makes timbre rich is the complexity of its regularity, which fades at its edges into the chaos of the irregular. All of the richness, the distinctive quality of a sound is a matter of timbre, which contracts the complex layers of tone upon tone and the variation of this layering over time, from the clarity and strength of the fundamental frequency that determines the pitch of the note, to the infinite subtlety of the random fluctuations of the air that sound different in every room and at each event. An open E-string bowed on a violin excites at once the string, the body of the violin, the other strings, the body of the violinist, the air around the violin, the material of the room, and the bodies of the listeners. When one wave meets another, they add together, reinforcing each other when they are in phase and canceling each other when they are out of phase.[7] Thus, every sound interacts with all the vibrations already present in the surrounding space; the sound, the total timbre of an instrument is never just that instrument, but that instrument in concert with all the other vibrations in the room, other instruments, the creaking of chairs, even the constant, barely perceptible motion of the air. Measured at some point in space, all of this vibration adds up to a continuous variation in pressure, a wave. Complex, irregular, and erratic, this wave changes constantly and incorporates many frequencies and shifting amplitudes, though the dominant fundamental frequency may dwarf the other components of the wave. The timbre of the sound includes not only the many other components issuing from the violin but all of the incidental vibration that already animates the space, waiting to be modulated to the point of audibility by a suitable sound.

Fidelity

Timbre therefore fades into a background, at its subtlest limit becoming indistinguishable from all the vibrations ongoing in the surrounding space. As long as the instrument is actually operating in that space, there is no criterion that would differentiate sharply between the sound of the music and the other vibrations in the room. Once the sound is recorded, however, and no longer produced live in an actual space, there is a de facto standard that allows such a sharp distinction: the music is whatever is actually on the recording, and all other sounds are inherently undesirable. Or, at least, this is the implicit standard maintained by that group of (mostly) wealthy, (mostly) white, (mostly) men called *audiophiles.* The audiophile trains his ears to sort out the "true" sound of the violin from the artifacts introduced by the recording and playback process. Audiophiles are the self-appointed guardians of *fidelity.*

The Absolute Sound—a disturbing name, indeed—makes it doctrinal: the sole criterion for judging recorded music is the extent to which it sounds like live music. Fidelity is the single standard for evaluating recordings and the equipment used to play them. "The only correct goal of high fidelity sound reproduction, in our estimation, is a perfect re-creation of the musical experience."[8] *The* musical experience. Which experience is *the* musical experience? According to *The Absolute Sound*, you had to be there. A concert of live, unamplified music provides a reference for what music should sound like. Paradoxically, this standard is effectively inapplicable; one almost never has the opportunity to compare a recording to the live performance that it purports to document. So, the standard is generalized: by attending (to) concerts of live music, one learns what live music sounds like *in general*, and this is the standard against which to compare recordings. Clearly, this standard privileges a particular kind of music, namely, unamplified acoustic music. And, although most "world music" is unamplified and acoustic, its contribution to the standard of fidelity is minimal compared with the institutionalized standard of the European art music tradition. Schematically speaking, according to the audiophile community, every good recording should sound like Beethoven played live: fidelity = *Fidelio.*

None of this should come as any great surprise. The same wealthy European men who buy expensive audio equipment are the same wealthy European men who uphold the high art standards that place so-called classical music at the top of the musical art pyramid. Though these distinctions are undoubtedly established and maintained by power (and/as money), we do not wish to claim that either of these hierarchies is *merely* the effect of a power that seeks to enforce otherwise arbitrary distinctions for the purpose of domination. Like it or not, Beethoven is fantastic music; and, whether it matters or not, really good speakers sound way better than crappy ones. At issue is not whether the hierarchies have any merit but which other worthy experiences are excluded as a result of these hierarchies. What kinds of music might be taken seriously in the academy were it not for the stranglehold of European art music? How might the practice of music be different, were it not so desperate to achieve the status of high art? (Even popular music, at a significant remove from high art elitism, retains the form of high art: music created by gifted individuals for the pleasure of passive observers.)

Audiophile: one who loves sound. Apparently, however, not all sound is equally lovable. The audiophile's chief goal is to eliminate noise from the listening environment. Noise in this case is anything that interferes with the signal, impairs fidelity. In principle, the aura is there in the recording, but its subtlety ensures that it will not be heard until noise is reduced to a bare minimum.[9] The strict distinction between noise and music, between the accidental and the intentional, between distraction and absorption, lies at the heart of audiophile culture. The zealous audiophile devotes a room to his obsession, sonically isolating himself if possible from the distractions of the rest of the home and family. The head and ears generally need to stay still, having been properly aligned in relation to the speakers and the rest of the room through hours of trial and error. Electricity powering the system must be filtered to cleanse it of impurities, cables carrying the signal must be draped just so, lights on the front panels of the stereo components are dimmed or covered. The work of art to be appreciated deserves an utter concentration, a total focus, in music as in the other arts. If the audiophile attends too much to the technology, this is because, unlike the other arts, the piece of music only becomes an artwork in the age of technology.

Prior to the existence of sound recording and playback technology, music could only be a social art form, tied to its time and place of production, embedded in a particular social space and, despite the economy of the score, unrepresentable as a work.[10] Recording technologies changed all that. Suddenly it became possible to isolate and control the musical work of art, to identify something as a work, and to re-present it to oneself under conditions of one's choosing. The piece of music could be placed on a pedestal (the Victrola as inverted pedestal?) and set before the listener, subject to his persistent gaze. In this context, the musical work takes on an objectivity that was formerly the exclusive province of the material arts and is still lacking (though this may not be a bad thing) from dance and theater. Indebted to technology for offering him music as art, the audiophile comes to love not so much sound but gear in the service of sound.

Aside from technophilia, what does it accomplish to isolate the work of music as art? In its original social contexts, music drew its meaning from its surroundings, connecting to the lives of listeners and connecting them to the time and place of the music's production. Once isolated, the music neutralizes its context, removing itself from lived experience, to stand before the listening subject as an object. The subject-object pair, listener and recording, form a closed system with an inside (the listening room) and an outside (everywhere else). Whatever meaning accrues to the music does so not by virtue of immanent connections among listener, music, and world but by a set of analogies, wherein features of the internal system are compared to features of the outside. That is, music as art object is given meaning through interpretation rather than via an immediate effect in the world. Recorded music is sterilized, frozen in place, turned into a medium that stands between self and world instead of an experience of the world. Isolated on a museum wall or on an audiophile turntable, the artwork reflects only its audience.

There is thus a contradiction in the audiophile standard that cannot be reconciled. For the experience of live music is fundamentally unlike the experience of recorded music. Live music is lived music, so that its meaning or experience is intimately tied to its context. Live music is inherently timbral and cannot strictly be distinguished from all the vibration of the room, the murmur of the audience moving and breathing, all the accumulated noise of the moment. Recorded music has no context of its own and does not fade smoothly at its edges into the surrounding atmosphere. Instead, it cleaves itself from its surroundings, distinguishing sharply the signal it wholly and completely contains from the noise that threatens it with interference and interruption from without. Self-contained and unconnected, the recording consigns music to a controlled environment where the distractions of reality can be regulated so as to minimize their potentially deleterious effects on the listener, who alone decides what the music means and how.

Recorded music versus live music; art versus life; signal versus noise; high art versus popular forms; isolation versus context. Add to this list at least one more binary: original versus copy. For the audiophile, the recording is always an approach to an ideal, a copy that strives to mimic the original, an attempt to revisit that mythical moment when the performance was present. There is no comparison between live music and recorded music. Or, rather, the latter is definitely the copy and deficient as such. And this returns us to the question of fidelity.

"The philosophic assumption in the listening sessions is that components, ideally, should duplicate exactly the signals they are fed."[11] It seems to be an innocuous ideal that stereo components should accurately reproduce the signals sent to them. Of course, as stated, it is strictly nonsensical. If a stereo component (like an amplifier, turntable, or speaker) were to duplicate exactly the signal it is fed, then its output would be identical to its input. Which is to say, it wouldn't do anything. Every component alters the signal somehow: amplifiers amplify the signal; turntables and speakers transduce the signal, changing its form; preamplifiers route and attenuate the signal; cables take a signal in one place and transport it to another. The ear, and its associated person, are undoubtedly the components with the most dramatic effects, doing all sorts of things to the signal, grouped under the heading, *hearing*. So we must amend Harry Pearson's statement to include the recognition that each stage of the playback chain must do its job without *otherwise* altering the signal. Challenged to capture and reproduce extremely subtle and complex waves, and lacking any other standard with which to judge fidelity, engineers appeal to this ambiguous material standard: good sound is a question of accuracy, so the recording and playback equipment should re-create the pressure wave as felt at some typical spot in the recording space, be it a concert hall or a recording studio. No gap exists between the wave and the sound; perception drops out of the picture. The listener is a placeholder, an any-body, and the place that the body holds is defined by the physics of acoustics. Thus, fidelity in the reproduction of recorded music, and implicitly also the best sound, is achieved by the accurate recreation of the same pattern of sound waves at the listener's body (especially the ears) as would have occurred at the body of a listener who was present at the recording.[12]

Audiophiles believe themselves to be pursuing the "best" sound by aiming for the most accurate reproduction of pressure waves. Fidelity, as a standard, is unquestioned, along with the epistemology of hearing. So, they are puzzled and disturbed by an evident lack of correspondence between high fidelity and musical involvement. Car stereos and transistor radios are notorious for providing that rare transcendent music listening experience.[13] And *lo-fi* is not only the current buzz (!) in popular music production, but has been an integral part of the rock aesthetic. What might these lo-fi listening experiences provide that higher fidelity does not? Audiophiles unknowingly undermine fidelity by attacking the objectivism that buoys it and insisting that human ears are the only acceptable judges of the best sound reproduction.[14] Perhaps the contractions involved in perception exceed the capabilities of the mechanical. After all, music is a human practice, even if it incorporates the nonhuman, the incorporeal, the technical. To the extent that something moves in music, something that makes it more than a measurable aggregation of continuous sounds, but brings it together, relates it to its outside, to that extent, music is *expressive.* It is the expression in sound which cannot be measured, the expressive dimension which operates in conjunction with a person, a listener who also brings something to the sound. Where sound involves percepts and affects, where it presents a world, a world one could be in, there can only a person go.[15]

Analog and Digital

The audiophile debate about the superiority of analog versus digital media, specifically, the LP versus the CD, focuses attention on the question of expression in the reproduction of sound. At the introduction of the CD in the mid-eighties, critical listeners had to learn to hear new kinds of problems in music reproduction since digital's shortcomings differed from the pops, hisses, and other usual distortions associated with analog media. The industry had to work "toward a vocabulary that will help us 'hear' [digital] distortions with greater celerity."[16] Initially, many of the criticisms of the "sound of digital" are inspired by a certain popular image of technology generally and by the specific process of digital sampling. Digital sound, especially digitally reproduced music, is said to sound sterile, dry, or cold. It is claimed that CDs, by reducing music to a bunch of numbers, fail to capture its spirit, its feeling, its emotion. According to Neil Young, "There's no challenge, there's no possibilities, there's no imagination. You're hearing a simulated music."[17] To others, thinking perhaps of the process of sampling, digital sounds choppy, broken up, thin, or lacking detail. LPs are, by contrast, warm, full, rich, and expressive. Two decades of engineering have overcome many of the problems that plagued early CD recording and playback, but the primary complaint among digital's detractors remains that CDs lack a certain pace, cohesion, integrity, musicality, wholeness. Though the right notes are all there in the right places, the music does not move and so does not gather up the listener into its motion. In short, digital reproduction is accused of failing to express. Though these criticisms belie a misapprehension of digital sampling theory, they nevertheless register a genuine dissatisfaction with CD recordings. How does digital recording work, and where might it fail to reproduce the expressive elements of sound?

An analog recording records an analog of the original sound. A sound wave described by continuous variations of pressure over time is spread out in space onto a recording medium. Time is transformed into space and pressure variation is transformed into the variation of a specific property of the recording medium. The wave may be etched into the grooves of a vinyl record or coated onto the surface of magnetic tape by varying the magnetic properties of the tape over its length in a pattern geometrically analogous to the original wave. In both cases, the recording must be played back—its variations allowed to modulate a loudspeaker thus producing an air pressure wave—to translate the variation in space on the recording medium back into a variation (of air pressure) over time.

Digital recording works by sampling, taking a measurement of the air pressure at regular intervals, and storing those measurements as numbers. It is like a movie camera, which opens and closes its shutter to take a series of snapshots. The snapshots, as they pass rapidly before our eyes, simulate the motion of the original scene. Likewise, the series of numbers that represent pressure measurements is used to recreate a wave of varying air pressure, which simulates the original sound. A single sample is a (binary) number that acts as an instruction to a volt-producing machine. Successive samples trigger a wave of voltages, which is amplified and sent to a loudspeaker whose driver moves in concert with the voltage variation, thus producing an approximation of the original wave. (Since the volt-producing machine must ramp up or down from one voltage value to the next, the signal is changed at that point from digital to analog, from discrete values to a continuous wave.) Because sampling takes place at a regular interval, it is possible for some pressure variations to escape recording altogether: whatever variation occurs in the time between two samples will be missed. Higher sampling frequencies allow the sampler to capture shorter-term acoustic events; and as the length of an acoustic event is effectively a matter of its frequency, this means that faster samplers can record higher pitches.

Besides sampling frequency, the other primary factor that contributes to the theoretical accuracy of digital sampling is resolution. *Resolution* refers to the number of possible values that any one sample may have, or how fine a distinction can be made between adjacent pressure levels. A higher resolution means finer distinctions between values but also more information to store. CDs have a sixteen-bit resolution, so each sample can have one of 2^{16} or 65,536 values. When long-distance telephone signals are converted to digital (for example, to send them over a fiber-optic cable), they are converted using only about eight bits of resolution, or 256 possible values. Increasing the resolution of a system allows that system to capture more subtle variations, greater nuance. Just as the sampling frequency limits the recordable range of frequencies, so the sampling resolution limits the recordable range of nuance. Complex real-world sounds almost always have components above the cut-off frequency of the CD (about 20 kHz[18]) and below the noise floor or maximum resolution of the CD. Sound varies faster and more subtly than CDs can capture. So why do we continue to have any faith that CDs store sounds the way we hear them? Engineers take solace in the conjunction of the Fourier theorem and psychoacoustics. Since every sound is made of a bunch of sine waves, it is supposed that those components (sine waves) in any sound with a frequency higher than the threshold of human hearing can be discarded or ignored in the recording and reproduction process without affecting our overall perception of the sound. Thus, though a wave may have a great many variations at high frequencies, these upper frequencies are chopped off without being recorded. In theory, this will not alter the way we hear the sound, as long as the missing frequencies are outside the range of human hearing, which is up to about 20 kHz. (High-frequency hearing range was the main criterion for determining the CD sampling frequency.) If a sampler captures all the parts of a sound up to 20 kHz, it is supposed that it captures all the parts of that sound that we hear. Moreover, clinical tests show that the resolution of most people's hearing is no better than the resolution of a CD. Even though the variations in air pressure are more subtle than what CDs can capture, we cannot hear them, so they need not be recorded.

Critics of the CD have argued that both the sampling frequency and resolution of that format are inadequate.[19] There is, in fact, some evidence that frequencies above 20 kHz affect human hearing, as our brains register activity under high-frequency stimuli, even if we are not consciously aware that we are hearing something.[20] And audiophiles and other critical listeners have long contended that finer-than-CD resolution is audible as a smoothness or liquidity of the sound, even if it is undetectable under objective testing circumstances. There is still another technical complication of the CD, which, unlike those so far discussed, relates not to the principle of the recording/playback of digital sound but to the pragmatics. Machines for recording and playback of digital signals rely on very precise timing mechanisms. The "shutter" that opens and closes to take a sample of sound pressure or reproduce that sample must do so at exact regular intervals, for the dots (samples) that represent the waveform must be played back in their exact correct places. To shift a sample slightly too early or late is tantamount to adding a low-level, high-frequency wave to the original waveform, a new frequency that was not in the original signal. The result of these timing errors is a kind of distortion called *jitter*, which is now blamed for most of the poor sound audiophiles have heard in CDs for the past ten years.

This analysis of the problems of the CD format only begins to suggest an explanation for the impaired expression that discriminating listeners hear in the CD. Undoubtedly, musical expression is a matter of some subtlety, as the difference between a great performer and a merely good one is not often primarily a question of technical proficiency, nor even of dynamics or pace, but rather a question of touch or feeling, vague and subtle notions that point to something one cannot quite put one's finger on but that make all the difference. Moreover, the singular sound of a particular violin in a particular performance hall on a particular day is distinguished not by some one analyzable component of the sound wave but only by the unique character of the entire sound, all the tones, all the variations of pressure, gross and fine. No doubt, we experience this singular sound not only in the consciousness of hearing but in the unconscious vibrations of our bodies, and expression is lived as much as recognized. Even the performer cannot assume conscious control over the fine details of the sound, but in the greatest performances, can almost stand back, letting her body, letting her instrument do the work, shaping the sound in its infinitely subtle variation, as she rejoices in the creation she feels lucky to be a part of.[21] The subtlety of expression will not show up when sound is dissected, since it is a coherence, a proper fit of the entire sound to its environment, to the audience, the room, the air, the other performers. Expression is the art of matching the notes to the room, of playing the audience as much as the score, of shaping the silent movement of air into sound.

An Ethics of Intensity

One of the most touted features of the CD was its increased signal-to-noise ratio, the nearly complete silence between notes that contrasted sharply with the crackles on the surface of an LP.

It is true that there is always a point at which the signal is masked by noise. Variations of a certain subtlety are so small as to be absorbed into the background of fluctuations of pressure, the constant movement of the air, the vibrations of the earth. What is this noise but cosmic vibration, the fused sum of all the vibrations to reach this point in time and space? Vibrations do not disappear, but dissipate, echoing all the while, for energy is conserved. Every vibration, every sound, hangs in the air, in the room, in bodies. Sounds spread out, they become less and less contracted, they fuse, but still they remain, their energy of vibration moving the air and the walls in the room, making a noise that still tickles the strings of a violin playing weeks later. Every sound masks an entire history of sound, a cacophony of silence. Even our bodies hum along with the noise of the universe. (At its most disparate limit, noise dissipates eventually into the tiny motions of individual molecules, which is to say, heat.)

In this complete history of sound, this cosmic echo that constitutes noise, sounds are not distinguished one from the next. Noise is the inarticulate, the confused mass of vibration, in which sound relaxes or dissipates. Perception contracts sound into sense, but noise is the uncontracted. Imperceptible, insensible, and sense-less, noise is the depth that gives to be contracted. Physicists have it backward when they characterize the formal relationship as one where noise modulates signal. Though it is often the case that signal overwhelms noise, it is noise that binds the signal, that serves as a medium, a baseline, a plane of relief against which signal stands out. The background of noise means that the air that a sound vibrates is not at rest to begin with, and silence is never total. Every string plucked, every throat cleared vibrates a vibration, modifies an existing difference without dampening or squelching it. Sound is a modulation of difference, a difference of difference. This eternal return of difference, noise, is what gives to be contracted but is not in itself contracted. The contractions of frequency into pitch, of pitch into timbre and harmony, and the further contractions of melody, duration, rhythm, meter, are unproblematic, analytic; none of them can yet give sense to sound. Noise is the uncontracted, the depth from which these contractions of perception are drawn, and, though sense-less and insensible, it makes sense or gives sense to sound by providing sound with its direction and by focusing it to a point of clarity. Noise is the reservoir of sense, the depth in which sounds connect to each other, the difference whose modulation is signal. Music and speech include many differences not only between notes, words, or sounds but within each sound, a wave of rising and falling pressure, whose difference gives sound its character. What rises and falls is already a field of difference, an entropy of difference, a noise that is the problematic substance of sound, the obscure reserve.

Noise gives sound to the contraction of perception, gives itself to sensation. To be perceived, noise must be contracted to a point of focus, a clarity that distinguishes itself from the obscurity of the background. This is still not enough, for focus and clarity alone cannot give sense to sound; sounds only have sense when what is heard includes not only what is heard clearly but includes also the implicated in what is heard. To hear meaningful sound—be it the articulate meaning of speech or the ineffable meaning of music—is to hear sound in motion, heading somewhere. This *somewhere* is implicated in the sound one hears, implicated without being explicit. Before frequency is contracted as pitch, and pitch as timbre, noise is contracted as the implicated of sound. Sound implicates what it does not make clear. Explication only goes so far, and the contraction that draws clarity from noise drags along with it a residue of obscurity, lines of relaxation that anchor every sound to the noise it modulates. Sound implicates these obscure tethers, which connect sound to noise, thereby giving sound its sense. The implicated difference inholds an obscure reserve of sense.

The obscurity is not a problem of epistemological limitation, as though the difference that is not explicated were veiled but still specific, as though noise contained sounds that were only too soft or too many. Only the explicated is specific, clear. Only the explicated can be distinct, set apart from its background and neighbors: a specific rhythm, a specific pitch, a specific volume. The implicated is obscure by its nature, it withdraws from scrutiny. It provides the sense of sound by being itself unhearable, the imperceptible of sound. The composer and the performer capture percept and affect in sound, implicating worlds of forces not yet unleashed but whose reserve powers the music, driving it along. Personal histories, impersonal events, an intake of breath, a bloody battle. An entire history of music insists implicated in every note, every phrase, every contraction. A sonic history in every utterance, whose most contracted, whose clarity is the specificity of the sound but not its sense. It is this contraction, the contraction of all sound, the contraction of all vibrations, which gives sense to sound, contracting clearly just *this* vibration, *this* sound wave, and letting the rest remain obscure, implicated in various degrees of relaxation. Implication pushes the music forward by contracting noise again and again to a new clarity each time, and sound gets its sense in this movement. The implicated also moves itself, for the obscure is contracted along with the clear. Implicated difference makes the music move, but it is also what moves in the music, the equicentral force of contraction.[22]

We must be careful to distinguish the relative and casual sense of noise from its absolute, productive sense. In its relative sense, noise is just another signal, albeit a confused one: too many contractions which cancel each other, a babbling of many sounds at once. It is in this sense that one claims to hear noise, as static that interferes with FM radio reception or the air conditioning fan that masks the soft passages in the concert hall. However, in its other, absolute sense, noise cannot be heard, it is the imperceptible, the uncontracted. Absolute noise, the very tendency to relax, to diffuse, is a different type altogether, not the same sort of thing as signal, nor as the relative noise that is a confused signal. It is a depth without dimension from which dimensions are drawn; noise is not a matter that gets formed but the matter of matter, not a vibration but the null space in which the vibration opens space. One can therefore hear only the effect of noise: one hears that there is sound one does not hear. But noise's effect is not primarily negative. One hears also a positive effect of noise: to give force to music, to provide the implicated reserve of sense. Or, perhaps one only *feels* this effect, as the movement of music, as the contraction that makes music more than a sequence of unconnected sounds and that draws together breath into words, phrases, meanings. The concert pianist draws on this noise, this background that she contracts in her playing, bringing certain frequencies, certain timbres, volumes, harmonies, melodies to the fore, while implicating the rest. To play music expressively is to demonstrate a sensitivity to this background, not only to read the audience, to hear the space around the instrument, but also to contract the silence between, beside, or behind notes and to draw from this silence the appropriate contraction, just the right sounds. An instrument is a tool for shaping noise, contracting parts of it into perception, and a performer is always a sculptor who works at once the contracted material and also the relaxed space around it. Noise is also perceived but only as implicated.

Perhaps it would be better to say that noise contracts itself, for agency is particularly problematic in music and speech. (See chapter 4 for an analysis of this problematic agency.) Credit must be shared among composer and performers, but each performer owes his productivity to the others, so only a multiple subject can really take credit.[23] Moreover, what of the audience, the instruments, the instructors, the influences? What about the conductor, the bandleader, a previous recording? In speech, the subject of enunciation is not just the same as the speaker, for enunciations are machinic, the noise machine contracting meaningful speech from an intensive depth, which involves speaker and listener as well as a context and culture. From the imperceptible depth of noise, contractions pull or stretch into a new dimension that does not preexist them, creating a space whose poles are signal and noise in a relative opposition. The contraction articulates at least twice, separating the signal from the noise in amplitude while articulating the signal in itself in the rise and fall of frequency and shape. These two articulations are distinct but interdependent, for it is only the molar variation in pressure, the up and down of a perceptible wave, that contracts this wave in itself and places it as foreground against the background of noise that retains within it the implicated. In this sense, the implicated remains as much in the signal as in the noise, as these are bound up in the same articulation. The implicated depth places both signal and noise in relief; it is the inarticulate matter in which they gather themselves. Thus, implication is both the force of contraction and is itself contracted in this contraction: the implicated comes into focus, or a part of it does, and this most focused aspect is a signal that rises out of the noise, which is only then heard in the background.

Still no agent of contraction has come forward. Who selects what of the implicated is contracted? It is only the repetition of the contraction, the implicated implicating itself who makes this selection. The whole of sound is contracted each time, as noise gathers the entire history of sound into each point. The contraction is always repeated, the implicated always implicates itself again, drawing its own skin inside of it, turning itself inside out to show a new face each time. It is this repetition, this reimplication that moves sound forward, pushing the music along, as though squeezing it from a tube. Contracted sound immediately relaxes again, falling back into the noise it rose out of and allowing other contractions to come to the fore. If sound is squeezed from a tube, then it is being squeezed back through its point of exit in a dimensional paradox, a Klein bottle, the unsatisfactory resolution of which is the paradoxical repetition that sets the implication in motion. The movement of the implicated is an involution, implicating itself again and again and leaving melody, harmony, direction, and sense in its wake. Sound is this contracted repetition which contracts the whole of sound differently each time, a seizure that writhes through the body of noise, turning it perpetually inside out like a salted slug.

What takes place in the movement from implication to explication? Which parts of sound are held back and which parts contracted? Vertically, we contract the relations among pitches as harmony, so we do not so much hear several notes but a chord. Horizontally, we contract harmony as progression; chords are not heard alone but as a motion, a progress. And this motion is not created by the chords but produces them as its force, expressing itself through harmony. Chords do not make a progression but are themselves created by a force that progresses in its headlong push. Noise is the reservoir of force that, in its repeated contractions, forces the flow of music through the musicians, the instruments, the audience. In the greatest performances, performers feel this flow when they *float*, when the sound sweeps through them, revealing that its sense, its movement, comes not from within the musician but from the unconscious implicated, the contraction of the noise of the room, the air, the bodies of the listeners. The performers are straits of contraction where the flow of force is narrowed, focused, to the point of perception. Though the contracted pitches, rhythms, harmonies, even progressions are themselves explicit—available to consciousness, written on the page of composition—their coherence, their sense, what makes them pass is not explicit in the music, but heard only as this coherence, the drive of the music, the force of expression.[24] We *hear* the implicated as the sense of the music, including its drive, its resolution, its tension, the ominous of a melody, the profound joy of a prolonged dissonance. Implication is what connects isolated elements to each other, in a creative synergy that produces more than it contracts: isolated pitches become timbre, isolated notes become chords, and isolated chords are perceived as movement, a harmonic progression. There is still a deeper instance, a greater contraction that gathers progression, harmony, rhythm, and timbre into the coherence of a piece. Creativity in music is always a matter of finding a force of movement, a new coherence, a world that produces or explicates an intensity, by drawing on its implicated. What of melody, itself a contraction that operates in a complex relation to the contractions of harmony and rhythm? What of dynamic variation, textural variation, stylistic variation that contract musicohistorical eras; Beethoven lurking in Hindemith, The Velvet Underground moves in Nirvana.

It must be emphasized that implication is not operating behind the scenes or after the fact but is heard in perception. The contractions of melody, harmony, and rhythm are not just abstract but are perceived: we hear chords, progressions, the motion of music. We do not construct this movement after the fact or infer it from elements of the music. The music would never move but would remain a mere sequence of sounds without a force that produces it as this movement. To hear a chord instead of isolated notes, to hear a progression instead of a bunch of chords is to hear the implicated. Moreover, the implicated is already heard at the outset; we do not hear a chord progression and then understand it, but we hear its progress already at its beginning.[25] Expressive music gathers whole worlds into a single measure and to hear a world in implication is to hear where the music is going. The feeling of tension before the resolution of a harmonic progression is neither an innate characteristic of human perception nor a learned response to patterns of Western music. The tension is real *in the music*, and not just in the listener, but it is implicated so that the same progression performed without the appropriate expression will fail to induce the same tension in the listener. To bring implication to consciousness is to anticipate in the music, but implication is not the same as anticipation. Although we do form expectations on the basis of what is implicated in the music, it is not primarily what is to come that we hear in implication, but what is already there. "The implications are inherent in the melody itself, by virtue of its structure; such implications may or may not be picked up by a listener and used to form expectancies on a given hearing."[26] We hear an expression, a coherence, or a force, and if these produce expectations, then note that these expectations can always be radically incorrect without denying the implicated as heard. As obscure, the implicated is not conscious or explicit. It is a force that pushes the music forward without specifying where it must go.

This is not to say that musical form is arbitrary and purely conventional, as though the implicated were indifferent to the explicated. Consider, for example, the great role harmonic relations play in Western music: they not only determine the tone or mood but also regulate the overall structure of many pieces. Melody also implicates what it does not make clear. A motif is a melodic line repeated, but differently each time; this development calls for further development, another repetition. It is as though the implicated motion of the melody were unfinished, its momentum not yet exhausted. Nowhere is it more true than in music that repetition is never a repetition of the same but always of the different. Theme and variations are the rule. Rhythm and timbre are rich with implication, each masking characters whose exposition is the motion of the music but is accomplished only in the change of timbre, the variation of rhythm. Even long sections of music, an entire movement perhaps, delimit what they implicate. Sonata form is based on these grand implications, which give rise to the expectations established and satisfied in the sonata.[27]

The notion of implication risks misunderstanding if it is thought in terms of expectation or other phenomena of consciousness. Though Meyer is quite correct that we already hear in the music what is not yet played, he construes this implication on the model of the clear and distinct. For Meyer, the implicated is just like the explicated—comprising all the specificity of melody, rhythm, and harmony—except that it exists only in the mind or expectations of the listener. On the contrary, the implicated is not contracted, or is not explicated in being contracted, and its vagueness or obscurity is not a matter of epistemological limitation. What is implicated is not an obscure version of the music yet to come, not a specific direction for the music to take, nor even a bunch of possible directions. Implication does not gather within it the specific vibrations that will be expressed as variations in air pressure. Rather, the implicated is obscure by its nature, incorporating not so much the clarity of sound waves as the singularity of events, historical events, musical events, masking within it affect apart from object and percept without subject. The implicated contracts noise, an entire history of sound, but the contracted events, percepts, and affects are still inarticulate, too relaxed to be clear. They are singular but not specific. Unlike expectation, implication does not specify the resolution, the harmonic progression, the melodic continuation, though it does establish the realm from which possibilities for these specifics can be drawn. In contracting noise to the point of clarity, implication brings close to the surface some of the depth of noise, powering the music while focusing the next contraction, the next repetition. If implication creates expectations, this is only so that the unexpected may also result.

When the relative clarity of a contraction rises out of the obscure implicated, the implicated changes its nature. The obscure is not just made clear, as though it had been clear in itself all along. Something must be lost for the obscure to become clear, and what is lost is the difference that the implicated holds within it and which gives force to the implicated. Implicated difference can only serve as the reservoir of sense while it is obscure; once it is crossed or canceled in the contraction it loses its potential. Explication crosses this difference by moving from one air pressure to another, from high to low and back, which exhausts the difference that forces the sound forward. Difference expends its potential when the implicated is mapped into this linear motion, a two-dimensional function of pressure over time.[28] Only an exhausted difference is clear, for a difference still held within cannot be circumscribed, it cannot be perceived as a whole but only obscurely, in bits and pieces, the whiff of a percept, the hint of an affect. Explication, which crosses or cancels difference in its movement, is the clarity of a pitch, the specificity of a meter, and the percepts and affects implicated in this clarity can never rise all the way to the surface.

The performer's challenge is to explicate just enough in order to implicate according to the demands of the music, as well as other demands of the audience, the room, the instrument. Performance requires a sensitivity to the whole situation, to the event of performance, to the entire history of sound implicated in noise in order to coax from this noise just the right contractions. The performer plays her instrument, she plays the music, but in so doing she also plays the noise. She uses her instrument to play the noise, shaping it, contracting it as demanded by the musical material but also by the noise itself. The implicative possibilities will always be specific to the venue, to the audience, to the event, and though performances of the same piece may elicit similar feelings, they never really implicate the same world, for each is singular. To explicate just enough means to leave just enough implicated, to draw the implicated to the verge of clarity, while letting it also extend back into the noise from which it is contracted. *Expression* is this ethics of implication, a question of finding the right balance, of explicating just enough, so as to tease the implicated depth into perception, to make the unhearable heard. "The ethics of intensive quantities has only two principles: affirm even the lowest, do not explicate oneself (too much)."[29] To affirm the lowest is to embrace the accidental, the fuzzy edges where timbre becomes noise, where music wraps itself around the world and the listener. Not to explicate too much is the maxim for the performer.

The traditional aesthetics of performance locates the performer's challenge in the need to respect the composition as written while playing it "with feeling." The musician must "modulate" the score. It is not enough to play the correct notes; a great performance molds something new out of the same old notes, choosing just the right passages of crescendo and diminuendo, ritardando and accelerando, legato and staccato, in order to implicate a different world, bringing as yet unheard percepts and affects to perception. Of course the subtleties of expression only really begin where the possibility of appropriate notation ends, so this musical terminology is too gross. Expression can only be expressed but never made entirely clear, for it is precisely a matter of the correct balance of clear and obscure. Where a performance explicates too much, it sounds wooden, sterile, robotic. (Computers, which are at present mostly incapable of implication, generally make poor music, and, though digital sound synthesis has made a significant mark on modern music production, the current rage in electronic music is the revival of analog synthesizers, with their quirky but "full" sound. Modern digital synthesizers routinely attempt to reproduce the "sound of analog."[30]) A performance that implicates too much allows the music to be overcome by the expression, so nothing becomes clear, and the audience hears only muddied implication, an obscure depth pierced by the murkiest light. Too much implication does not draw the implicated into perception but leaves the unhearable unheard, and so offers only confused percepts and inarticulate affects. Sometimes an overwhelming implication results in poor technical performance, and the clarity of the score is marred by mistakes. At its limit, the imbalance of implication brings the depths surging to the surface, but without exhausting their force of difference, so that musical performance manifests the raw power of implication, the implicated history of sound brought to action, and the music crosses a threshold where it joins other revolutions, leaving its unique form and matter behind. In this case, the musicians may destroy their instruments, or the stage, the hall, or even themselves, for the implicated difference is a madness, and bringing it to perception always risks a loss of control, in which the implication gathers up even the performer in its violent expression of difference. Finally, music becomes revolution, and the musicians play the world as their instrument, contracting not just sound but other matter into new configurations, violently shaping not just percepts and affects but also subjects and objects, bringing a world to life.

Given the subtle balance demanded by the ethics of implication, it is not surprising that the CD should lack some expressive potential. If noise contracted as implication is what holds a piece together, what gives it its force and pushes it forward, then the preservation of this noise is paramount in relaying expression. Or, at least, the right kind of noise must be recorded and played back, for expression demands that the noise and the sound suit each other. It is only the connection of the explicated to the implicated, the implication, repeating differently each time, that provides a thread throughout the piece, a structure that weaves together any dissonance, no matter how fragile. But the subtleties of noise extend even to those highest frequencies that the CD does not capture. Indeed, the CD is designed not to capture noise but to focus exclusively on signal, the explicated of sound, the clear and precise, so that the lowest resolution components of a signal, the noise that is modulated by the signal, are left out. Audiophiles should have embraced the CD, for it provides the most unequivocal standard for distinguishing signal from noise. If they largely rejected it, it is because, without knowing it themselves, they were already listening to noise, already appreciating the fuzzy boundaries preserved on the LP.

Further, the introduction of artifacts through jitter disrupts the underlying consistency of the noise, giving it a new character, *digital* noise, which may not be suited to the music. If the performers are playing the noise, if expression is a matter of a sensitivity to the implicated, then a failure to preserve the character of this noise will necessarily also be a failure to capture the expression of the music. The result would sound like a loss of coherence, a lack of pace, a feeling that the musicians were disconnected; the music would no longer push forward or would stop making sense. At its extreme, the loss of expression would sound sterile or cold. Implication—which the performer manipulates unconsciously, creating a sostenuto or a vibrato in response to or in concert with the sound in the hall on that day, choosing her contractions according to the ambient noise—this implication is specific to the event and is easily lost in any reproduction but especially in one that does not heed noise. The CD may accurately reproduce an E♭ or a D♯, but in a performance, the notes are not just E♭ but this particular E♭, which is contracted along with the implicated out of a depth whose singularity includes all the specificity of the hall, the audience, and even the stars. Musical expression is about capturing worlds, fitting together the intensive world of depth and the extended world of the performance, but the CD captures notes and durations while ignoring the implicated difference to which these contractions are still connected.

This is enough to debunk the whole myth of the absolute sound, for expressive music is never the same thing twice. One should not ask of a recording that it re-create the experience of live music but that it create new expressions, that it involve the listener in a new world. This is possible only through an accord with the listening context, a sensitivity to the environment including not just the space but also the listening event. Some recordings and some equipment may demonstrate this sensitivity better than others, and perhaps the "noise of analog" meshes better with much music than does the "noise of digital." But there will still be contexts for any recording when it just does not sound right. Expression is a delicate balance between implication and explication, a mixture of the clear and the obscure. If the absolute sound is a matter of repetition, the repetition of the musical event, then we should look not so much to fidelity, which is only ever an objective standard, but to the implicated, which repeats entire events in expression. One climbs a mountain listening to Beethoven in one's living room, one is drunk to the point of sickness with Nick Cave. Though there are no sore legs or nasty mess to clean up afterward, these events are real, if implicated. We *hear* them in the music, differently each time. The idea is to climb a new mountain, to find a new intoxication. The reproduction of sound is not a matter of physics but of affect and percept. Expression exceeds fidelity, so hold on to your LPs.

T W O

Sound and Time

Inflection and Innuendo

V

I do not know which to prefer,
The beauty of inflections
Or the beauty of innuendoes,
The blackbird whistling
Or just after.

WHAT WALLACE STEVENS MEANS is that sound is rhythm, "The blackbird whistling / Or just after." Sound is always thus articulated, punctuated, it starts and stops. He does not prefer one to the other, the blackbird whistling or just after, inflection or innuendo, because a sound does not go away when it stops, nor does it begin without dragging its genesis along. Innuendo persists in inflection, and inflection in innuendo. If innuendo—from *innuere*, to nod at—if innuendo nods at something, then this is precisely an inflection: attention, following the nod, is directed elsewhere, inflected or bent from its path to focus on something else. Of course, innuendo does not specify what that something else is; it leaves its object ambiguous, unheard, to be determined.

For its part, inflection seems to be all about sound. Though in music an inflection is usually a change in pitch, this definition must be expanded to include alterations of all sorts in a sound. Not just pitch, but timbre, rhythm, voicing, tempo are all inflections and must be inflected to compose, perform, or hear a piece of music. Inflection shapes words to express gender, number, mood, and tense, twisting their vowels, prefixes, suffixes, so that they point to the words and world around them. Even this broad definition is too restrictive, for every word is inflected by its context; else we would need a different word for every difference of meaning. Inflection makes language possible in speech. Meaning becomes sonorous only by virtue of the articulation of sound; and sound must be bent to invite the listener to share in its meaning. In her turn, the attentive listener must bend her hearing just so, in concert with the sound she hears. Every sentence, every sound is thus an instruction, a set of directions to follow as best we can. To understand is to follow these directions by striking the poses they suggest, to practice an aural tai chi in which one bends one's listening this way and that according to the inflections of the sound. We do not all follow directions the same way even if they are the same directions, and it may take a few different attempts, different ways of inflecting one's understanding, before the instructions become effective. The difficulty of understanding is linked to a fundamental ambiguity of inflection: inflection is never fully articulate, can never instruct conclusively, because in language as in sound generally, inflection inflects innuendo. You begin to speak without knowing exactly what you will say; you begin with innuendo and you inflect. Do you express an idea by anticipating its entirety in thought before articulating it in speech or writing? Do you speak a sentence only after first choosing each word? Before you utter a word, have you planned each phoneme, each motion of lips, tongue, lungs, jaw, cheeks, throat? No. Idea, sentence, and word all begin in innuendo, and to inflect that innuendo is to invent a sound that may surprise the speaker as much as the listener. At least one image of semiotics is thereby disrupted: the speaker does not reveal a prior private knowledge to the listener but articulates the sound between them. Listener and speaker share the innuendo to be inflected, and the difference between them is not a matter of an understanding already held by the speaker and lacking in the listener but a matter of attitude: the speaker inflects sound spoken, the listener inflects sound heard.[1]

Likewise, both composer and performer begin to write or play, at once knowing and not knowing what will come next. The composer hears a melody, a rhythm, a form before she writes it down, before she can even hum it. Paul Hindemith claims that the greatest composers know the entire piece in a flash of intuition; then it is just a matter of filling in the details almost by rote. Certainly, this intuition is not a complete and articulate piece, a conclusion foregone. Rather, it is the insight of knowing that one has an insight, the confidence that one need only begin composing, and the composition will spill itself onto the page.[2] What flashes in the composer's intuition is innuendo, a nod, and a perceptive and well-trained intuition can follow this nod to find there a whole piece. Going into each performance, the performer leaves some part of the music not yet fully determined, something must be left for the performance, a modal or gestural indeterminacy, a feeling that is familiar but must be actively recalled each time, re-created to suit the occasion. The performer must follow an innuendo, which inheres in the piece of music, but also in the audience, the other performers, the atmosphere in the concert hall.

> You have to react to the conditions of performance—the actual circumstances. You play differently in a different hall. The acoustics make a difference. The instrument makes a tremendous difference. You may be feeling more—I don't know—you may be feeling more worked up on this occasion—you feel something brighter is needed. You go into the music in a kind of unbuttoned way, and if you play something which doesn't fit absolutely perfectly, well, it doesn't matter too much. You've really got to be on your toes, to be alert to do something which occurs to you which may seem a good idea, and be prepared also to find that it doesn't absolutely work. But it wouldn't matter because then the thing is alive, it's got some vitality in it.[3]

Maybe the performance will be slightly faster tonight, maybe more legato. To heed the innuendo, the performer listens for new sounds in the piece and is surprised and pleased to hear something not there in the previous performance or rehearsal. To perform is to create monsters ("the thing is alive"), and one's ardent wish is that the monster should have a life of its own.

Innuendo inheres in the inflection that bends it, articulates it to produce a word or a note. Innuendo persists throughout, to connect each inflection to its history, to inject sound with the movement that draws out a sense of the sound, always in relation to other sounds (and silences) around it. But inflection also remains in innuendo, even after the lips are closed and the bow no longer touches the strings. Inflected sound persists as noise, as vibration, as heat, as entropy, as inertia; it dissipates but does not disappear. Always, the problem of sound is how to inflect innuendo, how to discover in the score—but also the concert hall, the audience, the other performers, and the noise surrounding the music or speech—just those elements that can be bent so as to bend the ear of the listener. And that noise, the innuendo, does not disappear in inflection but persists: not-whistling a constant undertone of the blackbird's whistle.

Composer Karlheinz Stockhausen demonstrates the mutual persistence of sound and noise, drawing, in his music, each out of the other. Noise, he says, is an aperiodic vibration of the air, sound, a periodic vibration. He gradually removes the periodic elements of a sound to leave noise and then reintroduces regularity, to trace the fuzzy path that leads from inflection to innuendo and back. But noise is more than just a lack of regularity, for even noise has its rhythms.[4] Neither the substance of sound nor its complementary background, noise punctuates sound. Each beginning and ending is a noise: the moment when the blackbird starts or stops whistling, the leading sound of a string plucked, or a column of air beginning to vibrate, the plosive *p* at the parting of lips. Inflection begins with a chaotic irregularity, a compact jumble of sharp and unpredictable vibrations that calms in an instant, selecting from among the irregular vibrations certain ones that repeat to define steady, enduring characteristics, fixed pitch and intensity. Vowel sounds are formed by maintaining a relatively constant ratio among three frequencies *(formants)* defining pitches. Breaking up the constancy of vowel sounds, consonants mark an abruption and consist of singular pulses, brief and unpitched bursts of noise.[5] It is as though sound has to be jump-started, to burst ecstatically out of noise. Stockhausen proposes that vowels are a constant background, a substrate, which is articulated and thereby given meaning only by consonants: "that is the function of consonants in our daily language, to clarify meaning."[6] Roland Barthes claims that consonants are too articulate to be musical, for music produces a different sort of meaning: "Music is both what is expressed and what is implicit in the text: what is pronounced [submitted to inflection] but is not articulated: what is at once outside meaning and non-meaning, [. . .]"

Even the symbolic notation and numerical indexes of acoustics cannot purge its ecstatic origins from sound, which rend a hole in the rigid fabric of physics. There is an uncertainty principle of acoustics—analogous to Heisenberg's uncertainty principle for quantum mechanics—which holds that a sound cannot be fully determinate with respect to both frequency and time.[7] That is, the more closely we determine the specific timbre or frequencies of a sound, the less precisely we can specify when the sound happens and vice versa. Only a sound with no beginning or ending has an exact frequency; every sound with a duration, every sound that starts and stops must include physically inexact frequencies, patches of noise describable by Gaussian distribution functions (bell curves), wherein pitch is defined statistically over a fuzzy range instead of discretely at a specific note. The most sudden events—where inflection leaps abruptly from innuendo or returns thus to it—these sudden transitions are inevitably marked by noise which obscures and even distorts them.[8]

The implication of the uncertainty principle is that frequency and time in sound are mutually dependent and ultimately inseparable. Acoustical engineers, physicists, and others who work with mathematical representations of sound routinely treat time as an independent variable while air pressure or wave amplitude is considered dependent. Nonetheless, the uncertainty principle guarantees that this is only ever an approximation, which usually sacrifices the temporality of the sound by regarding it as an ideal periodic wave that neither starts nor stops. In reality, we must consider that just as sound compresses and rarefies the air, so too it compresses and stretches time. Time does not pass indifferently to sound but constitutes its material. We know already the intimate association of sound and time. We regard vision as instantaneous: Hindemith is not alone in claiming to see something in an instant, and we do not often consider that vision need take any time. A photograph captures a single moment, and only photographers routinely remember that an exposure has duration. On the other hand, everyone knows that sound requires some duration, at least a short one. Which is why sound is time's traditional vehicle: think of the bells of a church or a clock, the town crier, a wrist alarm. What good would be a clock alarm that gave only a visual indication of the chosen moment's arrival? Ticking marks the passage of time, by defining a duration (between ticks) while also suggesting the indefinite extension of this duration forward and backward. We hear time passing in a ticking clock, whereas to look at its face is to see the time only right now. If the face of a clock can indicate the passage of time, this is because the clock *says* the time and does not just show it. "What time does your watch say?" Children learn to *tell* time rather than to read it. Sound resists study in Western metaphysics because time is traditionally subordinate to space; it is hard to get a handle on sound because it does not sit still to be examined, motion constituting its very essence. Perhaps it takes a composer working *in* sound to investigate without metaphysical prejudice its temporal nature.

Unified Time Structuring

Recognizing that temporality is not an indifferent abstraction when it comes to sound but a significant part of its very material, Stockhausen composes by seizing and manipulating three durations of sound, three scales of time. Certainly music is constructed from airwaves, vibrations of the air that determine sound's pitch and timbre, but it also involves crucially the vibrations of rhythm and of form. Wave, rhythm, and form: Stockhausen operates on each of these "temporalities," treating them as the stuff of his music. Sound as wave can be readily measured as a continuous variation of air pressure or a vibration of the air, and this increasing and decreasing pressure describes over time the shape of a wave. Sound waves define a relatively rapid temporality involving vibrations faster than one-twentieth of a second and as fast as twenty thousand vibrations per second or more. The rate of this variation in air pressure we hear as pitch, while we hear the particular shape described by the rising and falling pressure as timbre or the texture of the sound. The second temporality, sound as rhythm, is a variation of accents, a pulsation felt as such in the sound. This temporality is slower, on a scale of one-twenty-fifth of a second up to sixteen seconds or so. We hear rhythm as sudden or sometimes gradual alterations in one or more aspects of a sound (pitch, timbre, amplitude, duration), but to constitute rhythm the occurrence of these alterations must be not so frequent as to constitute a pitch. Inasmuch as it defines a temporal scale, rhythm need not be regular or recurring, though we often reserve the term *rhythmic* for an alteration in the character of a sound that forms a repeating pattern, simple or otherwise. Finally, there is sound as form, in which structural or conceptual elements of sound are varied over time. This temporality spans larger durations, its periods lasting for at least a few seconds each. Any aspect of sound can contribute to the variation of form, including not only alterations in pitch, dynamics, timbre, duration, and rhythm, but complex combinations of these, as well as conceptual or semantic aspects of sound. So, a formal period might be demarcated by a shift in tempo, or by a change in lyrical content, from French to English, or free prose to rhyme, or consonance to dissonance. To hear the contrast and connection between one melodic phrase and another requires a human ear and a familiarity with the musical tradition of our culture. Likewise, all the factors that index elements of form—mood, intensity, tempo, density, verse versus chorus, etc.—rely on a trained hearing, or at least an interested ear.

Just as he amplifies the barrier between sound and noise, Stockhausen magnifies the boundaries of these temporalities to question their distinctions. He creates a sustained sound, then slows it down, until the periodic wave that constitutes its pitch and timbre can be heard as a rhythmic pulsation.[9] He thereby melds the two temporalities, transmuting timbre into rhythm. He proposes further transmutations based on the same principle:

> Suppose you take a recording of a Beethoven symphony on tape and speed it up, but in such a way that you do not at the same time transpose the pitch. And you speed it up until it lasts just one second. Then you get a sound that has a particular colour or timbre, a particular shape or dynamic evolution, and an inner life which is what Beethoven has composed, highly compressed in time. And it is a very characteristic sound, compared let's say to a piece of Gagaku music from Japan if it were similarly compressed. On the other hand, if we were to take any given sound and stretch it out in time to such an

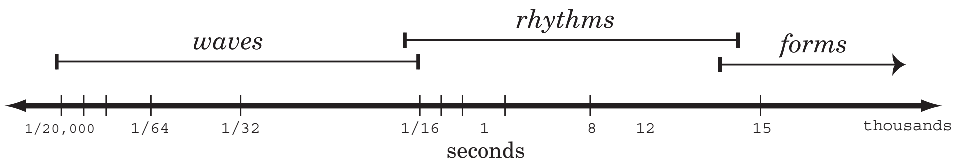

Figure 5. Unified time structuring.

> extent that it lasted twenty minutes instead of one second, then what we have is a musical piece whose large-scale form in time is the expansion of the micro-acoustic time-structure of the original sound.[10]

A whole piece is hastened to the point where its sections take on a rhythmic pulsing. Even while Stockhausen was inventing these experiments, one of his primary influences, John Cage, had enmeshed two of the three temporal scales through his technique of prismatic composition, wherein a piece is divided into sections according to a specified form, which form also governs the internal structure of the sections themselves. (See, for example, Cage's "Lecture on Nothing" in *Silence*.)

Insisting on the unity of the temporalities ("unified time structuring"), Stockhausen emphasizes that they are not merely formally continuous but materially continuous. It is possible, after all, to treat any cyclic or wavelike form—such as variations in the rabbit population in England over time or the variable density of grass over the space in your yard—as a sound.[11] But such representation of a wave as sound demonstrates only a formal correspondence: any wave might as well be a sound wave and can be transformed into one with the right technology. On the contrary, Stockhausen's techniques underline a continuity that requires no transformation; only by acceleration and deceleration and without otherwise altering the material of the sound, he establishes the continuity of the rhythmic scale with the scale of vibrations in air pressure that it comprises. A rhythm is already made of sounds, their vibrations in the air constituting the rhythm in its matter.

Recognition of this continuity opens compositional resources formerly unavailable. Stockhausen composes not primarily notes or chords, but abstract properties, concepts derived from his analysis of the temporalities, which determine notes and chords only secondarily or not at all. *I can compose with a series of degrees of change* (Stockhausen 1989, 64). His piece "Momente" specifies four "moments" of form. Horizontality: *I could define how thick the line, the melody may be at any given place* (65). Verticality: *timbres, sound spectrums, chordal control, homophony* (66). Duration: *to deal with durations means to break the flow of time* (66). And Informal: *fairly vague, static, without direction; [. . .] they serve to neutralize the three main categories*

(68). For each performance, these properties are shuffled according to Stockhausen's prescriptions to create a composition that is only then derived as to its notes, words, and sounds. In "Kontakte," his temporal manipulations demand a more visceral composition technique, so he constructs a tape in the lab to accompany the performance, using methods necessarily brute to create and alter sounds on tape. (In 1959, computer synthesis was nascent, but unsophisticated and not readily available.) He adds waves together by layering tapes to construct a timbre, then peels off one-by-one the timbral components of the sound, leaving only a sine wave, the null timbre. He affects pitch-shifts by accelerating and decelerating tapes, a precursor of today's turntablism. Stockhausen's material and conceptual subjection of sound yields not melodic intervals or harmonic blocks but texture in waves, texture in rhythm, and texture in form.

And why stop at three temporalities? An entire piece, an oration, or the sounds of a day in the life are vibrations of the air and demand of perception different powers. These sounds each have unique timbres or rhythms, and so do a concert, a composer's oeuvre, a musical style, and every history of music. These are all rhythmic, structured, respiring. We hear a piece as part of a concert which has its own rhythm. A composer's entire oeuvre breathes and draws its breath in relation to culture and history, personal, familial, local, national, and global. "In a manifold sense, music uses time. It uses my time, it uses your time, it uses its own time."[12] Musical periods and epochs operate in complex polyrhythms, sketching a history in counterpoint to those of economics, politics, technology. These broader temporalities are not extensions by analogy, for, like wave, rhythm, and form, we hear such durations, grand and minute variations, concretely and without intermediary. How do you identify twentieth-century American music, or Russian Romantic music as opposed to the Western European variety? Which composition does not implicate its contemporary war or the vainglory of the king who commissioned it? Culture, politics, and history are audible in a piece of music or an Australian accent or a jackhammer. Jacques Attali demonstrates compellingly the inclusion of a culture in its music, paying special attention to economy and politics. The nineteenth-century organization of an orchestra—with a leader who represents the composer as proxy, sets the tempo and dynamics, establishes a hierarchy of "chairs"—all of this can be heard immediately in the music of the period. One hears the soloist set *against* the orchestra, her virtuosity a virtue only in a culture that recognizes and values individuality over, say, accord.[13] (Attali notes that the virtuoso arises alongside democratic ideals that promote the individual and capitalist economics that reward individual accomplishment. There was no virtuoso when music celebrated only the glory of the King. Indeed, early Western music is monophonic, each musician playing or singing the same thing. Many voices, one body, always His Majesty's.) In the adherence of the musicians to standards set by the conductor, one hears the hierarchical organization of the orchestra, whose members submit to the conductor (and to their training), as she submits to the composer, who submits himself to the compositional standards of his era. History inscribes these standards in the music, to define epochs (baroque, expressionist), periods (late Beethoven, serialist Schoenberg), genres (blues, a capella), etc.[14] The orchestra is heard in its sections, and the physical organization of the players makes it nearly impossible to single out an individual; even from the front row, a discerning listener is hard-pressed to distinguish the second from the third violin. Not by accident, these sections and their hierarchy reflect a societal organization; such regularity, such organization would be impossible in a culture with a much weaker notion of centralized authority. One hears in a piece the very fact that it *is* composed, and this too bespeaks a history of music and of a socioeconomy that produces individuals who compose music. One hears the composer's voice in his unique style, which bears its own relation to history, a dialectic of convention and invention. Composed music is unified or totalized in the mind of the composer, who imbues the music with his personal relation to history and politics. How different this sounds from group music, where a fulcrum is at best momentary, and focus a constant struggle.

It is certainly contentious to claim that an entire history of culture is heard in a piece of music (or a speaking voice, or a fax machine) in the same way that the pitches and words are heard. More mystic than scientist, Stockhausen has been challenged by acoustic physicists regarding his assertion of the material continuity of the temporalities of music.[15] Acousticians point out that if one slows down a sustained sound, so that the air vibrates more and more slowly, the pitch will not become a rhythm but will simply drop out of audibility. There may be a small window of frequencies where one can hear a very low pitch as a rhythmic woofing sound, but below these frequencies it will just be unhearable by human ears. A single sound stretched out over the course of days does not become an epic symphony as Stockhausen would have it but is perceived exactly as that other slow vibration of barometric pressure, the weather. (In this sense, meteorological variations of pressure are "sounds" of extremely low pitch and huge wavelength. We might feel them in our joints and in the vegetable prices at the supermarket, but is this hearing?) In other words, the material continuity of the temporalities of sound cannot be understood on the model of a single material substrate taken at different durations. The three temporalities are not material analogs, identical but for scale, as though time could be sculpted in sound by starting with a larger or smaller block, making the same motions in any case and simply choosing one's hammer and chisel to scale. Though rhythm is certainly a variation of air pressure, one will not hear it except by attending to "pieces" of sound that are already more complex, more involved than the compression and rarefaction of the air over time: pitch, density, intensity, timbre, attack, etc. To make a waltz rhythm, tap *1*-2-3 repeatedly on a drum, or play bassnote-chord-chord on a guitar, or alter the timbre of a sound on the guiro so that it repeats, rough-smooth-smooth-rough-smooth-smooth every couple of seconds. But ears hear nothing when one compresses and rarefies air pressure, *updown*-updown-updown, at this same tempo. Each temporality is a material motion of the air, but one will never arrive at rhythm or form, or even timbre and pitch, by considering only these vibrations, this material.[16] Unified time structuring is not a naïve confusion prompted by the common material (air pressure) of all sound. Instead, the three (and more) temporalities are materially intertwined, constructed each from the others. Stockhausen well knows that an effective composition is built in this way at many levels, of many times, and includes an understanding of their relations. What sorts of relations do we find among the temporalities?

Persistence of Audition?

If we examine sound only as air waves, the temporalities will never be distinguished: the differences between 5×10^{2} Hz (wave), 5×10^{-2} Hz (rhythm), and 5×10^{-5} Hz (form) are of degree, not of kind. To find the differences of kind among these temporalities, we must acknowledge their close relation to perception. Temporalities are paces at which things move and their thresholds index powers of perception. "The ranges of perception are ranges of time, and the time is subdivided by us, by the construction of our bodies and by our organs of perception" (Stockhausen 1989, 95). For example, each temporality corresponds to a different autonomic system: we feel rhythm in a manner only distantly related to the specific timbre or frequency of the notes. And one does not generally tap one's foot in time with the change in the key signature of a piece. Hearing a paragraph is not just a longer version of hearing a sentence. Pitch discernment, foot-tapping, the beginning and end of a dance or a shift in one's seat, a change in one's breathing, thinking, and feeling; what alteration, gross or subtle, might not mark a sonic temporal boundary?

We can dispense quickly with the hypothesis of parts and wholes. Form is not created just by putting rhythms together in patterns, even if we mean something very general by *rhythm*. Form is not exclusively about the rhythms *inside* it, but about larger forms: movements, pieces, concerts, and their connections to politics, economics, biography. It would entirely fail to express anything if it dealt only with rhythms as its parts. Form—whose pace is that of the linguistic idea, paragraph, chapter, parable—form tends most often to the conceptual, the logical, the linguistic. It can tell a story, dramatize an argument, praise or critique. This is as close as music comes to representation, the call and response, the tension of the shift from major to minor, the alienation of an unresolved dissonance. Whereas timbre's connection to history is more diffuse, more micropolitical. Timbre is sound's signature: the quality of a voice that makes the *Hello*s of a thousand people instantly recognizable; that part of sound that announces its origin in a Yamaha DX-7, a Samick piano, a hollow-body electric guitar played through a clean British amp. One hears in the timbre of a guitar its lineage in the string family; one hears a whole history of problems and their unique solutions in the guitar.[17] How to project enough sound? How to make a broad range of pitches technically realizable by the player? How to fit a human body? How to accommodate cultural habits of posture, of propriety, of property? What materials are available? Will this be a sacred object? Does it have to sound the same every time? Will it be mass-manufactured? How much training will players undergo? Each of these concerns is already economic, political, biological, technological, and we have not even mentioned the necessarily mutual evolution of different instruments, questions of complementarity of timbre, pitch range, and dynamics. Will this instrument accompany a voice? Solo over an orchestra? Be played through an amplifier? The instrument "is literally composed and manufactured by culture."[18] There is a history in timbre of culture, just as there is a history in rhythm of the body's articulations and gestures, breath, heartbeat, elbow, sex. Words are rhythm through-and-through and rhythm shares its long history with language.[19]

Consider the role of the downbeat. It orients all the instruments, as well as the players and listeners. The orchestra gathers in semicircular rows, all facing the conductor, who becomes a focal point. He focuses and distributes like a prism the will of the composer and the constraints of style to the other performers, primarily by keeping the beat. He generates this standard by his emphatic gestures, which each performing body mimics in some of its parts. The standard is not just a tempo but serves as the criterion of correct participation in the music. The conductor standardizes identity, both the identity of the piece, which is recognizable as the same piece at each performance, and the identity of the performers, who submit their individuality to the conductor. Individuality is then a remainder: the difference between a given performance and an ideal *average* one. It is whatever the performer *adds* to the piece, a contribution not mandated by the standard of identity. Everyone bears an analogous relation to the center, everyone participates in roughly the same way. On the other hand, where there is no downbeat, individuality rules identity, and any coordination is entirely voluntary. Each finds her own way of participating, for the whole is not governed by a hierarchy from the top down but by an elective construction. This populism is part of Steve Reich's fascination with African percussion, which requires no leader and so achieves at its best a spontaneous and precarious ensemble, where the individual does not cease being creative when he becomes part of a group. As we will see, twentieth-century Western art music employs numerous techniques to purge itself of the tradition of transcendent composer and his representative in the conductor. Serialist composers subjugate their wills to the rule of the series, algorithmic composers program computers to generate music according to a formula, minimalist composers eliminate large form in favor of a simple repeating figure, free composition attempts only to have no rule, conceptual composers write pieces that are different every time. Still, this distinction between traditional conducted music and recent unconducted music is far too stark; the conductor does not maintain a rigid control over the instruments and the performers do not give up their spontaneity when they follow the conductor. The identities of the players and even of the piece are always problematic. Is it the same piece with period instruments as with modern ones? Is it the same piece when it is rearranged, recorded and played back, transcribed for piano, played much slower or faster, or in rehearsal?[20] And twentieth-century techniques *also* demand the performers' submission to the composer, as Steve Reich's musicians become automata, mechanically hammering out patterns on African percussion instruments, entirely at the mercy of the process that defines the composition. The relative proportions of collaboration and identity, indexed by the strength of the downbeat, are not accidents of the music but fragments of culture that are heard there. To hear the place of the individual is to hear a history and a politics. *1940s:* Trombones disappear from the jazz ensemble, saxophones rise to prominence, and the audience quits dancing. *1970s:* Digital technologies escape from the laboratory and even rock musicians prick up their ears to study more carefully the timbre of sound. *1950s:* Teenagers with money to spend stake out an autonomous domain, the charts do not so much track music sales as promote them, and music becomes an industry.

All of this history is *compressed* in the sound but not ground to a uniform consistency in the process. The compressions of perception are asymmetrical, and point by virtue of their involved history to other compressions, particularly those just past and those just to come. A rhythm already involves the next beat, and to hear the rhythm is to be in the middle of it, hearing its history at each moment, hearing at once the beats that came before and the beats that are still to come. "[A]t the deepest level, [...] in developed music no event is purely itself, but receives its meaning from what is absent—from the past and the future—which it then influences in its turn."[21] Even the rigid rule of the conductor's downbeat can never be a total standard, for to play music is to hear the past and the future, before and beyond the downbeat. The sonata form persists widely in Western music as the standard against which other standards are measured. But sonata form calls on particular powers of perception: to hear a chord prolonged (Schenker) in the chords that follow it, to hear a melody as already a small sonata, with a building tension that finally resolves, to feel the center of the tonic and the displacement of the dominant. These events demand of hearing a compression that hears them together.

The compression involved in meaningful hearing does not take place on its own; hearing is an activity, not a passive reception. (We must therefore rethink the difference between listening and hearing, which is usually understood as active versus passive.) Derived from hearing, the temporalities of sound are things that we *do*, extraordinary powers of perception and the perceptive body. The body must compress time, it draws into a singular moment an interval of difference, "brings all the beats between 'one' and 'one' into a group."[22] To feel a rhythm means to feel the entirety of a beat all at once, even while anticipating the next beat. The space between one beat and the next is not itself a metrical or metered interval; to the listener, performer, conductor, and composer, it is rather a pulse, a moment that does not lose its integrity when divided. Once entrained, the perceptive body can hear the rhythm even when it is not being played.[23] And not only rhythm is an act of the body; each temporality demands a compression of sound, to grasp percepts that do not divide without changing their natures. The most rapid temporality requires the most dramatic compression: in an instant, one hears a fast and regular fluctuation of air pressure as a constant and indivisible pitch. Perception of timbre, too, needs a compression, for one hears not its acoustical equivalent, the aggregation of a number of pitches, but a uniform and steady texture.[24] The ear does not hear difference but subsumes all the difference, all the variation in air pressure, as a quality of sound. Form calls for still other compressions, draws other bits of history into its web. Like timbre and rhythm, though, it is the perceptive body that conducts the compressions of form, viscerally expecting, for example, the resolution of a dissonance or the triumphant return of the theme. The listening body's rhythms—its breath, its motions, its attitude—betray the formal divisions in a piece of music.

This should be enough to disfirm the hierarchical model of parts and wholes: rhythm compresses elements of pitch and timbre, but these do not become the constituents of rhythm by being compressed in it. And timbre's parts are neither the sine waves that are its mathematical equivalent nor a single period of its wave representation. It is true that each temporality gathers into its duration elements of the other temporalities to suggest a loose hierarchy of organization, like town, county, state, region, nation. But sound would never have the subtle and awesome power it wields if it adhered to strict hierarchy. For the biunivocal relations in a hierarchy—each level relating to the next one up in the same way—can only ever produce one effect, the transcendent one. Planes arranged hierarchically would allow only homogeneous relations between each plane and the next higher. Every compression would be effectively symmetrical, and sound could never matter, could never point. But the temporalities do not relate each to each in a hierarchy. Compression does not gather together into a uniform whole but collects heterogeneously, making an asymmetrical, weighted duration that spills over its edges to implicate past and future, history and anticipation. Each compression is unique, its operations related to but not statically defined by the other temporal spans. Each compression includes its own difference.

We must therefore correct our earlier claim that the ear does not hear difference in compression. The ear does hear difference but hears it in value or quality; we hear the difference that makes a difference. We compress sine waves to gather a history of timbre into the character of the sound. Only because this compression is asymmetrical, heterogeneous, does a particular timbre point toward the next note, the next sound, and elsewhere, to its origins, its culture, its material. The asymmetry allows the ear to hear each note and each sound as significant, as moving and as part of a motion. We do not hear a bunch of notes that we aggregate to make a rhythm but already hear the rhythm in the motion of the note, its leaning or intention (intensity). To hear form is also to compress, since one hears a melodic line even before its collection of notes, one feels the differences between the drive in the chorus of a song and the suspension in the verse, and one knows without any analysis the imminent ecstasy as a twelve-bar blues approaches the final bar of its form. The body does these things, and it does them by hearing a history, recent and ancient, in the present.

> [Artists] do not juxtapose instances of the figure, but rather each time combine an element of one instance with another element of a following instance. They introduce a disequilibrium into the dynamic process of construction, an instability, dissymmetry or gap of some kind which disappears only in the overall effect.[25]

In their chapter on double articulation, Deleuze and Guattari discuss an animal's relation to the various milieus in which it is found: the animal demonstrates affective thresholds that divide the milieu according to powers of the body.[26]

Figure 6. An example of Schenkerian analysis. The top staves are the original first few bars of the "very slow" movement from Beethoven's Piano Sonata Op. 10 no. 2. The bottom staves represent the fourth and final stage of the Schenkerian reduction of these same few bars. Adapted from Thomas A. Pankhurst, Schenkerguide.com: A Guide to Schenkerian Analysis, http://www.schenkerguide.com/stagefour.html.

These thresholds connect perception to the milieu and so also connect affects of the body to forces of the environment. We hear and do in concert with environmental forces: conservative forces of energy storage, counterforces of resistance, resonant forces to amplify and direct energy. Perception is not passive, but affective; in perception, the body behaves itself, acting on and reacting to its environment.[27] Perception compresses, and in so doing it makes the difference between one temporality and another. The body thus draws lines through perception, articulating a range of behaviors or affects and generating the indexes that mark time.

In other words, the body must remember. To hear pitch and timbre, one must remember the last few vibrations of the air. These few milliseconds are compressed, drawn together, their internal difference extinguished, covered, or crossed by the compression. One does not hear a variation of air pressure, a difference over time, but only the effect of this difference, the steady quality of pitch and timbre. To hear the fill at the end of a four-bar drumbeat is not just to hear that brief, halting rhythm but also to remember in hearing the steady three-and-one-half bar pattern that led up to it. Schenkerian analysis elevates to a basic principle ("fundamental structure") the method of *prolongation* of a note or chord by placing other notes amidst its occurrences. Both the term *prolongation* and its notation in music suggest that one hears the note throughout its prolongation or perhaps that one hears it in its recurrence as having never really gone away. Memory hears the note or chord prolonged in notes and chords different from it, but memory's job is to forget this difference.[28] A D at the beginning of a melodic phrase might travel up to E or down to C♯ before returning to a D at the end of the phrase; Schenker claims that we hear throughout this motion no genuine departure from D, but only a difference internal to the D, as though E were just a tension of the D which bends but does not leap. (That is why only small motion is really considered prolongation.) Perception remembers to forget, to forget a difference even while retaining that forgotten difference as a symptom of memory and a quality of the sound. The difference forgotten is essential to hearing, for the structure of forgetting in memory gives time its direction and points hearing toward the future. The compression of a beat, a rhythm, a melody, a verse, a pitch, or a timbre does not create a homogeneous block of time-sound but a singularity, a weighted hearing that is open to the next moment precisely because it retains the last ones. This is the paradox of memory: one hears the recent in the current, the past in the present, not an aggregation of past instants but the whole past compressed into the now. Hearing is the fulcrum at which sound's past leans into the future. One forgets, but one remembers what one has forgotten, one remembers it not as an explicit and conscious difference, but as the asymmetry of the sound, the arrow of time, a history in hearing.[29]

Perhaps this explains why so many people are content to listen to music without regard for the fidelity of the reproduction or the ability of the playback system to produce definitive sound pressure levels and a sense of acoustic space. Most people do not bother to listen to music but instead only want to be reminded of it, for "the pleasure of mere recognition." Stanley Cavell points out that sound is essentially indirect, that it comes from a person or place but does not reach us without leaving that person or place. "[I]t is the nature of hearing that what is heard comes *from* someplace, whereas what you can see you can look *at*."[30] We hear all the time things that are not there before us, the person on the other end of the phone or the woodpecker hidden in a grove. Sound involves a mental reconstruction of its origin, it requires the perceiver to relocate it there where it comes from. Since we are all used to listening to what is not there, we are hardly troubled by the ontological problems of recording and playback. We refer to what we hear as "the flügelhorn" whether it is Clark Terry before us or just a CD of his playing. We are not terribly bothered by a poor recording since we are used to constructing from memory the reality of the object "in our heads." To hear is to remember, to recall, not to witness. Sight, on the other hand, is a matter of looking at something that is evidently there. Were it not there, we wouldn't be able to see it or, rather, look at it. To see is to be in the presence of the object under regard. Thus, we take for granted the difference between a visual reproduction (photograph) of a scene and the actual scene before us. Though one might regard a photograph as an authentic viewing experience *of that photograph* (as opposed to, say, a reproduction of that photograph), one never regards it as an authentic viewing experience of the photographed scene. But to play a recording on a stereo *is* considered an authentic listening experience, not just a document of something that happened previously. In either case, one hears the sound of the flügelhorn, which does not seem to require the presence of an actual flügelhorn. (Cavell wonders whether there is some visual analog to the sound of an object, like the "sight" of it? Its sight or image is not very separate from the object itself.)

So you need a memory to listen to music. How will you know what to feel next, why would you feel anything without a sense of what has come before? "A note or chord has no *musical* significance other than in relation to preceding or following events. To perceive an event musically (that is, to recognize at least part of its music function) is to relate it to past events."[31] The previous chord, the previous phrase, the previous section, movement, piece, performer, composer, period. Is it enough to remember the previous sound? The previous peak in air pressure? (But air pressure is in a variation so continuous that it has no *previous*. How do you choose which Fourier transform to look at? Or which regularity to attend to?) It is not always the same memory that is called upon. Traditional Western music relies on a linear and discrete memory, a memory that draws from the sound a universal history and a set of conceptual differences. It operates by comparing one section to another, noting similarities and differences and taking its cues from them. Form conforms to standards, and the lines that divide one formal unit in a piece from another are clear to the ear and in the score. "This was the process characteristic of classical Western music: actual memory of real objects and 'angle of hearing' checked at major points in the structure—in other words, an a priori awareness of the formal schemes employed by the composer, a sort of common fund shared by the musical consciousness of a whole society." Classical European musical form is, as Wim Mertens says, teleological and narrative, even representational.[32] One *interprets* the music, guided by the common fund or musical vocabulary shared by the culture. Motifs play characters, which interact and undergo alterations throughout the narrative. The narrative itself is linear and objective, with marked events in series that serve as hinges for the changes to the characters.

Pierre Boulez

Characters are introduced in the exposition, developed in the development, and the consequent tensions are generally resolved in the recapitulation.[33] Wishing to purge music of teleology, to eliminate the last traces of romantic expression, Boulez distinguishes another kind of composition with a different sort of memory and new conventions. He adheres to a total serialism, in which series of timbres, pitches, durations, dynamic values, etc., determine the nature of each note in the piece. Prior to writing down the composition, the composer chooses the series (of timbres, durations, etc.) according to rules that largely eliminate the composer's intention from the ultimate sound of the piece. For example, the composer initially decides on a series of durations (e.g., half-note, then sixteenth triplet, then dotted eighth-note, etc.), and then composes a piece sequentially by always assigning the next duration in the series to the next note (or rest) in the piece. (The series is considered a loop, with the first element always following again after the last.) Each characteristic of the "next" element is determined by some such predetermined series, a series of pitches, a series of dynamics, note durations, timbral indications, etc. The composer creates the various series, then the composition writes itself. In a total serialist composition, there is no transcendent organization, no sense of beginning-middle-end, no development, no story. Memory is not called on to compare large sections with each other. Instead, memory attends to the immediate, comparing each sound to itself, to its neighbors, and to whatever sound. Memory loses its hold on a linear and continuous time as, without the organization into formal structures, each element represents only itself and context shrinks indefinitely. One hears the universal and the singular in the same moment, the timeless and the atemporal.[34] Boulez attempts to present sound per se, sound decontextualized or unadorned. Without a narrative, sounds are free to get out of line, to draw on extraordinary temporalities, breathtaking affects, and saturated percepts. The dissolution of a formal context places greater emphasis on the sound itself, to the point where some composers write only one sound to offer listeners a close-up or "microphonic" perspective of timbre: a smooth sheet of sound as a singular universal, a composition whose variation is entirely internal to the sound. As such, the twentieth century saw an increasing attention to timbre, as formal elements were flattened into immediacy or immanence.[35]

La Monte Young

Wishing to examine sounds from the "inside," La Monte Young began experimenting with "long durations" as a student. Under the influence of Fluxus artists in New York, he wrote the same piece thirty times: *Draw a straight line and follow it.* Another piece ("Composition 1960 #7") simply instructs that a two-note chord is "to be held for a long time." Eventually he would write pieces that combine his interest in long durations with his ideological commitment to nontempered tunings. According to Young, by playing notes whose frequencies are ratios of whole numbers, one ensures that the piece will be effectively the same each time it is performed. For two centuries, standard Western tunings have guaranteed an irrational frequency relationship in every interval but the octave.[36] To achieve such irrational tempered tuning requires an in-principle impossible precision so that the chord will never be exactly the same from one performance to the next. The consistency from one performance to the next is not so much an end in itself but testifies to the perfection of the sound. Young wishes to "penetrate the inner essence of the sound," and he finds this essence in the exact relationship of one tone to another simultaneous tone.[37] Again, the context of the sound disappears, for the piece does not vary over its duration, or does not spread its variance out over time, but compresses it into each moment of the singular and universal chord.

> Listening is tending to become increasingly instantaneous, so that points of reference are losing their usefulness. A composition is no longer a consciously directed construction moving from a "beginning" to an "end" and passing from one to another. Frontiers have been deliberately "anaesthetized," listening time is no longer directional but time-bubbles, as it were.[38]

Young recognizes explicitly the universal singularity of each of his pieces. On the one hand, he titles not just each piece, but each performance, and stamps it with its time and place: "*90 XII 9 c. 9:35—10:52 PM NYC*, The Melodic Version of the Second Dream of the High-Tension Line Stepdown Transformer from The Four Dreams of China." On the other hand, he believes that each performance is not the creation of a new sound, but only the instantiation of a persistent and universal dream, the dream of an ancient tortoise, whose dreams give rise to all of sound. "They are primitive sounds that do not remember ever to have started and that are perpetuated in the Dream House project."[39] Memory shrinks to a moving point, an immanent action, which marks only accidentally and contingently the beginning and end of a piece, for the same piece, the same sound is taken up whenever the piece is performed, "modes of vibrational structure [...] repeated exactly from performance to performance" to "trigger the same moods every time."[40] In total serialism, too, the beginning and end are arbitrary, since the series are themselves arbitrary and the order in a series random or indifferent.

This makes some sense (and there are other explanations[41]) of Young's obstinate refusal to release recordings of his own work, especially the many tapes he has of Dream Syndicate performances with Tony Conrad et al. Why would

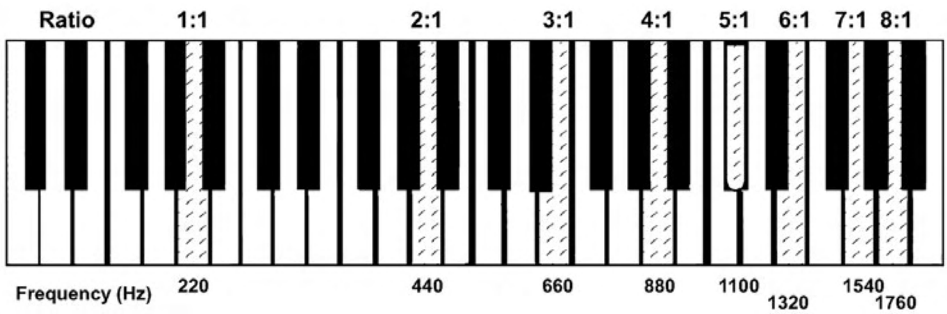

Figure 7. A well-tuned piano. Because this is a nontempered tuning, the intervals and frequencies shown here only approximate the way pianos are ordinarily tuned. For example, on today's concert piano, the note G, which here corresponds to 7:1, would be tuned to 1568 Hz, not 1540 Hz. The G on the piano in the illustration would sound flat to our well-tempered ears when playing in the fundamental key of A.

one need a recording, when every performance is the same, so that one may as well instantiate the piece again, here and now? What recording could do justice to the crystalline perfection of the lived event of a rationally tuned chord? Perhaps Young is attempting to reject memory altogether, to deny memory its relation to the piece, which then remains outside of time. A mass-produced recording treats the piece necessarily as something with a beginning and an ending, voiding its singularity by reproducing it in a mass medium and stripping it of its universality by placing it on the store shelves among thousands of other recordings. Though the molar memory of form is denied in Young's pieces, the molecular memory thrives in the moment of performance. Even in his compositions that vary and incorporate large forms, one hears already the entire piece in a single chord. The universality of a rational tuning comprises the whole key, all the notes at once. Writing of Young's "Well-Tuned Piano," Robert Palmer notes both the singular quality of the sound and the universality in the tuning, for the whole piece resounds in its opening chord: "The sound of the piece is so novel that one has trouble recalling it after the initial impression has faded, but as soon as one approaches the upstairs room and begins to hear the chord floating softly under the door, something extraordinary happens. One begins to recall, in detail, the sounds and structures of the entire composition."[42] For Young, even the horizontal line of melody is just harmony's vertical, stretched into duration: time as a suspension of eternity, reality a turtle's dream prolonged.

Young's fascination with whole-number frequency ratios *(just intonation)* and their relation to memory is an ancient theme translated into California New Age. That great champion of the whole number, Pythagoras, postulated the music of the spheres, a rarefied sound, too rarefied to hear, produced by the rational perfection of orbiting heavenly bodies. Modern acoustics updates this myth, retaining a special place for rational tunings. For an instrument does not produce a single (fundamental) tone without also sounding its harmonics, all the tones bearing whole number frequency ratios to that fundamental tone. It is the relative amplitudes of the various harmonics that determine the timbre of the sound. In other words, to sound a note on the trumpet or didgeridoo is to sound not just that one tone but simultaneously another tone an octave higher (2:1), and another tone a fifth higher still (3:1), and two octaves (4:1), two-octaves-and-a-third (5:1), etc. In Figure 7, when the lowest highlighted key, an A at 220 Hz, is struck, the strings will vibrate to produce sound not only at 220 Hz but also at 440, 660, etc., as though all the other highlighted notes were being played simultaneously. The relative amounts of each harmonic determine whether it sounds like a trumpet or cornet, clarinet or oboe, Fender P-Bass or J-Bass. (See Figure 8. Timbre also includes changes in the character of a sound over time. We recognize a guitar not only from the harmonic spectrum of its steady vibration but also from the sudden and noisy attack when it is plucked.)

Acoustics thus supports the claim that every note already sounds an entire nontempered scale. Even a sine wave, once given life in a room, will excite its harmonics in sympathetic bodies. A sympathetic tuning will align an instrument's various notes (strings, columns of air, membranes, etc.) with each other so that simultaneous or successive notes share significant portions of their frequency spectrums and chords sound perfectly harmonious, with no beating or roughness in the sound.[43] La Monte Young knows that whole-number frequency ratios are the closest we can come to hearing for ourselves the music of the spheres.[44]

The ear does its part to promote rational tuning. Pitch discernment is based on the harmonics of a note rather than its fundamental. Psychoacoustics experimenters use synthesis techniques to generate sounds with a "missing" fundamental, sounds that are only harmonics. Test subjects nevertheless identify the pitch of the note in terms of its absent fundamental, which is not actually being sounded; the ear recognizes the fundamental by hearing the third through fifth harmonics. We hear sounds that are not there by hearing harmonics that are.

> La Monte Young's music provides a unique experiential link to a primordial evolutionary basis for human sensations and perceptions. [. . .] La Monte Young has carefully studied the current psychoacoustic place and volley theories of hearing, after having created and musically explored "missing fundamental" tones—tones which are not physically present in the auditory stimulus, but which are supplied by the human ear, nervous system, and

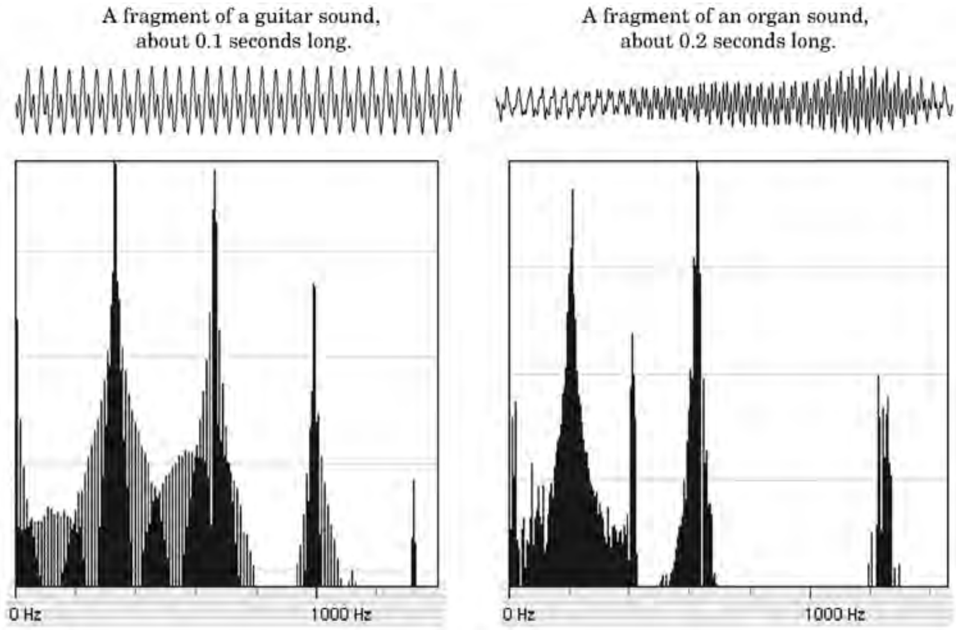

Figure 8. Spectra of sounds. The left column shows a guitar waveform and its spectrum. The right column shows an organ waveform and its spectrum. The waveforms are graphs of amplitude (air pressure) over time. The spectra are graphs of amplitude (energy) over frequency, averaged over the entire short duration of the waveform. For each spectrum, the first *(leftmost)* peak represents the frequency of the fundamental. Other frequency peaks are spaced at regular intervals because they are multiples of the fundamental.

> brain. These induced auditory experiences are in turn rooted in millions of years of neurophysiological evolution, representing in their own way certain fundamental constants of human biology.[45]

The rational tunings in La Monte Young's music manifest these fundamental forces of sound, acoustic and psychoacoustic universals. These forces make sound and make sound effective, so to hear them is to hear the cosmic origin of sound itself, the differential force that sets sound in motion.[46] To expose still other sides of these forces, John Cage eliminates the foreground of sound entirely, drawing the background into the foreground, most famously in "4′33″," but also throughout his oeuvre, which includes a judicious use of silence and an increasing emphasis on performance as a "happening." The elimination of the foreground would be to no avail were the background hypostatized thereby, for one would then have just a new foreground. However, what we discover

John Cage

is that the background does not sound like the foreground. What shall I listen to? What shall I attend to? How (in what sense) is this music? Cage would be delighted with this self-conscious confusion. He wants desperately to rid compositions of every shred of intention and so eliminates his own intention, his self, through aleatory and Zen techniques, which constitute his very methods of composition. He tosses yarrow sticks *(I Ching)* to determine which of sixty-four elements will come next in a piece and so composes "Music of Changes." He offers prepared nonsensical answers to questions from the audience at his lectures and gives impossible instructions to performers. He thereby foils the listener's intention by foisting uncomfortable and irresolvable questions on us, setting before us an interrogatory music, a problematic music which poses hearing any number of koans. Consequently, "one may give up the desire to control sound, clear his mind of music, and set about discovering means to let sounds be themselves rather than vehicles for man-made theories or expressions of human sentiments." Stripped of intention, sound no longer triggers responses from the standard catalog of emotions, no longer refers to the human activities of manufacture, performance, etc. The composition loses all relation to representation and denies its human origins in favor of a universal or cosmic origin. Sound ceases to signify and presents only that nonhuman force that drives sound per se, the any-sound, whatever sound. But Cage is quick to note that this unintentional, inhuman hearing is not the same as indifferent hearing or deafness. To hear without presupposition and context is not to hear without interaction or without care. "[S]ounds, when allowed to be themselves, do not require that those who hear them do so unfeelingly. The opposite is what is meant by response ability."[47] One still hears difference, sound is still pointed, but now out-of-joint, no longer pointing along a two-dimensional line with a universal history and a determinate future. It is up to the listener to hear this way, to be able to respond, to be responsible. Cage thus calls for a new hearing and a new listener.

This is how music makes a difference, by demanding something of the listener, by directing memory to construct new subjects of hearing. Here is music's entrée into the political, the social, and the economic. Here is how music rouses a crowd and soothes the savage beast. Stockhausen means it when he says that sound changes people, that whatever you hear alters you irrevocably and without the intermediary of ideology. "Whenever we hear sounds we are changed: we are no longer the same after hearing certain sounds, and this is the more the case when we hear organized sounds, sounds organized by another human being: music."[48] He knows, too, that sound draws its transformative power from manipulations of memory.

Karlheinz Stockhausen

"Play a sound with the certainty that you have an infinite amount of time and space," demands one of his compositions, once again directing memory away from the historical and into the immanence of the sound. What sounds do we censor as less than crucial, before even making them? What forces do we hold in reserve, waiting for the right moment? Stockhausen teases out these forces, asks his performers to make explicit those connections between sound and time that they usually push into the background. His piece, "Connections," makes a list of rhythms and instructs the player to follow them: Play a vibration in the rhythm of your body, your heart, your breathing, your thinking, your intuition, your enlightenment, the universe. "Mix these vibrations freely," he says. The result is the juxtaposition in sound of the personal and world-historical experiences of the listener and performer.

Stockhausen's compositions challenge the traditional divisions of musical time by connecting them to other extramusical rhythms. Memory must grasp new durations, operate across temporal distances both vast and fleeting. This contrasts starkly with pre–twentieth-century European art music, which usually assigns memory an unambiguous role by giving hearing distinct phrases in familiar lengths to compare to each other. However, even the existence of a discernable elementary unit does not prejudge the role of memory in a piece. Whereas La Monte Young, Tony Conrad, Phill Niblock, and others sustain a single note or chord to get inside of it, their fellow minimalists Steve Reich, Terry Riley, and Philip Glass repeat an internally differentiated motif and alter that motif over the course of a piece. Each composer uses particular techniques of differentiated repetition, but these techniques overlap and borrow from each other. Phase shifting involves at least two sources of sound (instruments, tape recorders, etc.) playing the same phrase (rhythm, melody, sentence, etc.) at the same time. One of these two sources is shifted in time so that it no longer aligns with the other. The shift can be continuous (e.g., Reich's "Come Out" and "It's Gonna Rain"), so that as it progresses, the original phrase is heard to stretch or thicken, then become an echo, then morph into an incomprehensible jumble of pitches, beats, chords, or phonemes. A continuous phase shift dis-articulates the sound, turning a voice inside-out to expose the sonic material of speech and eliminating the distinct boundaries between notes and beats in a musical phrase to demonstrate the priority of a motif over its parts. For one still hears the motif, not as the sum of its parts but as a lump or clot of sound. The force of sound is discovered thereby to operate in temporalities both more supple and more gross than the words, notes, or beats. Instead of a continuous shift, phase can also jump by discrete rhythmic values, one part leaping ahead of its twin by, for example, an eighth-note at a time (Reich's "Clapping Music") so that the

Steve Reich

ear discovers new rhythms and new melodies resulting from the staggered overlap of a motif with itself (Reich's "resulting patterns").

Other minimalist techniques for differentiating repetition abound: a single repeated phrase can be altered by augmentation, substitution of rests for notes or vice versa, dynamic reemphasis, the introduction of a new theme, transposition, inversion, etc. (Many of these techniques predate the American minimalists, and Olivier Messiaen deserves particular recognition for his inventiveness.) In any case, it would be a mistake to understand the fundamental repetition in such a piece as the repetition of the elementary phrase. For repetition is not first of all an external method imposed on the phrase to turn it into a composition. Rather, repetition is the principle of the music before any phrase is repeated: each note, each phrase is already a repetition. That is why even La Monte Young's held chord is a repetition: its principle is repetition. His justly intoned chord is born of repetition (the repetition of harmonics, the repetition of timbre), and the tortoise's dream is not an original instance repeated in the performance, but indicates precisely that there is no original, that the original is already a repetition.[49] Like Young's held chords, the effect of repetition in Reich, Riley, and (usually) Glass is to present a smooth surface to the ear, to eliminate the distance between foreground and background, so that the ear can no longer orient itself with respect to molar boundaries or objective points of reference. One hears the cosmos open up to envelop the listener.[50] It is thus not a matter of a certain number of repeats. Reich does not repeat a phrase so that we might hear the phrase repeated but so that we might hear the repetition itself. Repetition as a cosmic force, the principle of sound, generating each tone, each phrase, each performance, each piece. Total serialism proceeds exclusively by the repetition of composed series, but even keen listeners are hard-pressed to hear these individual series. We hear instead just their quality, that singular character of total serialism that *is* the sound of repetition. (Though one can hardly discern the series, serialism is nevertheless readily identifiable by ear, and different series produce aurally distinct results.[51]) Reich aims constantly to reveal the forces at work in the music, to render the process of composition sonorous, "to hear the process happening throughout the sounding music."[52] Repetition is heard not just from one element to another, but the compositional principle of repetition emerges from behind the scenes into perception. New music repeats according to an internal principle: the immanent alteration of the figure or the accidental variation in performance of a single note. "[E]ven if you try to play the same thing over and over, it will always be different."[53] Repetition is a repetition of difference, so memory grasps it only by crossing that difference, covering it with a singular sonic quality.

In Reich, as in Young, Cage, and total serialism, the boundaries that mark the piece and give it a distinct place in a linear time sequence are missing. The internal principle of repetition does not identify a first instance of a motif, and its smooth surface presents no cracks where it might begin or end. As such, when the piece does begin or end, it seems to do so arbitrarily or in the middle. Moreover, Reich arranges his pieces so as to collapse the distance between a melodic line in the foreground and a harmonic motion in the background. In "Music for Eighteen Musicians," each instrument plays its own line, which moves enough to constitute a proto-melody while remaining sufficiently static to serve as a harmony and rhythm. When these lines are played together, the ear is free to choose any number of resulting patterns, melodic lines built by taking a note from one instrument and then a second note from a different instrument in the same register, and so on. Reich invites the listener to construct her own melody out of the music, while the harmony too is somewhat ambiguous, consisting only of the superposition of multiple melodies. He sometimes deliberately brings one resulting pattern into the objective foreground by doubling it with an independent instrument. That is, he chooses a melodic line already available in the conjunction of different instruments and assigns a new instrument to play it. Usually, this instrument begins softly and builds in dynamics, so that the foreground lifts slowly and imperceptibly from the background and then drops back again. Paradoxically, the effect of this doubling is to remind the listener that she is free to choose what to listen to, that the music does not impose a hierarchy of instruments or musical ideas but presents itself on a plane where any element can be brought into the foreground simply by a shift of focus. No part of the performance is authoritatively sanctioned as more significant or particularly demanding of attention so that, in collapsing the distinction between foreground and background in the music, Reich also collapses the distinction between the sounds that are part of the music and the ambient sounds of the concert hall. When the listener is given license to listen to anything whatever, then there is no longer a basis for deciding what counts as music and what counts as noise. The blurry boundaries demarcating the beginning and end of the piece collapse this distinction even further. Reich himself is no better placed than the audience members to distinguish the essential from the accidental in performances of his compositions. Like the serialists before him, Reich relinquishes the decisive power of compositional authority in favor of a mechanical process: "I accept all that results without changes."[54]

In fact, he goes beyond mere acceptance to celebrate the contingent moments in his music. Though his compositions frequently employ a steady pulse, "it is actually tiny micro-variations of that pulse created by human beings, playing instruments or singing, that gives life to the music."[55] Each repetition of a motif includes microtonal and microrhythmic variations, as players cannot strike notes with exactly the same force, tuning, and timing from one iteration to the next. These glitches or imperfections act synergistically in ensemble performance, where *microphonic* individual alterations complement each other, to determine a *macrophonic* phenomenon; the uncoordinated dynamical inconsistencies of many players might bring a particular resulting pattern to the fore, or slight variations of timing might create an overall sense of tension as the whole piece is felt to slow down almost imperceptibly. Reich lays bare a musical conflict that inheres in every tradition, but most notably in Western classical music, between the ideal composition represented by the score and interpretative deviations from the score by conductors, musicians, technology, circumstance, fashion, etc. To render sonorous the musical force of this conflict, essential to the actual production of sound, Reich pushes the poles to extremes. On the one hand, the ideality of the composition is utterly ossified by his mechanical methods of composition: "once the process has been set up it inexorably works itself out." Every variable is accounted for, "all the note-to-note details and the overall form" are immediately composed by the process that generates them. On the other hand, precisely because the process is laid bare, we hear even more clearly the "slight irregularities in performance," the contingent elements that the Western tradition tends to overlook or ignore in its treatment of music.[56] One hears the process of the composition and, more important, one hears the musical force of this process in its tension with the vicissitudes of performance. To submit the composition to a process is to establish "a direct contact with the impersonal," to imbue the work with those cosmic forces that motivate and can be heard in it.

Alvin Lucier

Alvin Lucier arranges a room with a microphone feeding a tape deck and a second tape deck feeding a speaker. He sits in the room and records a brief text onto tape by reading into the microphone. This tape is then transferred to the second tape deck and Lucier's short speech is played back through the speaker. The recorded sound of his voice is rerecorded through the same microphone onto a second tape. This second tape is then likewise played back and recorded onto a third tape. The process is repeated thirty or forty times. The resultant composition, "I Am Sitting in a Room," is just the successive playback of each tape, starting from the original speech recording. Each iteration excites more of the room's vibrations, accentuating or exaggerating certain pitches in the original speech and attenuating or damping other pitches. The text-speech slowly slides from articulate words to a continuous hum of pitch, and eventually—even where there was a silent pause in the original, say, between two sentences—the noise of the tape and the room is selectively reinforced to produce an unbroken and perpetually evolving chord from an exhausted organ. Each room, says Lucier, has its sonic character, those pitches it chooses by virtue of its shape and other acoustic affects. The room is called upon to participate in a memory-machine; the room's memory, which interacts mnemonically with the voice, the recorders, the microphones, etc., becomes sonorous. Every sound is shaped by both the means of its production and by the space wherein it propagates. Lucier calls forth this space, this sonic signature whose repetition brings the room and equipment to the attention of hearing. The room remembers, and the ear hears this memory in the composition. Again, memory is not primarily comparative but productive; the room remembers *in* the sound, placing there its aural stamp. In the terms of acoustical engineering, the room is a complex filter, accentuating some bands of energy, damping others, and altering the phase (time shift) and the pitch (frequency shift) of any sound caught in its space. Moreover, the complex effects of the room vary widely over that space so that the precise locations of the speaker and microphone in the room crucially determine the sound of the recordings, and alternate locations would likely generate wholly different results.

Lucier captures in his composition the force of memory, as it conjugates time and space. His method of composition is the magnification of the *reverb* or reverberant character of sound, which lies at the junction of time and space. Reverb reminds us that sounds are never instantaneous but always heard over time in a duration. Reverb also reminds us that sounds do not reach us from an unambiguous source; we do not receive a transmission directly from the speaker or instrument. Instead, the whole room, the entire space becomes an instrument, which spreads out and shapes the sound in myriad ways. Sound is where time and space collide, where a room is mapped in compressions and rarefactions, sound translating space into time.[57] (Bats and submarines both effect the reverse translation, using sound to map time into space. Recordings, particularly vinyl records, lay time out over space, imprinting a duration into the spiral groove of a record. We might say that recording is a reflux or distillation in which time is boiled off, for time must be added back in to get sound, in the form of a steady motion of the turntable or tape heads, or the crystal clock in digital recording. Attali bemoans this distillation, for it makes possible the stockpiling of sound as a material possession.[58] Modern consumers collect sound in the form of records and CDs, storing up time they never make use of. Ownership of time as commodity takes precedence over the productive expenditure of time listening to or making music.)

Lucier's experiment confirms that memory's job in perception is to forget. For the room, while imparting its sonic signature, dis-articulates the text-speech even while remembering it. His words lose their definition progressively with each iteration until speech becomes music. But neither the room nor Lucier's process introduces this music into speech as something new, for the pitched notes in the final iteration can only consist of frequencies already in the speech to begin with, frequencies excited by the room. Speech is made to yield the music already in it while the room invites this music by spreading out the edges of the sounds, successively flattening the inflections, smoothing the consonants to give rise to a drone that one might hear in the music of Young or Charlemagne Palestine. The room effectively forgets inflection, crushing inflection into the innuendo whence it came. The most articulate sound is washed into the hum of noise. Lucier's stutter, a rhythmic punctuation in the original text-sound, becomes first a continuous consonant roll and, eventually, only another smooth glissando of pitches, open vowels streaming through virtual organ pipes, which render a stutter all but unthinkable. This is another molecularization of sound, a pulverization of words in order to instill a spatial memory of them, to bleed them into each other. In this sense, Lucier's reverberant technique places before the microphone the event at every juncture of sound and noise. His piece explodes the transition from inflection into innuendo, the dissolve at which sound melds into noise, inviting its close observation. Lucier and Stockhausen thus share an artistic goal but proceed by very different means.

Alban Berg

Adorno notes that already in Berg sound is molecularized to give it the smoothest consistency. Where Webern heads in the direction of the molecular with his pointillist techniques, Berg presses the sound even beyond a point, smashes the sound into ever smaller parts, "minimal distinctions," so that any parts might fit together, any juxtaposition become available. "The initial atomized material is fragmented still further, insofar as that is at all possible. The entire set of compositional interconnections arises in Berg from such dividing and subdividing. Thanks to this everything pushes up against everything else." The music proceeds entirely by immanent self-determination; any influence might be chosen, and no principle guides its progress. Such a music forges a new relation to history by allowing direct contact between the personal and the global. "The only listener to take it in properly will be the one who follows its flow from one bar to the next, following wherever it chooses to lead him. The attentive listener must expand and contract with the music, instead of listening attentively for correspondences." The good listener must relinquish her will to the music, yield to its directions, follow its inflection without anticipation; such a listener will become along with the music, becoming musical herself. Berg's music denies historical determination in favor of a will, which is not so much harmonious as problematizing. That is, the music is not homogenized or leveled in the exercise of an immanent will, for it is a will to difference, which never resolves itself. Adorno is particularly fond of Berg, for his music emphasizes both the lost possibility of a reconciliation between individual and culture but also the double-edged blade of this radical alienation. When sound is thus freed of history, any relation becomes possible, any events, any percepts might confront each other there in the music. Adorno notes the paradox that underlies this new relation to history, culture, and critique: On the one hand, "[Berg's] formal devices organize the flow of the music without imposing themselves upon it from above or outside."[59] But in the same paragraph, Berg's sound is said to be "unmistakably characteristic, never just results." His unique sound happens neither by accident nor by an imposition of the composer's will; the music must therefore compose itself. Berg's role is to atomize the sound enough for the subtle forces of history and harmony to take effect, to tease from the sound enough force to push itself forward.

Adorno's analyses typically tempt an allegorical interpretation. For example, he takes tonality to represent the harmonious accord of a culture, and departures from tonality to represent the alienation of the individual in relation to that culture. He reads this dialectic of subject and object in every aspect of music (see Figure 9). How will the music defer to current and traditional musical standards and how will it subvert them? The linear organization of traditional European art music has a universal history that elevates the objective and individuates the subject according to this objective model of identity. The subject, represented in music by a motif, is whole, interacts with other subjects, and demonstrates both continuity and development over time. It can stand in a harmonious or ironic relation to its culture, but there can be no radical alienation for a subject itself objective. To express genuine alienation of the subject from society is to make a point in music where memory is separated from its condition, where the piece proceeds only by immanent experimentation and not by the guided motion of an intact and global memory.

Theodor Adorno

But Adorno defies both representation and allegory, for his analysis demands always new criteria for a new piece and cannot be applied formulaically or mechanically. "Aesthetic objectivity is itself a *process*, of which anyone who conceives of the work of art as a force field is aware."[60] A force field is affective, it operates, and so compresses new histories, new forces at

Jacques Attali

object	subject
form	content
social	personal
belonging	alienation
homogeneity	heterogeneity
the contributions of history	the self-expression of the composer
adherence to convention	insistence on invention
determination from above	immanent self-determination
the odyssey and return of a theme	the fragmented wandering of same

Figure 9. Adorno's dialectical representations.

every turn. What makes it possible for Beethoven's late string quartets to capture the truth of their milieu is not the same as what makes it *im*possible for Schoenberg's free atonal pieces to capture the truth of his. "The criterion of the social truth of music today is the extent to which it enters into opposition to the society from which it springs and in which it has its being—in short, the extent to which it becomes 'critical.'" Truth is a question of critique, and critique only thrives under a constant reexamination of its object.[61] Adorno challenges the cultural theory of music and then meets that challenge by finding in the music under consideration just those forces it makes sonorous, those events, those pieces of history and fragments of persons, those affects and percepts that inhere in a given piece or oeuvre or style. One of Attali's foremost theses is that music condenses or compresses elements of its context, and it does so so effectively that it prophesies an outcome of the cultural context. "Music is prophecy. Its styles and organization are ahead of the rest of society because it explores, much faster than material reality can, the entire range of possibilities in a given code. It makes audible the new world that will gradually become visible, that will impose itself and regulate the order of things; it is not only the image of things, but the transcending of the everyday, the herald of the future." Music plays out a dialectic of forces in a society, all the forces that shape composition, performance, and perception, forces of history and economics, forces of science and a self-reflective art. These are the forces that subtend culture, and music accomplishes the prophetic precisely because it dramatizes the interactions of these forces. "The code of music simulates the accepted rules of society."[62] If, as Attali claims, music is capable of a faster-than-life dramatization of the interplay of forces, then this is because of the pulverization of those forces. Their fine consistency allows a more intimate contact in sound, and the surfaces where forces meet are more supple and slippery. A century is compressed into five minutes of sonic duration, and forces from opposite sides of the globe clash in an immediate contact that does not sacrifice their complexity and subtlety. The molecularization of sound in music breaks down forces without reducing their intensities, providing a forum or stage on which the tragedies, comedies, histories, and romances of a culture can play themselves out, a microcosm in sound as perfect and detailed as the macrocosm whose forces it condenses.

We might say that music addresses problems. "Whatever happens musically nowadays is problematic in the full sense of the word, that of a task that cries out for a solution, and one, moreover, in which the difficulty of finding a solution is inscribed in the problem."[63] The forces compressed in sound cry out as they crash headlong or rub against each other like cats; and their cry answers to the problem of their collusion. Sound is a problem posing itself while working itself out. Inflection bursts ecstatically from innuendo, a tectonic ridge thrust into audibility in the clash of terrestrial forces. Water flowing down a mountain: which paths will it take? Gravity, landscape, geology, meteorology, biology, happenstance, these forces and countless others struggle in a war without warriors to solve the problem of their *ensemble*, a momentary and radically contingent solution to a problem that only evolves but does not dissolve. Percepts and affects are the force fields in a concert or a comment or a composition. What strange torsions will these fields undergo at their juncture? Whorls of noise, time fractals, new dimensions, discontinuities, incompossibilities. One hears in the sound of the river a pebble in the riverbed, and the boatman's song too furrows the river's path which carries his echo along its banks and into its future. We earlier wrote of the interaction of temporalities as problematic. Timbre, pitch, rhythm, form, each answers to problems of physics, sociology, and neurology. Each temporality compresses percepts into a complex knot of relations, not only drawing strands of time into continuous durations but tying them together in an unstable tangle. And this complexity defies representation, demands always a new listener. A representational memory could never bring forces together into a problem, for representation eliminates problematic motion in favor of the identity of a static solution. Only because memory is perceptive and affective, because memory lives in sound, can it capture the forces of history and culture alongside the demands of the room and the ensemble; a representation could never be supple enough, fluid enough, to pose anything but the shadow of a problem. Theories of sound based on indexical measurement, or any method that stays on a single plane to analyze sound, cannot find room on that plane for sound's rich meaning. Of course, meaning seeps onto many planes; everyone hears only part of the elephant.

Representation has never been adequate, for sound has always been problematic. We must therefore reconsider the distinction drawn above between twentieth-century and other Western music. Though the above examples reference techniques of twentieth-century music, their analyses address characteristics that are essential to music and sound per se. Sound does not evacuate its internal repetition when organized by the molar repetition of a large form. Bach's preludes and fugues repeat figures that change according to a structure in harmony, rhythm, and form, but the repetition still supplies its own reason and so is not merely a result. Berg lays bare the immanent self-determination of his music, but music *always* operates in immanence: "It would be most annoying if it did not aim to say the most important things in the most concentrated manner in every fraction of [its] time."[64] Sound does not tarry in wait for the twentieth century but challenges the authority of form at every turn, drawing according to the demands of the moment whatever history it will. Mozart sometimes designates formal divisions within a movement by changing from one style of accompaniment to another, say from a species counterpoint to an Alberti bass. These techniques often prescribe even the minute details of the accompaniment. The history of music supplies to Mozart these techniques and governs their use to create a standard structure that builds tension through harmonic motion. But this tension and the sections that construct it are only effective inasmuch as they generate their motivation intrinsically, offering sonic reasons beyond formal requirements. Even Mozart, for whom composition came easily, had to start his compositions with a problem. What piece of music, what sound does not pose and respond to problems? Everyone claims to hear Beethoven's struggle, Wagner's torment. But having heard these, cannot you now hear Hildegard's ecstatic frustration at her earthly limits? Or Debussy's aching discipline? Bob Dylan protests not just with his words but with his voice, instrument, and body. Glenn Gould, Itzhak Perlman, Keith Jarrett, and Joe Cocker are twisted, contorted by the forces they engage when they make music. Bathing in electromagnetics, today's musicians hunch over keyboards and mouses (!), searching for something new in sound. Every composer, musician, and listener introduces into the mix a new set of problems, unheard-of forces. The twentieth century invented plenty of new approaches to sound, explored and exploited it in ways formerly impossible, but sound was always and remains always problematic, at the conjunction of new and different forces. To forge within monophony the differences of homophony, heterophony, and polyphony; to select just that part of polyphony that constitutes counterpoint; to liberate the harmonic line of counterpoint from melody, achieving harmony's autonomy; to stray from the Church modes into uncharted tonalities; to release music successively from the grip of melody, then harmony, then form, opening new dimensions of sound to explore. Each of these moments in the history of Western music advances not by the discovery of a new property of sound but by the creation of a new difference where there was formerly continuity. The genealogy of music—which will be repeated in every sound as the spark that leaps from innuendo to inflection but will in vain be sought in sound's prehistory—this genealogy begins by marking a difference in time, separating out temporalities, pitch from rhythm from form. Music innovates by opening gaps, by cracking; the composer's pen and the musician's fingers and lips are pliers, which wrench open or tear the existing fabric of music, enlisting countless forces in their service. Sound's history is thus intertwined with technology, as new tools make possible new sounds. What takes place at the intersection of electricity and sound, computers and sound?

T H R E E

Sound and Digits

The Question Concerning the Digital

FIFTY YEARS AGO, around the time when computers became machines, Martin Heidegger questioned concerning technology. In a primordial sense, the essence of technology, says Heidegger, is to bring something about *(poeisis)*, to send something into the light of being. What technology lights up is how things work. When we do things with it, technology pits forces against each other and pools them together in order to solve our problems and so serve our ends. As such, technology reveals those forces it brings to bear, those problems it addresses, and those ends it serves; it brings them forth into presence. Heidegger's example of premodern technology is a chalice, a cup being fashioned. Its shape is a solution to timeless problems of fluid dynamics, to ancient problems of transporting and storing liquids, and also to problems of metallurgy, of beauty and money, fingers, lips, and noses. It reveals or lights up these problems and also manifests much else, including the hand that wrought it and the God whose praise it radiates in a ceremony of worship. This is the original, premodern essence of technology: to make a human world show itself in all the complexity of its relations. Technology is invention, whose mother is not only necessity but desire of all sorts.

So why, if Heidegger regards technology as essentially creative, is he taken to be so cynical about it? After all, he is certainly fond of creativity: for

Heidegger, technological *poeisis* has the nobility of truth itself.[1] If he nevertheless disparages technology, his concern derives chiefly from what technology has become in modernity. Modern technology does not take its cues from presencing or truth; rather, it *sets upon* the world, ordering that world to make it available for human being.[2] I drink today from a machine-made cup, untouched by human fingers. The cup serves. It refers no longer to its creator or to its immersion in any of the many worlds through which it passes, materially, historically, economically. It is rather at my disposal, ready to serve, and as such is also disposable (the paper cup). The cup constitutes part of an order whereby I shape my world to place it at my disposal, rendering the world's resources available for use when and where they are required. For Heidegger, technology in modernity is ruled by the human way of setting thus upon the world and so casts everything according to its single narrow perspective. But its persistent focus is part of why modern technology is also so *effective*.

Narrowly determined according to a way of setting upon the world, modern technology has a measure: one applies technology *in order to;* and one measures the result according to this *order.* Measure allows technology, both means and ends, to be refined, honed by a standard of precision. Technology sets upon nature, demanding that it be "identifiable through calculation" and "orderable as a system of information."[3] For nature does not order itself. It must be manipulated, its materials and forces extracted, isolated, and stored for ready access in warehouses and batteries, test tubes and tofu. Extraction, distribution, and refinement are the most efficient path to a given end; they are modern technology's techniques, through which it institutes its *order.*

Given technology's affinity for order, it is no wonder that it is so closely allied with the digital; ordering is what digits do best.[4] Refinement, precision, storage, isolation, these are the powers of the digital. Using numbers, *digits*, to measure and count things, we can impose on those things a precise order. Digits provide a universal standard that is easily transportable, exactly duplicable, and broadly applicable. Analysis of digital data allows the immediate detection and correction of variation across space and time. Accurate predictions are possible in extraordinarily complicated circumstances: just crunch the numbers. The digital implements an immaculate ordering that isolates desired properties and gives verifiable, repeatable, and measurable definitions. The digital thereby amplifies technology's powers in many ways, stamping the world with an order that is both highly malleable and utterly consistent.

What makes a technology digital? The digital is a logic, an abstract code underlying the technology's effects. A digital camera is digital because it turns light into numbers, encoding a flat image into a sequence of values that represent the color and intensity of pixels. A chip in a toaster is digital because it evaluates certain conditions as discrete quantities (the settings of the knobs, for instance), and alters other conditions (such as which heating elements are on and for how long) according to those evaluations. The computer is digital in that everything it accepts as input, everything it stores, and everything it generates as output are, in effect, numbers. And every manipulation of these numbers follows rules that are determined by logical instructions, reducible (and in fact generally reduced) to 0 and 1, on and off.[5] The computer operates by moving electricity around through silicon chips and other media, and the "gates" through which it flows are, at any given moment, each either open or closed. Logically, the computer is a huge network of intersecting pipes, and each intersection either allows the electricity to pass or prevents it.[6] It is this condition—this general principle of operation according to an abstraction whose rules are immanent to its code—that defines a technology as digital.

One cannot exactly point to a 0 or a 1. One can point to a condition that counts as 0 or 1, but this condition is a measure of voltage or magnetic field strength or some other physical value. The binary code is thus an abstraction, but it is nevertheless effective, for it governs the operation of digital technologies. Whatever "objects" appear on your computer monitor are representations of digital data, so that "inside" your computer these images or file names or window designs or check boxes are only a series of numbers and, ultimately, a series of binary values. Anything that gets stored on a computer is mediated by this binary code. Any alteration, any processing the computer does is definable according to this binary code, so that the capabilities and limits of the computer are confined by the possibilities of the binary.

The binary digit or *bit* is the brick from which digital order is built. Everything digital is made of 0s and 1s. Bits are strung in sequence, a string of 0s and 1s, and each bit is identified uniquely by its place (order) in the sequence. Often, a sequence is taken in groups of consecutive bits, where each group of n bits in a row represents a number between 0 and 2^n-1. (Just as n decimal digits [0, 1, 2, 3, 4, 5, 6, 7, 8 or 9] in a row can represent any number between 0 and 10^n-1.) Groups are usually a standard length (eight bits in a row to make a byte, for example), so that a sequence of bits represents a sequence of (higher) numbers, which themselves represent data. For example, the ASCII standard uses the numbers from 0 to 127 (seven bits for each number) to represent a set of text characters. The numbers 65 to 90 represent upper case *A* through *Z*, with other numbers set aside for lower case letters, *space*, various punctuation, and more. ASCII code thus allows any text (or at least any sequence of characters) to be represented as a sequence of numbers, and, conversely, any suitable sequence of numbers can be represented as text.[7] Everything digital is made of such a sequence of numbers. A computer performing a search, whether for text or for fingerprints, is simply comparing groups of numbers. Content drops out of the picture: image, music, text, nothing but ordered bits. The digital represents everything according to this same order, which hegemony is the source of both its great power and its grave danger.

Ordering, the digital represents, but what does it represent? Lots of different things are digital: what they have in common is their *form*, a string of 0s and 1s. To treat something as digital is to operate on form as the digital turns everything into in*form*ation. Digital storage, digital images, programs, sounds, data, text, all come as a list of digits, each of which is on-or-off, yes-or-no. Whether it is on CD, hard disc, or punch cards, in a vacuum tube or fiber-optic cable, if it is digital, it has the same form, a sequence of bits, where each bit is represented by some (ordered, binary) property of the storage or transmission medium. The digital achieves its breadth of application by dint of its form but also discovers its ultimate limit in its form. *For the digital has nothing but its form and so can represent* only *form.* The digital can accommodate a great many things, from operations to objects. But what it takes in each case is always only form. Thus, one can use any digital storage medium to store any digital information. The differences among media (storage density, ease of access, reliability) are nonessential characteristics; all digital media *do* effectively the same thing. As far as the information is concerned, the medium does not matter since the form is the same in each case.

Form and form alone can be exactly duplicated, whence the celebrated perfection of the digital copy. The digital captures the general, the representable, the repeatable, but leaves out the singular, the unique, the immediate: whatever is not formal. Actuality always exceeds its form, for it moves along lines that connect singularities; the actual is not a neat sequence of frozen or static moments but an irreducible complex process that cannot be cleanly articulated in time or space. By contrast with the actual, the formal includes only stasis, what remains fixed long enough to be measured, determined, specified. Whereas form is definite and can always be re-presented, the actual can be copied but can never happen again. Purely formal, the digital grasps only form and so falls ever short of actuality.

Critics of the digital identify its pure formality as a great threat or, as Heidegger says, a danger. The digital is nothing but form, and form can always be perfectly reproduced with the right *formula*, anytime, anywhere. A digital world has no uniqueness or immediacy, for it is inherently generic, treating every place as an abstract space represented by reproducible numbers, every object as a type defined by precise values. To live in such a world is to have reproducible and generic experience; everything in cyberspace, from location to object to event, is a matter of a set of numbers that can in principle be exactly reproduced.[8] But what would it mean to live in a digital world? Just because one's experience involves digital technologies does not mean that one is experiencing the digital. Moreover, one might encounter the digital not only through its technologies but also elsewhere. We must investigate, then, without presupposition, how *we* relate to the digital.

We need not look far to find a guidepost for our investigation, for we already bear an immediate and ancient relationship to the digital. Fingers, those primordial digits, are implicated in much of the activity that makes us human. Like the modern digital, the ancient digital also derives its power principally from an intimate relationship to form. Digital technologies enter into so many aspects of daily life, but fingers cover a far greater domain. Fingers draw, point, crush, connect, grasp, throw, cut, turn, examine, feel, feed, wave, reach, massage, muffle, tie, carry, repel, signal, underline, and more. These activities are not variations on a theme, for fingers introduce a novel relationship to everything they touch; they open a new dimension in each of their endeavors. Their scope is thus even broader than it might at first appear since they are not only widely used but used differently in each case. What brings them together is that, drawing or kneading, waving, counting, or grasping, it is by virtue of form that fingers cling to their activities and primarily through form that they shape the world. Though there is no common form that fingers manipulate, it is in every case their own form that lends them to their task and connects them to diverse other forms. The form of fingers appears at first glance rather straightforward: fingers are clearly structured or articulated. In fact, they are twice structured or articulated: each is divided from each other, and each is divided in itself. It is this pincer, this double-articulation that gives them such a wide grasp.

More than just the form of fingers, double articulation is the very principle of their form. Which is to say that each articulation is itself doubled to join heterogeneous elements. Each hand is opposed to the other, but each is also differentiated in itself: the vice formed by left and right hands broadens and refines its reach by the further articulation of thumb from fingers. The thumb is one finger among others, but it is also unique among fingers in its opposition to the others. Fingers are united by their mutual opposition to thumb but divided twice; each is divided from the others at the first knuckle (or, according to the skeletal structure, at the wrist) and articulated again within itself by the other knuckles. Each knuckle lies between heterogeneous divisions, themselves further articulated.[9] These multiple double articulations do not simply divide into two parts, but divide asymmetrically, so that the resultant parts are not at all the same. Left hand and right hand are not indifferent doubles, enantiomorphs,[10] any more than the thumb is simply the opposite number to the fingers. It is not the mere fact of division but the difference in excess of this division that provides fingers with their powers, immense and subtle, over form.

If fingers derive their extraordinary aptitude from their double-articulated form, we might examine more carefully the form of the digital to see if it operates along the same lines. What, besides articulation, does the digital have at its disposal? The binary is nothing but articulation, a simple difference between 0 and 1.[11] And it is a particularly refined articulation, an immaculate specimen: according to the form of the digital, every bit is either on or off. However, as with fingers, this single articulation is not enough. To be effective the digital requires another articulation. Consider the process of digitization. To apply the binary to an object, it must be first divided into parts—slices of time (samples), or space (pixels), or some other aspect of the thing (pieces, steps, characteristics, etc.). Then, each slice, each little piece, is evaluated according to a determinate scale and assigned a number. In the case of sound digitization, a sound is divided into small chunks of time (samples), and each sample is evaluated by measuring the air pressure at that point in time. In the case of image digitization, a flattened image is divided into tiny quadrants (pixels), each of which is evaluated as to hue and intensity. Even computer programs are double articulations: a task for the computer is broken down into smaller tasks (subroutines or operations), and each of these is given a value that corresponds to a particular action for the computer to take.[12] A first articulation of parts and a second of values: IP addresses, characters, databases.[13] Computers represent everything in parts, and everything must be divided into parts in order to get it into a computer. It is therefore quite appropriate that the fundamental digital unit is a bit, or *binary digit.* Even a bit is a small piece, one among others, distinguished from the others by its place in the sequence of bits and within itself by its definite and discrete value, 0 or 1.

It is therefore not just the number two, the binary, that gives the digital its power. The number two must itself be doubled, applied twice, to assume its greatest extension. Just to represent a number requires a double articulation: an ordered series of bits occupies two dimensions. For, on the one hand, the bits are spread out linearly, each divided from each, while on the other hand, each bit is either a 0 or 1. Binary numbers have a first articulation (the *n*th place) and a second articulation (0 or 1 in each place).[14]

Though the digital shares with fingers a double articulation and its attendant power, there is a significant difference in the nature of its articulations. Fingers are not wholly distinct from each other, nor each in itself.[15] Who can say where one ends and the next begins? Fingers exceed their form, and in their actions they touch more than form. They function as digits—indeed they lend themselves by their articulations to counting—but they always overflow that function as well. By contrast, the digital is entirely equal to its form, is nothing but its form. Digital articulations are immaculate, exact. The distinction between 0 and 1 is absolute, and this absolute difference carries over into the differences between two pixels, or two samples, or any two digital data. This confinement, this formalism, is the source of the digital's danger but also of its potential. Its equivalence to form means that our interactions with the digital offer a unique exactitude, robustness, repeatability, transportability, and applicability, but these powers are gained only by a reduction to formal qualities.

The exactitude deriving from the digital's equivalence to its form—the fact that every 0 is just 0 and nothing more—must not be confused with an infinite precision. On the contrary, the digital is calculably imprecise; it measures its object to a given level of accuracy and no further. Rather, what digital exactness means here is that 0 and 1 are, right from the start, completely determined, identical to themselves. Given its value, there is no more to be learned about a digital bit. Between 0 and 1 there is nothing, no *mi-lieu*, no remainder, so that a given bit asserts its blunt edge as the limit of its subtlety. Between two fingers, between any two actual individuals, there is always something more, something fuzzy, something to-be-determined. An actual individual's borders are never finally fixed, leaving open a space of exchange, neither this nor that; but a digital determination is utterly complete and perfectly divided from its other. Completeness here does not mean that the digital provides a representation of all of the actual object, for it leaves out a great deal. Rather, it presents its own completeness, its absoluteness or baldness, its total lack of concealment.

That the digital holds nothing in reserve, that it leaves nothing concealed but is equivalent to its presentation, would seem to preclude it as a site for the coming-to-presence of truth, at least according to Heidegger. Fingers and other actual things are always open to question and will offer ever more to a penetrating investigation. But the digital has shown everything in its initial appearance and so provokes no questions, poses no problems, demands nothing of its observer. With the digital, as Apple said in 1984 of its "revolutionary" new computer, what you see is what you get. (Note also the etymology of the word *data*, from the Latin *dare*, to give. Digital data are givens, and are, as such, not open to question.)

The determinate exactness of the digital suggests another perspective from which to regard its shortcomings. There is an inherent difficulty in the process of digitization, for the actual is fuzzy and imprecise and so does not lend itself without alteration to digital representation. For example, there is no such thing as an actual exact color that would correspond to the standard digital three-value representation of the color of a pixel. To overcome this difficulty, the digital operates by establishing thresholds in the qualitative continuum of the actual. These thresholds mark an absolute distinction, transforming the actual world of continuously varying qualities into the digital world of discrete and exact quantities. By dividing the actual into ranges of quality defined by endpoints or thresholds, the digital makes a range of the actual correspond to an exact value: 67 percent red, 31 percent blue, and 10 percent green corresponds to a small range of burnt orange, which may vary slightly over that range without crossing the thresholds (the value of a single bit) that would alter the percentages.[16] The gap between two thresholds (the *resolution* of the digital representation) is a range of quality; but the digital imposes a uniform value on that entire range that erases the difference of quality in favor of the stasis and consistency of an exact and determinate quantity. Divide and conquer, the strategy of the digital, which reduces the heterogeneity of an actual range to the homogeneity of a digital value but as such allows the exact comparison over time and space of a digital object to itself and to others. The digital, by virtue of its discreteness, establishes an absolute standard of sameness and difference, distinct thresholds that are either crossed or not.

Surely something is lost when heterogeneity is covered by homogeneity, but what gets left behind when the digital divides in order to represent? The digital misses whatever falls between its articulations. The digital has a resolution, and detail finer than this resolution is ignored by the digital's ordered thresholds.[17] This suggests that higher resolution and tighter thresholds approach a complete capture of the object, a digital representation adequate to the object represented. But this suggestion effectively treats the actual world as already digital, a world built from parts, irreducible bits and pieces assembled into the familiar objects around us. On the contrary, what distinguishes the actual from the digital is a haecceity, a "hereness" or singularity, wherein the actual testifies to its generation. There will always be an excess, always more than the digital can capture, because the actual is not fixed and static but creative. Actuality is not the sum of elemental facts, as was the positivist fantasy in the first half of the twentieth century, but includes essentially a force of productivity that sets it in motion.[18] What the digital misses, therefore, is not so much what falls between its thresholds but the creative power of the actual that will always defy fixed or static representation. This missing haecceity is not a further difference, not some*thing* about the object that gets missed, for any such thing about the object is amenable to digital capture. It is rather a productive difference, a not-yet-determined, an ontological fuzziness inherent to actuality itself. Every particular difference left out of a digital representation can be incorporated in the next round, the next scan, the next interpolation, but difference as productive cannot be digitized. The digital makes of every difference something external; it can divide and conquer but its divisions are always from the outside. According to the logic of double articulation, the first articulation is outside in the sense that it divides a thing from others but not within itself. The second articulation divides a thing within itself but only by cleaving it in twain, which still leaves two parts whose internal differences remain within themselves and do not give themselves over to the digital. Neither articulation reaches the creative force of difference, the differential power of the actual.

This is to say that productive actuality is not equivalent to its form; only the abstract, the ideal, can be equivalent to its own form. Though its idealization as pure form places a fundamental limit on the digital relative to the actual, its abstraction is also the source of the digital's great power. Each bit is precisely and immaculately separated from its neighbor; every pixel has a distinct and exact value. A digital datum holds nothing back, no margin or fringe of uncertainty. The digital only deals with problems in this refined domain, where everything is crystal clear. In a standard computer, nothing is uncertain, nothing is undetermined, and, at least in that sense, everything is perfect.[19] If this falls short of the plenitude of actuality, it has the great advantage of allowing complicated manipulations of huge numbers of elements without confusion and with definite, repeatable, and even undoable results. We can operate on just those parts of an image with a given percentage of red, leaving the rest alone. We can delay a combination of exact frequencies of a sound, to alter a voice undetectably, instantaneously, and consistently.[20]

Consistency, measurability, and abstraction are the hallmarks of any standard. If the digital is becoming rapidly ubiquitous, if its application seems to know no bounds, this is due to its fantastic ability to serve as such a standard. As pure form, it provides a standard of measurement and comparison across space and time. By representing the formal properties of an object independently of the object itself, we can effectively compare that object to others, or to an established standard, without needing any actual experience of the object. Weight, size, shape, texture, color, composition, and other properties can be formalized and carried from site to site, or transported electronically, to allow distributed cooperation and mechanized labor. With a universal, generic, formal standard, a process can be broken down into spatially and temporally discrete parts that need no longer have anything to do with each other, to create elements that are unrelated until a final assembly. The digital obviates the need for an overseer or a template by abstracting the standard in a set of formal requirements; the standard itself, the form becomes the final measure.[21] This standard, the form represented by digits, has only the thinnest dependence on any actuality. A few pieces of paper can store all the necessary numbers to represent the full details of huge rocket ships or manufacturing processes. A compact disc can store encyclopedias full of information in a format that fits in a coat pocket.

It is not just that the digital provides a standard that can be readily reproduced and replicated, and which allows for easy and unequivocal comparison. It is also that the digital *is itself* a standard, a standard form for representing objects, for storing, manipulating, analyzing, and transmitting information. The digital is able to accommodate a huge variety of different kinds of information, but in each case, it can store it on the same media, transfer it over the same lines, and manipulate it according to the same rules. The same analyses that reveal information about images also tell us about sounds and other data. A database, stored as digital data, can be analyzed using the same statistical techniques regardless of what data are actually in it. The notion that everything should be or can be digital is increasingly popular, and it is a dream of a universality whose proportion is matched only by such significant innovations as writing, language, and money. Besides these, what else is as broadly applicable as the digital?[22]

This sense of the digital not only as the representative of standards but as itself a standard for representation relates to the "inherent mutability" of digital content.[23] Digital discreteness, its exactness, its pure formality mean that digital data are indifferent to their content, so that a digital representation of a sound can be seen as well as heard.[24] Digital data can be isolated from the data set, manipulated independently, and then restored, while evidence of this selective tampering can be erased.[25] These sorts of arbitrary and selective operations are vastly powerful. Consider just the power of search-and-replace in a document or the possibility of rapidly sorting the millions of lines of text on the Internet by their relative relevance to specified digital criteria. Search engines routinely retrieve sorted lists of relevant Web sites in fractions of a second. The standardization necessary to allow such operations is made possible by virtue of the formal simplicity of the digital. There is no content to complicate things, to resist manipulation, nothing that requires special consideration.

So the digital achieves its vast extension and extraordinary powers by virtue of the purity of its form. It also risks by that same purity a significant impoverishment of our world. To avoid the danger of the digital while reaping its benefits would be the ideal circumstance, but we do not yet know whether this is possible. To tease out the advantages from amidst the hazards, we must inquire still further into the genealogy of the digital. Where does the digital go astray? How comes the abstraction by which the digital breaks its connection to the actual? Or perhaps we should ask the converse question: how do fingers succeed (where the digital fails), maintaining a connection to the actual while operating at the same time in the realm of form? Let us take a further step into the conceptual and etymological history of the digital.

Digital discovers its origin in the word *deictic.* This is a current if uncommon word in modern English, used primarily in logic and linguistics. In logic, a deduction is deictic if it demonstrates its conclusion directly, as opposed, say, to a *reductio ad absurdum.* Linguists designate a word deictic when it is used to point out or indicate something, as is the pronoun *this.*[26] In both cases, and in its Indo-European root *(deik-)*, the deictic is a showing, but not just any kind of showing is deictic; the deictic does not show by example or reference but directly. It shows what is already here before us, the immediate, the present. (This is not, therefore, the kind of showing or *poeisis* that Heidegger discovers at technology's heart, which, as creative, shows what was *not* already before us.) The word *this* epitomizes the deictic precisely because it always and only refers to the immediate: this here now. In his study of *this*, G. W. F. Hegel provides a useful analysis of the nature of the deictic and points the way toward an understanding of its digital progeny.

In the opening pages of *The Phenomenology of Spirit*, Hegel analyzes the deictic by considering the nature of the *this*. He discovers that *this* has two moments and passes dialectically from one to the other.[27] On the one hand, *this* is the immediate and singular experience of whatever is before you; *this* refers to the concrete being-here of *this here now*, to brute experience. On the other hand, *this* also has a mediated, abstract, and universal character: *this* refers to nothing in particular since it refers to anything at all that happens to be before you. We cannot be satisfied with either of these moments, says Hegel, because both are effectively empty.

The singular moment is empty because it has no form; whatever *this* is, as soon as it becomes definite, takes on a particular form, as soon as it becomes something *for us*, it is no longer *this* but now *that. This* refers only to what *is*, not to what just was. As Hegel points out, the truth of the concrete experience of an object is in that very experience. *This* is the immanent affront of sensation, and it bears no description, no form that would mark a distinction in this immanence; *this* has only an immediate and fleeting existence.

The universal moment is empty because it lacks any content; to be universal is not yet to be anything in particular. *This* just refers to whatever is before you at the moment. The universal *this* is thus a placeholder, the general form of whatever can be before you but without any specific content. Lacking content and utterly general, the universal moment of the deictic cannot even be said to be a form. Rather, as the form that might be any form, the universal moment of the deictic is the very form of form, the form whose only content is form. Likewise, without form, the singular moment of the deictic is not even a content, but the content of content, that which gives content to be formed. One moment of the greatest abstraction, *this* that might be anything, and another moment of the greatest concretion, *this* that is only the immediacy of experience. Form of form and content of content, the deictic passes from one empty moment to the other. As form does not meet content in the deictic, its articulations never take hold, do not endure, but mark in a moment only the entirety, the being-present of that moment. *This* does not extend beyond its immediate and instantaneous context, and Hegel is compelled to pursue truth beyond the deictic.

To make a lasting articulation, to spill over the immediate, the deictic must effect the meeting of form and content, which is to say, it must become incarnate. An articulation that lasts, a *this* that endures requires a deictic made flesh, for where else but in the flesh does form meet actuality? Fingers retain the two moments of the deictic but no longer as immaculately separate; fingers inhabit and admix two worlds, the material concrete and the abstract formal.[28] To fingers, *this* is both the concrete object whose surfaces they meld with in a direct contact, but also the abstract object whose points they align with, fingertip and knuckle arranging forces to a suitable shape and size according to the form. Fingers thus hold on to *this* while it remains *this;* they pin down the abstract in the real, forging a direct contact with the actual in order to meet and manipulate form. Any hand can throw a ball, steer a wheel, or knead bread, for every hand shares the same form, applicable by virtue of that form to each object. But every hand leaves behind its singular fingerprints, attesting to the actual meeting of surfaces, to the haecceity that the formal application of fingers does not evade. From the deictic, digits inherit an intimacy with both form and actuality, articulation and haecceity, and fingers do not touch the one except in and through the other. Fingers thus occupy the liminal surface between form and the actual (but also between our insides and outsides, passion and action, sensation and activity, etc.).

The digital retains from fingers an intimate relation to form but severs all ties to actuality, excluding from its pure formality all contact with haecceity. The move from digits to the digital is clearly a process of abstraction, but at what point in this process does content or the actual get left behind? In order to count with them, we align fingers with objects in the world. Fingers measure an amount, they are matched against whatever needs counting, be it figures on a hilltop, trees in a grove, or other fingers. In this alignment, fingers become placeholders, tokens[29] that stand for the objects they count, and manipulations of those fingers yield results that apply to the counted objects.

Note that in this usage, fingers lose their internal difference. As tokens or representatives, one finger is as good as another, and my fingers are equivalent to yours. If there is still a distinction, it is the merely formal distinction of place: as counters, second and fourth fingers do not differ in themselves but only in the order in which they are assigned. When the finger is removed from the hand to become a line on the ground or on paper, when the finger no longer points to what is before us but to an abstract or absent case—the general—then we are no longer employing its singularity or haecceity but treating it as a member of a species, an arbitrary digit, one among others. Soon enough, fingers give way to other tokens (stones, beads, dollars), signs and sounds, and these various practices of counting constitute numbering per se, which grounds itself in fingers but encompasses a variety of tokens and their uses. (In this sense, phylogeny recapitulates genealogy, for children learn to use numbers along these same lines.) Not only is every finger, as a counter, equivalent to every other, but tokens are generally interchangeable, and we choose to count with signs, sounds, or material tokens based purely on convenience, for the end is the same in any case. Each of these things loses its specific content, its haecceity, when it is used for counting to become a general representative not of an object to be counted but of a step in the process of counting.

Not just anything could serve as the basis of numbers; neither tails nor teeth fit the bill. The possibility of aligning fingers with countable objects is not invented from nothing but derives from their form. Prior to counting, we discover in holding hands the align-ability of fingers, the way in which they match each other to the point where they are almost indistinguishable. (Hand-holding is possible by virtue of the multiple articulations of fingers but also by virtue of the complementarity of left and right.) Where I impress my fingers in clay, there your hand too will find a grip. The manual manipulation of form is almost always generalizable: what one hand can do another can soon learn, primarily because the hand operates almost entirely through its form, and we all share this same form. Alignment is thus given as part of the hand, so that the hand, by its nature, already directs us toward the abstraction of counting. (Alignment relies also on the liminal character of fingers, noted above. Fingers could not become alignable objects if they were too close to us.

Though part of the body, the hand is also *at arm's length*, so that one can see and otherwise experience one's fingers as external objects to be manipulated, aligned with other even more distant objects.)

With this genealogy of the digital in mind, we can appreciate more perspicaciously its deficiency. When the digit is itself abstracted, it loses touch with the actual and so renders all difference extrinsic or formal. The digital still makes two articulations, but it substitutes in both cases an external, formal difference for an actual, productive one. The difference between 0 and 1 has nothing to do with 0 or 1, either of which, when taken as a digital bit, is strictly nothing. The difference between 0 and 1 is external to them both; it is just a formal difference and what it divides is itself only form. Whereas the fleshy articulations of fingers divide heterogeneously, leaving always an actuality to be further articulated, the digital makes two only by repeating one, which is why there is no positive difference, no internal difference between 0 and 1. They are exactly the same, only formally distinct, and could be wholly interchanged in the digital technologies that make use of them. The second digital articulation, of the object into parts to be measured, is also a means of making difference external. As far as the digital division goes, there is no difference remaining internal to the digital object. It is entirely comprehended by the formal distinctions that represent it.[30]

This analysis demonstrates the further conclusion that the digital is hermetic. Whereas the deictic remains in a context, whereas it necessarily operates in an already shared space, the digital, which makes two only by repeating one, no longer points outside of itself. It is a binary that is effectively not doubled, a binary that refers only to itself, which confirms Jean Baudrillard's digital interpretation of the twin towers of the World Trade Center.[31] Certainly, the digital is doubled, and more than once, but lacking any actuality and with only formal difference, its doublings never leave the plane of the digital to point beyond it.[32] Imprisoned in its own domain, the digital does not refer or show directly (the hallmark of the deictic) but merely represents. If it refers at all, it refers to the generic, not to a particular actual but to a species of them, a type. The digital makes contact with the actual only by accident or convention and only through the mediation of the nondigital. Which is why digital signature, digital time-stamping, and other techniques that attempt to mark a digital object as unique are so problematic.[33] The digital is never unique, never singular. It represents but does not present.

This understanding of the sources of the digital's power and the extent of its limitations allows us to look anew at the danger it poses. Indifferent to content and material, the digital renders everything it touches in the pure abstract form of form. When the digital is our means of approaching the world, when we apprehend and interact with the world through the digital, then we risk reducing everything to its form. In the digital, all differences become formal differences, all value becomes formal value. We can measure, quantify, and compare everything in the digital world, all according to a single, universal, formal standard. Human beings, apprehended as digital, are nothing more than a sum of formal characteristics: a digital résumé, a set of statistics, usage habits, sites visited, marketing target groups, a digital voiceprint, a digital signature, a digital image, homepage, ISP, IP address, screen name. Digital art foregoes aura by default to become generic, reproducible, equivalent to its representation. The digital world does not offer each time a new experience, does not unfold itself to reveal unique forces gathered from the depths of history, for a digital object is static and without history. It offers instead the promise of generic and repeatable experience, measured by bandwidth, buyable by the byte.

This conclusion—that the danger of the digital is a reduction to form—should come as no surprise, for it is just this fear that thinkers of the digital have expressed in their commentary. Distrust of the digital resonates in the popular imagination, and skeptical questions are reiterated and codified in an endless stream of books and articles on cultural theory and technology. (Most of these questions relate to the Internet and to computers, as those technologies are the best representatives of digital technology in general.) Does the digital impoverish our experience of the world? Do computers, despite their promises of enrichment, actually offer only sad simulacra of reality, flattened images of finite resolution, 1024 × 768 pixels, at 120 Hz? Is the excitement and danger of fleshy human contact a thing of the past, replaced by low-risk encounters in chat rooms and Multi-User Domains (MUDs), where only data pass from one person to another? Does the Internet narrow our daily experience, confining us to predetermined possibilities and outcomes? Is choice—which was once a question of the creation for yourself of a unique path amidst the infinite possibilities that the world presents at any given moment—is choice now only a matter of the selection of one of a finite number of links determined by the Web site designer? Does the Internet tend increasingly toward corporate control, the capitalist model, where the digital is just another form of money, a general equivalent that serves to define and measure all value? Does the digital, by guaranteeing the absolute equivalence of every copy, destroy the preciousness and fragility of art, obliterate beyond memory the singularity of the "live"? These are the pressing questions of the digital, posed in the margins of the mainstream by unlikely comrades: academics, intellectuals, the elderly, artists, Luddites, the Unabomber, naturalists, environmentalists, the disenfranchised, communists, and crazies. Their warning cries are loud enough to hear, if one listens carefully. Each of these many questions derives from the issue raised above: does the digital reduce experience to pure form, make every difference effectively equivalent or homogeneous?

Not to worry, assure the champions of the digital, only good things can come of it.[34] The affordability of digital technologies, the decentralization of the Internet, its unregulable character that defies national borders and subverts existing law, all ensure that the Internet and its associated technologies will serve populist interests, will bring a richer world to a greater variety of people, will break down the distinctions of class, ethnicity, and access to information that adhere so closely to national boundaries.[35] Though this promise is suspiciously utopian, it derives from real properties of digital technologies. From one perspective, browsing the Internet presents the user with finite and limited choices, predetermined by the Web designer or DHTML code; this limitation is consistent with the pure formality of the digital as analyzed above. From another perspective, the Internet appears to transcend its digital medium, to become an organic aggregate, rapidly changing its nature as more users contribute more parts, new technologies and techniques create new means of interacting, and production tools fall increasingly into the hands of inexpert users. Artists push the limits of digital technologies, stretching them to do things impossible only yesterday and creating a demand for the greater bandwidth that seems to make of the Internet a more palpable, more material, more detailed, and more real experience. Though much digital technology is advanced by corporate interest, and though the bulk of Internet use is guided by corporate concerns, there is also the possibility, frequently dangled before us, that the Internet enables grassroots organization, that it allows small, geographically dispersed communities to gather members and share ideas, that it disrupts the bond between power and wealth by making potent tools inexpensive and available to many, that it encourages elective participation, the subjugation of standard categories of identity, community-based politics, self-determination, and autochthonous organization.

Whence arise these optimistic possibilities? How can technology based on a sterile medium of pure form give rise to any sort of freedom, spontaneity, or creativity? Perhaps these hopeful promises are merely the duplicitous propaganda of those corporate interests that champion the Internet in order to make the bitter pill of global capitalism easier to swallow. (Positive rhetoric surrounding digital technologies is both populist and individualist, appeasing at once the cynical Left and the reactionary Right, who suspect all technology of being means by which dominant forces control dissent and enforce appropriate behavior.[36]) Undoubtedly, there is much hype in hypermedia, but the promises proffered for digital technologies are not wholly empty. On its own, the digital is indeed confined to abstraction, sacrificing fertility for perfection, innovation for predictability. Yet the digital is not on its own, as it engages constantly with the human world of actuality. For all its sterile purity, for all its immaculate distinctness, the digital maintains a border with the actual, a border where its perfection breaks down, its definitiveness gives way to the productive ambiguity of the actual. This liminal space of transformation, where the abstract melts into the concrete, is the digital's fuzzy boundary, and whatever vitality, whatever creativity inheres in digital technologies, it will be found in this interstitial zone.

For the digital by itself is sterile, static, and unproductive. Inert and ineffectual in isolation, the digital only becomes effective when it crosses that zone of ambiguity to become actual, a transformation that draws a line of contact between the digital and the human. Utterly useless by itself, the digital is put to use always by virtue of additional technologies that mediate between digital and actual. It is no accident that programmers, whose hands are most sullied by the digital, produce what they refer to as *code;* the digital is always a code, and as such, it requires a *decoding* before it can be used. A computer program running in the digital bowels of a machine will do nothing, have no effect, until that machine is connected to monitors, modems, keyboards, mouses, speakers, scanners, printers, etc. To run a program, the abstract code that represents it must be turned into electrical current, which flows through logic gates on silicon chips, ultimately imposing magnetic charges on the surface of a hard disk, or sending electronic instructions to a cathode ray tube that shoots a beam of electrons at a sensitive computer screen, or monitoring the electrical contacts made when keys are depressed on a keyboard. An image coded in digital data has no effect on the senses until it is transformed from a formal digital representation into an actual visual presentation. These processes take place in the gap between digital and actual, between abstract and concrete; what goes on inside a computer or on a silicon chip in a CD player is both actual and digital, corrupting each of these realms by mingling them together. Trapped in the abstract, the pure digital operates at a remove from the vicissitudes of concrete, material existence, and this distance lends it its qualities of perfection: repeatability, measurability, transportability, etc. But the digital's divorce from the actual is also a constraint, denying it any direct power. To make its power felt, to operate in the world, the digital requires prosthetics. Therein we glimpse what Heidegger might call the *saving power* of the digital: this essential transformation, connecting digital and actual, guarantees that we will always have at least the opportunity to intervene in our experience of digital technology, to restore some of the actuality that is stripped away when things are reduced to their forms.[37]

To safeguard the saving power of the digital, we must attend to this passage, the ambiguous space of transformation from digital to actual and actual to digital. Occupying this space are all those technologies that constitute what is commonly called the interface. The interface effects passage back and forth from concrete gestures, images, and sounds to abstract forms, coded as bits. It mediates between user and computer and so is itself a hybrid retaining characteristics of both the abstract and the concrete in the same material. (At the junction of formal and actual, the interface is thus an extension of the finger.) Not only does the interface convey the user's intentions to the realm of the digital, it also requires that the user enter that realm herself. To use digital technologies, one must become digital, aligning one's own articulations to the spatial, temporal, and logical articulations of the interface. Computer software does not execute the wishes of the user without the user first shaping those wishes into conformity with the interface. Digital technology determines in advance which commands it will respond to, in what order they must be executed, how far it can go, and in which directions. Desires that are not expressed in terms of these preestablished possibilities simply cannot be carried out. Computer users must organize their thoughts and goals into files and operations on those files; digital artists must generate their artworks in accord with the menus and tools of the software they use; users of the lowly VCR must think in terms of time slots, linearity, succession, inputs and outputs.

In other words, the user programs the interface, but the interface also programs the user, who must behave according to its strictures. Conforming to the interface, the user submits to its formal reduction, gives herself over to the digital. The interface is thus the realm of intervention, wherein we can call attention to the digital's pure formality and attempt to rectify it. It is the monitor, the digital-to-analog converter, the keyboard and mouse that determine the ways in which we accede to pure form when we interact with digital data. By challenging the interface to offer a more human experience, we fend off, at least for a moment, the threat of digital reduction. Ongoing refinements to the interfaces of digital technologies reveal the blunt edges of the underlying digital data, demonstrate the limits of the digital resolution, and highlight the repetitive or categorical nature of the tasks that can be performed. When the interface improves to the point where the medium draws attention to itself as digital, the digital data must then be reorganized or refined to take advantage of the superior interface. This dialectic of interface and data also implicates the user, who may have to reconfigure her senses in order to detect the digital origins of her experience. (Motion artifacts in digital video are generally overlooked by viewers who have not learned to see them, just as aliasing and jitter in digital sound are not heard by listeners who do not know what to listen for.) By comparing the digital always to the very experience of the actual—live music, oil painting, a roller coaster—we keep the pressure on it, push it to greater achievement, force the digital to open rather than foreclose possibilities. The digital is alive only where it is challenged, where the pipe that passes from the digital to the actual bursts its seams to carry the digital beyond itself, to show its limits even while surpassing them.

This dialectical project of interface enhancement supports the information industry's strategy of built-in obsolescence. Today's computer can do great things, but it is seized by a discourse that presents it also as a step in a direction, a promise of even greater things to come. The goal of increased transparency or realism—which drives the progress of interface technologies—is universally held but does little to circumvent the homogeneity that digital technologies bring to experience. This is the digital's greatest threat: by requiring each user to conform to its standards, it imposes a uniform experience that not only reduces the world to a pure formality but offers to each of us the same formalities, the same possibilities, the same pseudo-creativity. The most effective challenge to the digital targets its uniformity, and we pose this challenge by creating interfaces that encourage originality. Humanizing the interface means more than just increasing detail in texture maps and customizing data gloves to effect a more accurate fit over the user's hands. A more human interface would be widely distributed and would give creative license to nonexpert users who could make fundamental alterations in the interface, fostering competing standards and original uses of the technology. When many people, instead of an elite few, create digital content, their diversity resists the uniformity that standardizes the digital, and they pose an inherent challenge to the commercialization that straitjackets the Internet for its purposes. The possibilities mentioned above for enrichment of our lives by the Internet and other digital technologies—providing a forum for the creation of new communities, promoting grassroots organization, encouraging individual contribution—all of these possibilities are augmented and secured by more human interfaces. The key to vibrant and rich digital technologies is to make sure that content is never under the dominion of a single standard, that authors are various, tools multiple, and progress unpredictable. Only by ensuring that the digital remains an open, decentralized, accessible loose grouping of technologies and approaches can we keep it from homogenizing our experience of the world.

At the conclusion of "The Question Concerning Technology," Heidegger, suspecting perhaps that the saving power he describes is somewhat inscrutable, points to a tangible and practical domain in which to pose the question of technology: art. Art is both akin to technology, as a site of revealing, but is also different from it, for it serves no prescribed end. This unique relation to technology *(technē)* makes art the domain in which to cultivate and nurture the saving power. The arts are still more germane to questions of digital technology, as aesthetic matters suffer severely under the reduction to form imposed by the digital. What painting survives digitization intact? What concert continues to breathe on a compact disc? At the same time, the promise of the digital is especially tantalizing in the realm of art; the digital offers extraordinary new powers to manipulate image and sound. Three-dimensional design has been wholly altered by digital technologies. Few audio recordings today are not significantly aided by the digital, and much music is created entirely on computers, sounds unheard before being generated inside the machine. The images in newspapers, magazines, books, labels, posters, films, and everywhere images appear begin as digital, and much of the work to design them and prepare them for print is performed in the digital. The introduction of digital technologies here does not merely facilitate the application of old techniques but introduces new ones as the digital allows highly selective alterations of a work, from the extremely subtle to the bold and dramatic, with supersurgical precision. Digital technologies enable precisely predictable, goal-oriented, undoable manipulations of image, sound, and even text.

As such, art provides the best forum in which to pose and re-pose the question concerning the digital. By its nature, art pushes its media to their limits, exercising the most subtle elements, exploiting the highest resolutions, appealing to the most refined sensations. Moreover, art does not tolerate homogeneity, for it succeeds only by a fierce and determined originality. Art pursues invention and so explores the limits of its media to forge new possibilities and discover unexpected directions. Where art meets the digital, there will be a most revealing test of the digital's limits. And the essential novelty of art assures that the question concerning the digital will not cease to be asked.

Instrument and Articulation

When we refer to a tool, a technology, or a person as an instrument, part of what we intend is a reduction of that tool, technology, or person to its instrumentality. That is, an instrument is something that serves a particular end, and, as instrument, it is merely a means to that end. When a person is treated as an instrument, that person stops being for himself and instead exists only for a purpose, a purpose derived from outside the instrument. An instrument disappears in its use, is absorbed by its use, and the more effective it is, the more effectively it disappears. An instrument thus objectified no longer asserts itself, being wholly subjugated to the use to which it is put. Like any instrument, a *musical instrument* is a means. The player makes sound *by means* of the instrument, which transduces force into vibration. But a musical instrument is no mere means: it does not disappear in its use. The musical instrument remains opaque, and one does not know how it will respond to a given gesture.[38] Thus, *to play is to learn (to play)*, and one invents in concert with one's instrument. If there is a worry about digital instruments, it is therefore not the worry that they are instrumental—for surely they are—rather, the worry is that digital instruments are *merely* instrumental, nothing but means to ends. Does an electronic or digital instrument offer always a new challenge, or is it comprehensible, predictable, knowable?

Fine musical instruments are extremely sensitive, and this sensitivity offers to the performer a subtle control over the sound. Not exactly *control* though, since the performer shapes but does not finally determine the sound. To shape the sound requires an ongoing mechanism of feedback so that the instrument places not only the controls under the dominion of the player but also puts the player in direct contact with the sonic surfaces of the instrument. Subtlety is possible because the player hears, from some small distance, the sound produced by the instrument but also because he experiences in his body and immediately the vibrations of the instrument's parts. One does not simply adjust one's playing according to the sound produced but also according to the feel of the instrument against one's flesh, the sensation of the string pinioned under the finger against the fretboard, the back pressure exerted by the column of air in a trumpet varying against one's lips, tongue, and mouth cavity, the vibrating reed in the oboe that makes one's cheeks also vibrate. These feedback mechanisms preclude a wholly preconceived performance; the player's goals are always provisional, only starting points that set the instrument to vibrating. Ends are never determined beforehand but are produced from a complex negotiation between player and instrument.

Nor is the feedback unilateral. The instrument operates on the player as the player operates on the instrument, and each is altered thereby. The player's body (tissues, muscles, nerves, etc.) is reorganized around the instrument. Calluses, reflexes, ears, and fingers are attuned to the instrument until the player may no longer experience the physical divisions that separate her from her instrument. By resisting the player's gestures, and by directing the application of force, the instrument guides desire and generates new ideas in the player. This blurs both the instrument and player at their edges and allows their sonic surfaces to enmesh. The player would never achieve an extraordinary finesse if she regarded the instrument as a means, a separate mechanism to translate her applied force into the force of sound. The best, most sensitive playing occurs when the instrument is no longer an object that the player stands over but becomes an extension of her nervous system. Trained musicians do not *have* a technique that they can manipulate, as though it were something they owned. In training, a musician is altered in her body, and her technique is a way of adapting herself to the instrument, which is not without material consequences. Playing then overcomes technique, so that player, instrument, and sound are assembled in that sublime moment into a single machine with unlimited possibility. A finely honed group of musicians, say a choir, a jazz ensemble, or an orchestra, can similarly begin to assemble a machine of their differences, a monumental, instrumental sound machine.

The instrument melts its sonic surfaces by making them vibrate to produce sound and tactile feedback. On another scale, that of history, the instrument becomes even more fluid. The hundred-year history of the modern guitar reveals a progressive struggle to afford more possibilities to the player while adding greater volume and timbral control. The guitar becomes less bulky and lighter, though its body cannot be sacrificed altogether if its rich tone is to be maintained. Amplification substitutes electronic projection for the hollow body of the guitar as the amplifier provides another means of generating volume that does not rely on the resonant cavity of the instrument. Of course, these modifications to the guitar are themselves based on intricate feedback mechanisms: the player directly operates on the instrument to create something new. Again, there is a meeting of sonic surfaces, wherein the instrument extends itself to meet the player's touch while the player, through practice and technique and with tools, merges her nervous system with the body of the instrument. Instrument and player intermingle at their liquid surfaces, each dissolves its own boundaries, reorganizes itself, to effect more engrossing contact with the other and with the sonic result. These subtle surfaces may lie along physical boundaries where the two bodies actually touch, but not all of the surfaces of the instrument or player are on the outside. The body of the player and the body of the instrument are aligned according to their articulations, which determine their conjunctions, their machinic possibilities. Articulation determines the relations among performer, instrument, and sound. It indexes the possibilities of playing and of being played.

It is not by accident that the neck of a guitar looks like the musical staff of Western notation (parallel lines with spaces between), although the guitar and the staff do not correspond analogically. Like the staff, a guitar is divided along two axes, along the strings and perpendicular to them, a melodic direction and a harmonic one. Its magic lies in the diagonal that runs from one axis to the other. Harmony and melody leap along this diagonal, crashing into each other. Melody becomes harmony when it jumps from string to string, while harmony becomes melody when it moves up and down the fretboard or stretches itself over time. The arrangement and tuning intervals of the strings allow strumming or picking, chord or melody. The guitar's axes are reflected in the player, in two hands, one for fretting and the other for picking or strumming. The player's axes (two hands) do not strictly correspond to the guitar's but cut across them: the picking and strumming hand operates on rhythm and timbre while the fretting hand controls harmony and melody. The fretting hand tends to move linearly along the strings while the picking hand tends to move up and down from one string to the next. These various possibilities define the range of the guitar, its suitability and its adaptability. The intervals that define the differences among the strings are geared toward the Western conception of musical consonance: thirds and fourths are the bases of chordal construction and harmonic movement in Western music and encourage sympathetic vibrations of the various strings.[39]

The piano is the analytic instrument par excellence. Horizontal for pitch and vertical for dynamics; black keys and white keys organized according to the well-tempered twelve-step octave, asserting the priority of the Church modes based on the major diatonic scale; a logarithmic presentation of the whole range of the orchestra, laid out within reach of a seated performer who commands the entire instrument. The piano is a uniquely European instrument, as each of its characteristics reflects European music and a Western rational sensibility: eighty-eight keys corresponding to the eighty-eight playable pitches. Push a key and the mechanism responds, sounding the note until the button is released. A grand piano action features over one hundred parts for each of the eighty-eight keys to transfer the force from the pianist to the strings, a baffling complexity. The piano key is a lever, a seesaw with a finger at one end and a hammer at the other. Its alignment with the finger lends it a particular affinity for form; short of digital instruments, the piano maximizes the possibility of placing any (chromatic) pitch at any point in time. For this power of the arbitrary placement of notes, the piano sacrifices a fine control over timbre and microtonal pitch, which is why bowed and blown instruments are considered more typically melodic. The piano is thus built in complicity with Western musical notation, which also allows the placement of any chromatic pitch at any point in time but has no refined language for timbre and is poorly suited to microtonal or non-Western tuning systems.

The piano is sometimes described as eighty-eight instruments in one chassis since it features a materially separate mechanism for each note. However, the soundboard, which is the large wooden board under all the strings, unites the strings in one instrument; it plays an essential role in determining the sound of the piano as it amplifies the vibrations of the strings, mixes those vibrations together, and passes them into the air and the other strings. The separate instrument model might be more aptly applied to percussion kits, including the gamelan orchestra of Indonesia, and especially the drum "trap" kit developed in conjunction with the Western dance and jazz traditions. The articulations of most orchestral instruments (piano, trumpet, saxophone, bass guitar, violin, flute, marimba, etc.) are relatively homogeneous, dividing the instrument along axes of parallels to define homogeneous domains of sound. So, the piano keys are parallel mechanisms that divide the pitch range of the piano into equal (rational) steps; aside from this essential difference, each key is similar to each other.[40]

The violin divides its pitch range into four strings spaced at regular intervals, then implicitly subdivides each string by rational spacing along the neck of the violin. Again, each string is similar to each other, only tuned differently. While the keys on a saxophone align pitches with combinations of fingers (including an "octave" key under the thumb that shifts all pitches by an octave), the valves on a trumpet divide its pitch range into families of harmonics, where a given harmonic is chosen by the pressure of the breath and shape of the lips. In each case, the articulations of the instrument are homogeneous divisions of one or more similar dimensions.

By contrast, drums defy unification in a kit because their articulations are heterogeneous, with each element asserting its unique character. Cymbals differ fundamentally from drums with stretched heads. Cymbals are further subdivided into fairly different types according not only to size but to mechanism: splash cymbals are turned toward different ends from ride cymbals, and both operate differently from high-hats. Within the category of stretched-head drums, tom-toms, snare drum, and kick drum all employ different mechanisms of sound production and correspond to different bodily articulations. The three-dimensional layout of the drum kit, where the drums do not generally lie on a common plane, testifies to the heterogeneity of their articulations. This heterogeneity expands dramatically when one includes percussion not stereotypically part of the drum kit, such as idiophones, hand percussion, bells, gongs, found percussion, etc. The heterogeneous articulations of the drum kit keep its definition open: the instrument has no clear boundaries, and one can smoothly incorporate anything from ethnic percussion instruments to kitchen utensils into one's drums. The diversity of instrumental possibilities, and the relatively gross scale of articulations (nine or ten divisions that define individual drums), means that a single alteration changes every sound in the kit. The drums operate essentially by combination as the player chooses a stick, a drumhead, a tuning, a force, a spot to strike, etc., so that changing any one element, such as substituting nylon brushes for wooden sticks, creates a whole new set of possibilities.[41]

Though electronic instruments may resemble their acoustic counterparts in form, function, and feel, there is a significant difference. In an acoustic instrument, it is the energy of the player that is transformed into sound energy (with rare exceptions, such as pipe organ). In an electronic instrument, the sound energy is drawn from electricity, so that the musician does not supply the force but acts as a trigger. There is thus an abstraction inherent in electronic instruments since the player's gestures are interpreted (as on/off commands) rather than providing a direct force. A keyboard-synthesizer is responding to key presses as triggers, and it does not so much convey the force of this key press as measure it and then, using mathematical formulas, apply the resultant number to other numbers representing a signal. (For example, if the signal should be louder when the key is pressed harder, then the relevant numbers can simply be multiplied by an appropriate scaling factor.)

The measurement process adds a layer of abstraction to an electronic instrument, a degree of separation between the applied force and the resultant sound. This abstraction, especially in the case of digital instruments, is where the uniqueness of the instrument gets lost. Each of the structures of acoustic instruments described above refers only to the general form of the instrument. Any actual acoustic instrument has its own unlimited and unique set of articulations that gives it its own sound and feeling. Every acoustic musical instrument has a sonic signature, and the choice of which violin or piano to play is, for a master musician, a complex and shaded decision. This signature or uniqueness is precisely what is lacking in the digital. Digital instruments by nature are generic, interchangeable: a digital synthesizer can be perfectly duplicated, exactly reproduced. Even outside of the digital, technology often reduces objects to their genera: one set of pliers or telephone will do the job as well as another.

The mediation of the measurement process has many further consequences that determine the powers and limits of electronic and digital instruments. The abstraction not only generalizes the instrument, removing its singular character and allowing exact reproduction, it also serves as a filtering mechanism since the measurement process selects in advance which forces will be relevant to the production of the sound and what sorts of differences they will make. In a digital instrument, sound production takes place mostly in a microchip, which manipulates sequences of numbers representing the sound signal. This microchip does not respond to just any gesture, it is not open onto the world around it as is an acoustic instrument. It has been decided in advance, designed on purpose how a given digital instrument will respond and to which forces.[42] Whereas a tuba makes sound in response to the accidents that befall it—a gust of wind, a child's playful fingers, the dents of a sudden drop—a digital synth responds only to those gestures that its designers took into account; drumming on the cabinet of a digital synth yields no result, at least not in the output of the synthesizer. John Cage "prepared" pianos by inserting various materials into and under the strings; there seems to be no analogous possibility for digital instruments, which either make their intended sounds or, if sufficiently maltreated, no sounds at all.

The abstraction that separates the sound production of an electronic instrument from the force that triggers that production allows the triggering itself to be automated, displaced from its original time and place. An instrument can be programmed to trigger itself or a computer can act as the triggering device. (To this end, witness the networks of clocks that synchronize digital instruments with microsecond accuracy in the hopes that precise timing will yield more musical and less mechanical sonic results.) Gestures, or rather their metrical representations, can be stored, edited, and tweaked in numerous ways. A performance can be exactly duplicated years after its initial playing, and another instrument, with a very different sound, can be fed the exact same performance data. The process of playing a digital instrument is thereby further abstracted, the playing separated from the sound at a further remove.

The mediation inherent to digital instruments institutes a distance between the musician and the music, but this distance does more than limit the immediacy of performance by separating performer from sound. It also allows all sorts of intervention in the sound via digital manipulation and digital performance techniques that open countless new possibilities. But at what cost? A glance at a modern synthesizer, with its numerous buttons and LCD display, makes it appear that digital sound technologies multiply the options available to the musician, but "despite these appearances, the musician has never been so deprived of initiative, so anonymous. The only freedom left is that of the synthesizer: to combine preestablished programs."[43] Jacques Attali's remark finds substantial evidence in the Musical Instrument Digital Interface (MIDI) standard. Both in playing the instrument (triggering) and in altering its synthesis parameters (sound design), the standard for measuring and storing the values for the past twenty years has been MIDI. The player of a digital instrument is effectively inputting data in real-time; to play the synthesizer is to input values for a number of parameters, which are combined in the *synthesis engine* to create a sound for output. MIDI captures the data describing which notes are played and when and how hard and how long, etc. Because the MIDI standard is based on binary encoding of values, and because of compromises in the MIDI standard (formerly) necessary to allow efficient and rapid communication among instruments, most values are limited to 128 possibilities: 128 different notes that can be sounded, 128 dynamic values measuring how hard the note is struck or how loud it should respond, 128 positions for the pitch-shifting knob, 128 values of modulation amount, 128 possible lengths of time for the attack of a note, etc.

Unlike the discrete finitude of MIDI, an acoustic instrument allows ever finer gradations of force and time, minute, momentary timbral alterations. There is always another note between two notes, another dynamic value between two values. Such an instrument can never be fully analyzed as to its timbre; its possibilities are infinitely subtle, so that it occupies more dimensions than its number of parameters. Though many electronic instruments make distinctions more subtle than the MIDI standard, every digital instrument stops subdividing at some point, as that is the nature of the digital. In other words, practical limits of computation power, timing accuracy, instrument sensitivity, data storage, and potentially more restrictive limits imposed by design and materials costs require that a digital instrument ultimately assign each parameter a particular value at a finite level of subtlety. Many of the synthesis parameters that determine the sound of a given "patch" on a synthesizer are not manipulable, or are hard-linked to other parameters, or have a restricted range, or are otherwise not completely free for the user to determine. Though digital synthesizer architecture has tended increasingly to provide a more detailed user interface, allowing greater control of low-level synthesis variables, most synthesizers hide much of the architecture from the user, making it difficult or impossible to manipulate many crucial parameters of the generated sounds. Sometimes this compromise is a matter of cost-cutting, as when a manufacturer does not want to include a chip to interpret so many user parameters, or a screen interface to allow such interaction. Other times it is a question of design: the designer must find a compromise between a powerful synth that makes a variety of sounds and one on which it is easy enough for a general population of musician-consumers to generate and use those sounds. Sometimes the design limitations exist to protect the user from useless or bad sounding patches by limiting parameter manipulation to a range deemed broadly useful. (For example, beyond a certain range, some parameters may not make much difference or produce no sound at all.) Sometimes the limitations of a synthesizer design are deliberate and extraneous, to cripple the synth in order to generate demand for more powerful synthesizers at higher price points. (This is especially common in computer-based [software] synthesis, where materials and distribution costs are negligible.) At the limit, some synthesizers restrict the choices to that of one sound from among eight or ten possibilities with no control over the timbre of each one.

Whether the choices are broad or narrow, due to the discrete nature of the digital, a digital synth has its possibilities preinscribed, determined by design, and its identity set in silicon, measurable by the code that constitutes it in the abstract. Fernando Iazzetta points out that every facet of a digital instrument is implemented by design; sound is produced only in the manner implemented intentionally by the designers of the instrument, and there are no accidents that expand the possibilities of acoustic production.[44] With an acoustic instrument, one never knows what sonic possibilities will show themselves by accident in the course of free experimentation; a digital instrument, on the other hand, can do no more than it was created to do. Despite these forces of ossification, fixed designs and predetermined possibilities, there are counterforces that encourage transgressive uses for digital instruments, ways in which the instruments remain open or can be forced open into new possibilities. The extreme complexity of modern digital instruments guarantees that there are almost always further avenues to explore, especially if the instrument can be expanded with additional hardware or software.[45] However, the greatest possibilities for expansion of digital instruments lie not on their insides but on their outsides. Whereas traditional acoustic instruments have an open interior, exposing to the performer the tactile sonic surfaces of the instrument, digital instruments have a relatively closed interior but an open exterior, encouraging all sorts of connections to their outsides, plugs and wires, input and output.[46] Digital and electronic instruments are intended to be used together, side by side or linked together in a chain. Their data representations are standardized (MIDI, AIFF, WAV, MP3, etc.), and many instruments produce none of their own sound but only modify sounds coming from other instruments. Not only has the player become a trigger, removed from the sound and even from the generation of expression, he must develop whole new skills, a new approach in order to make creative use of instruments open primarily on the exterior. The player must be a programmer, a designer, an engineer, and these terms are replacing the traditional nomenclature that identifies a player by instrument (e.g., drummer, pianist, flautist). Perhaps the player is one module among others, one source of input to the digital synth but not the only one.

There exists a further possibility of extending the synthesizer's reach beyond the designer's intentions. Some artists are turning to the cast-off or unwanted sounds of the digital, digital detritus that usually is weeded out of the recorded signal during the tracking, mixing, or mastering phases.[47] Scratching the surface of a CD causes unpredictable errors on playback, including clicks, skipping, stuttering, or tracking problems. Such sounds can be recorded and used, as can other illegitimate noises created by feeding “illegal” data to the synth engine, data that cannot properly be processed because it has the wrong form. This may result in a simple lack of output, or it may generate bizarre effects, from white noise to stabbing percussion. Digital distortion is caused by sampling a signal that is too *hot* or has too much dynamic range for the analog-to-digital converter; avoiding such distortion is one of the engineer’s primary concerns in the digital studio. In defiance of this strict distinction between the noise of distortion and the clean signal, digital distortion is now employed on records by artists who challenge the standards of good taste and proper form implemented by the recording industry. In his article on music in the age of electronics (discussed below), John Mowitt suggests that the subversive power of noise has been codified by the digital, which distinguishes absolutely between signal and noise. Noise can therefore be recouped as signal in a music that is both completely tied to the digital and politically resistant to its uniformity.[48]

Digital instruments make explicit a previously ignored aspect of music production. Performers were always concerned with producing the right notes at the time of performance, but digital instruments introduce another phase of performance: sound design. A synthesizer generates sound, but it also allows that sound to be meticulously crafted prior to the performance, and these two linked processes of sound production are often reflected in the instrument’s interface. (An interface might feature a keyboard for immediate note playback, as well as a series of menus and buttons with which to program and alter the sounds.) The playback phase is where the instrument generates sounds triggered by pressing its buttons or keys or by sending the appropriate MIDI signals to it. No less a part of the digital musician’s art, the sound design phase allows the instrument to be programmed, a process wherein new sounds are created by altering parameters of the synthesizer. (Available parameters will depend on the synthesis architecture and might include anything from an oscillator waveform to length of decay to filter cutoff frequency.) These two layers are not strictly separate, as one often alters synth parameters during a performance.

Designing musically satisfying sounds is no simple task; even the word *synthesis* suggests the potentially inauthentic character of its results. The ideal (and inconceivable) synthesizer would allow the generation of any sound imaginable, turning musical ideas into sound with a transparent interface.[49] The realistic promise of synthesis is that it opens up the sonic palette to vast new potentials, allows the generation of distant acoustic spaces and expensive customized instruments, a Steinway Concert Grand piano in a world-class concert hall for a few hundred dollars. Digital instruments put the sounds of an entire orchestra at the disposal of an amateur composer in the middle of the night. Though this promise is already largely fulfilled, synthesis falls short of the ideal, as any actual implementation involves numerous compromises.

The heart of a digital synthesizer is the synthesis engine, which employs one or more methods of sound synthesis to produce a stream of numbers that represents a sampled sound signal. Whatever the specific architecture of the engine, the method of synthesis is the fundamental determinant of the capabilities and limitations of the synthesizer and frequently characterizes its overall sound. Some synths are designed with a particular goal in mind, such as to emulate an organ or a string section, or to alter the pitch of monophonic vocal sounds. In most synthesizers, however, it is desirable to have a broad range of different sounds easily accessible as well as the potential to create dramatically new sounds without having to alter too many parameters of the synthesis engine. Sounds that evolve over time, have distinctive attack and decay phases, and produce complex harmonics including some dissonance are rich with possibilities for music. Nonsynthesized instrumental sounds and other real-world sounds demonstrate all of these desirable characteristics, which accounts in part for the sustained interest in the French horn, timpani, and cello even after these instruments have been explored for hundreds of years. Particularly appealing is a synthesis method that generates a complex and varied output from relatively simple and few input parameters. It is also desirable that these parameters are musically or at least sonically significant, so that the synthesist can learn the correspondences between the parameters and their effects and thus alter the sound in predictable ways. It is often essential that the synthesis be sufficiently straightforward to compute in real-time, so that the synthesizer can output the sound just as it is triggered. (There are popular systems, notably Csound, in which the computer-synthesizer is given instructions as to how to generate the sound, on which basis it creates the sound as a binary file, which may be played back only once it is complete. Unaltered, this system makes a poor instrument for performance since the synthesis itself may take seconds or even hours, but it allows an extreme degree of control over the generated sound.)

Each method of synthesis has its computing requirements, its power, and its ease of use. Early electronic music studios, in the forties and fifties, focused largely on *additive synthesis*, in which a sound is created by adding together some number of sinusoidal waves in various proportions. In theory, this method can produce any sound at all since, according to the Fourier theory, any sound can be decomposed into a (possibly infinite) number of sinusoids. In practice, however, this method is somewhat impractical for general purpose synthesis for a number of reasons. First, the complexity of the resultant sound scales in proportion to the required computational power. That is, each sinusoid added to the sound makes it more rich and complex but also requires another oscillator (the component that generates the basic sine wave). Even mediocre simulation of real-world sounds often calls for twenty or more summed sine waves while more than six physical oscillators is an expense rarely found on commercial instruments. Of course, in the digital domain, one can simulate arbitrarily many oscillators with little cost in terms of design issues or computing power. But, additive synthesis is still too static and still requires too many parameters in order to make complex sounds. If one specifies fifty oscillator frequencies and amplitudes, this may generate a rich sound, but changing any one of these frequencies or amplitudes will make little difference in the overall result. To really alter the sound in interesting ways requires a whole new set of fifty frequencies and amplitudes, which makes sound generation laborious. Early electronic composers occasionally spent hundreds of hours creating a single sound that lasted only a few seconds, but the novelty that made this task worthwhile has long since faded.

Subtractive synthesis produces rich sounds more easily, but it borrows its complexity from preexisting samples. In subtractive synthesis, a given sound is altered by boosting or attenuating certain frequencies using a filter, which is one of the basic components of sound synthesis and manipulation. One feature of filters is that they are inexact, spreading their effects over a range of frequencies, and this range varies depending on the specific frequency of the filter, its amplitude, and the manner in which the filter is implemented. This inexactitude is often an advantage, as it adds a variability and complexity to the resultant filtered sound. However, subtractive synthesis begins with a sound already generated using some other method; though it adds interest to this original sound, it does not provide a general means of creating ever new interesting sounds on its own. It is thus better suited, and generally used, in conjunction with some other method of synthesis, which then becomes the limiting factor in the usability and interest of the resulting sound.

As digital instruments became prominent in the eighties, recording techniques adapted to the high signal-to-noise ratio of digital recording, and storage of digital data became less expensive. The result was the commercial feasibility of *sample-table synthesis*, a method of sound generation in which a recorded *(sampled)* sound is played back, possibly in a modified form. On playback, it is possible to alter the pitch of the original sound, as well as filter it, and change its envelope and amplitude.[50] Nevertheless, repeated listening to the same sample, even at different pitches and amplitudes, soon reveals the static origin of the sound. Even among noncritical listeners who might not identify the problem explicitly, hearing the same sample triggered again and again at different pitches and amplitudes becomes quickly tiresome.[51] Despite this disadvantage, which is characteristic of digital synthesis generally, sample-based synthesis became and continues to be immensely popular, primarily because it allows very accurate synthesis of real instruments. Short of the real thing, nothing sounds quite so much like an actual guitar as a recording of a guitar! Synthesizers based on sampling synthesis are extremely versatile, inasmuch as any recorded (or synthesized) sound can be used as the basis for playback. Not only are there synthesizers sold that use exclusively this method of sound generation, but the sampler has become an indispensable instrument in the recording studio. In addition to playback of sampled sounds built into the instrument, the sampler allows the user to record her own sounds and use them as the basis for the synthesis. Sample-based synthesizers come with a variety of sounds built in, and one can add additional sounds by recording them oneself, by buying commercially available CDs of recorded samples intended expressly to be used in a sampler, or by inserting special hardware to expand the sampler with additional sounds and capabilities.

In addition to the problem of sampled sounds growing tired, there are further complications of this form of synthesis. Most acoustic instruments have a timbre that varies with pitch, so that using a single sample recorded at one pitch and then shifting its pitch to make lower and higher notes does not generate a convincing simulation of the instrument. Timbre also tends to vary with amplitude: a softly struck piano note is not just a lower volume than the same note struck hard but also has different timbral and temporal characteristics, fewer overtones, shorter decay, etc. On instruments such as piano where it is possible to sound many notes at once, the real-world result is not equivalent to the "sum" of the struck notes, for the simultaneous sounds interact, reinforcing each other and canceling each other to add further complexity to the overall timbre. Even where it is not a question of simulating an acoustic instrument, it is desirable, and musically interesting, to have timbral shifts based on register, volume, and thickness of the sound. Sampling synthesizers, which use a single recorded sample played back at various frequencies and volumes, do not account for any of these subtleties and tend quickly to sound wooden and boring. Synth designers compensate for some of these problems by using algorithms to simulate reinforcement and cancellation when multiple notes are overlapped and by *multisampling*, which is the process of using different samples for different registers and volumes, say a sample of a low note (pitch-shifted as appropriate) to play back all low notes and a sample of a high note to play back the high notes. Many additional subtleties are put to use to squeeze the greatest realism and creative possibilities out of samplers, but sooner or later, the sound still tends to become too homogeneous.[52] The sampler is ultimately limited by its samples.[53]

FM (frequency modulation) synthesis—in which the frequency of one wave *(the modulator)* is used to continuously alter (modulate) the frequency of another wave *(the carrier)*—offers a means of generating complex and changing sounds from scratch by specifying only a few parameters. Changing the fundamental parameters (modulator and carrier frequencies and amplitudes, modulation index) can make dramatic changes in the resultant sound, but with some experimentation, these changes are fairly predictable and controllable. Introduced commercially in the early eighties by Yamaha with their DX-7 keyboard-synthesizer, FM synthesis has enjoyed significant popularity and has been much used and further developed. However, it retains a distinctive, recognizable sound. Its recognizability, signaling its limited range, can be explained by appeal to the mathematics that underlie its application: FM synthesis creates symmetrical sidebands around the carrier frequency, which are additional frequencies that spread the energy of the original sounds (modulator and carrier) in musically interesting ways. By using feedback loops and by modulating the modulator, one can extend this synthesis technique beyond the generation of sidebands, but extensive use eventually reveals a fundamental similarity in all of the produced sounds. Moreover, simulation of acoustic sounds is often difficult with FM synthesis, as there is no method of sound analysis that will easily determine synthesis parameters for FM. In other words, though FM synthesis can produce many interesting sounds, it is difficult to employ it in the service of a goal outside the typical range of sonic possibilities.

Fourier Analysis and Other Techniques

Each of these methods of synthesis arises in response to the demand to create sounds that are musically interesting but that offer more possibilities—greater sonic range as well as different kinds of control—than those afforded by traditional acoustic instruments. While all of these synthesis techniques have enjoyed immense popularity, finding their way into plenty of commercial instruments, each also seems hampered by its own characteristics, tied to its distinctive sound. This limitation is inherent and even desirable in an acoustic instrument; we want a violin to sound uniquely like a violin and to be playable in just those myriad ways that violins offer themselves to violinists. In a synthesizer, however, especially a digital synthesizer, such limitation is less desirable and sometimes comes to be intolerable. For a given method of digital synthesis tends eventually to sound "same-y"; despite the wide range of possible inputs to a synthesis engine, its output remains sonically somewhat homogeneous. The reasons for this acoustic conformity lie in the technical bases of the synthesis engines, so an analysis of these engines will reveal not only how they impose limitations on the resulting sounds but also how we might break out of this digital prison.

The warden of this prison is surely the Fourier model of sound, for each of these methods of synthesis is based more or less directly on that model. Additive synthesis makes this most explicit. Additive synthesis constructs a sound from a number of sine waves of different amplitudes and frequencies, but it is precisely the Fourier theorem that guarantees that any sound can be so constructed. Fourier analysis even provides a method to determine which sine waves to use and in what proportions: the Discrete Fourier Transform (DFT), a formula or method for manipulating the mathematical representation of a signal, analyzes a sound by re-presenting it as a number of sine waves in specific proportions so that an additive synthesizer can easily reconstruct the sound by adding those same sine waves back together in like proportions. The DFT thus reveals that sample-based synthesis is the inverse of additive synthesis, for the Fourier model effectively allows a switch back and forth between a frequency representation of a sound and a time representation of that sound. A sample is just such a time representation, governed by the Fourier model of sound.

Even subtractive synthesis is implicitly connected to the Fourier model by virtue of their mutual linearity.[54] Though FM synthesis diverges somewhat, each of these other methods of synthesis demonstrates a linear relationship between input and output complexity, wherein the complexity of the sound is directly proportional to the complexity of its method of generation. To use additive synthesis, sample-based (wave-table) synthesis, or subtractive synthesis to create a complex sound requires adding the complexity in up front by adding in more factors (more waves in additive synthesis, more filters in subtractive synthesis, a higher sample rate or greater resolution in the sample). The result is usually a sound that, especially after repeated listening, belies the static character that subtends its complexity, revealing its origin in the digital. The complexity is formally injected into the sound instead of arising by accident (the latter case being generally more interesting).

We might also consider the issue of complexity in its relation to the distinction between signal and noise. As Mowitt points out, the digital takes this distinction to its rational extreme, defining the signal in absolute terms as equal to the series of numbers that represents it.[55] A method of synthesis in which output complexity scales linearly with input complexity will necessitate that noise be added in explicitly. In additive synthesis, for example, one gets out only what one puts in, leaving no room for the accidental or haphazard, the contingent or noisy. Without an appropriate noise, sounds fail to connect to the implicated reserve of sense, fail to move or cohere, do not live. Digitally synthesized sounds, cut off from noise, are produced in a vacuum. Like digital instruments themselves, the sounds they produce have immaculate edges that do not degenerate into a surrounding context of noise from which they can draw sense into perception. This is no doubt what one means when referring to digital instruments as sterile. They sound thin, emaciated to the point of a purity that no longer holds any weight. It is as though by removing the inherent limits to acoustic sound production, by allowing the arbitrary manipulation of timbre outside of any context, synthesis loses its grip on the world and no longer generates enough friction to turn sound energy into music. In *Acoustic Communication*, Barry Truax points to a related theme when he discusses the acoustic ecology of electronic music, which, by feeding off of electricity instead of human force, outputs more energy than it takes in, with significant environmental consequences. These consequences include not only the unlimited expenditure of electricity in musical instruments and playback systems but the unlimited volume potential that is sometimes unleashed at rock concerts. Without ecologically unsound sound production, claims Truax, sound pollution could never become a problem.

As the linearity of synthesis imposes a limit on its musicality, and as this linearity is linked to the Fourier model of signal analysis, it is this model that must be challenged to yield more musical synthesis. How does Fourier analysis work? Fourier analysis is a method (actually, a family of methods) for taking a wave represented as a change over time and characterizing it in terms of the frequency of that change.[56] Fourier analysis measures how much energy there is in the original wave at a number of different frequencies. A complex wave, such as a real-world sound wave, typically changes not only at, for example, 300 cycles per second (300 Hz), but also at integer multiples of this *fundamental* frequency (600 Hz, 900 Hz, etc.; see Figure 8). A real-world wave also generally includes some nonharmonic variation, oscillation at frequencies unrelated to the fundamental. Only a simple sinusoid comprises just one frequency; any other wave, any wave with *timbre* will have more than one and probably quite a few frequencies in it. Given a representation of a signal as change over time, the Fourier transform produces a representation of that signal as the sum of the frequencies that constitute it.[57] An inverse Fourier transform goes the other direction, from a frequency representation to a time representation of the signal. In the digital domain, a signal is generally represented by a sequence of discrete values (samples), so the appropriate method of analysis is the Discrete Fourier Transform (DFT), which operates on a signal made of discrete samples.

The DFT compares the original signal, f, to a bunch of sine waves of various frequencies, the sine waves being taken for comparison one at a time.

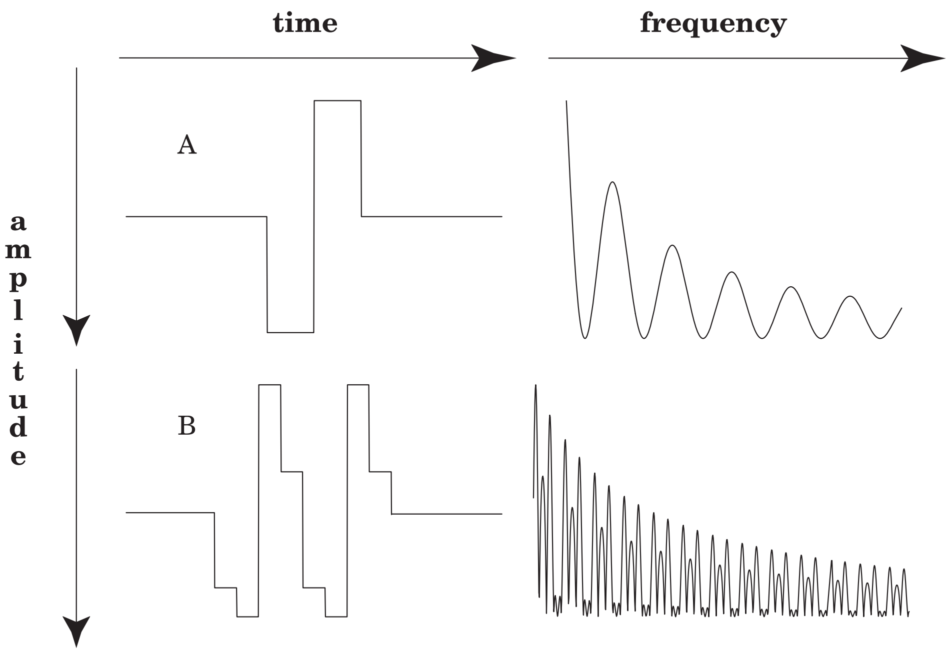

Figure 10. Fourier transforms. *A* and *B* are a square wave and a squarish wave, each followed by a graph of its transform. The descending humps of the Fourier representation of *A* correspond to the regular sequence of sinusoids that sum to a square wave. (See Figure 11.) As *B* looks like a modified *A*, so *B*'s transform looks like *A*'s, but with additional factors.

The more closely f resembles a sine wave of a given frequency, the more energy it contains at that frequency. Resemblance, however, is a somewhat tricky notion. If one draws a sine wave, and then compares it to its mirror image (flipped across the horizontal, x, axis), one will notice that the two signals are at once very similar and very different. They are absolutely similar in that they are mirror images, identical but for sign, one positive where the other is negative. Yet they are absolutely dissimilar in precisely that same respect, for each is the opposite of the other, its additive inverse; add them together, and the result is zero, which testifies to their perfect opposition. For the purposes of Fourier analysis, this mirror imaging is counted as a strong form of resemblance. Taking the mirror image of a sine wave is equivalent to shifting it over by half a cycle, a phase shift of 180° or π radians. If the original wave, f, resembles a phase-shifted version of a particular sine wave, then f, though it does not "line up" with the (non-phase-shifted) sine wave, nevertheless has a lot of energy at the frequency of that sine wave, and this fact should be revealed by the Fourier analysis. Thus, a proper comparison of each sine wave to the original wave, f, requires that

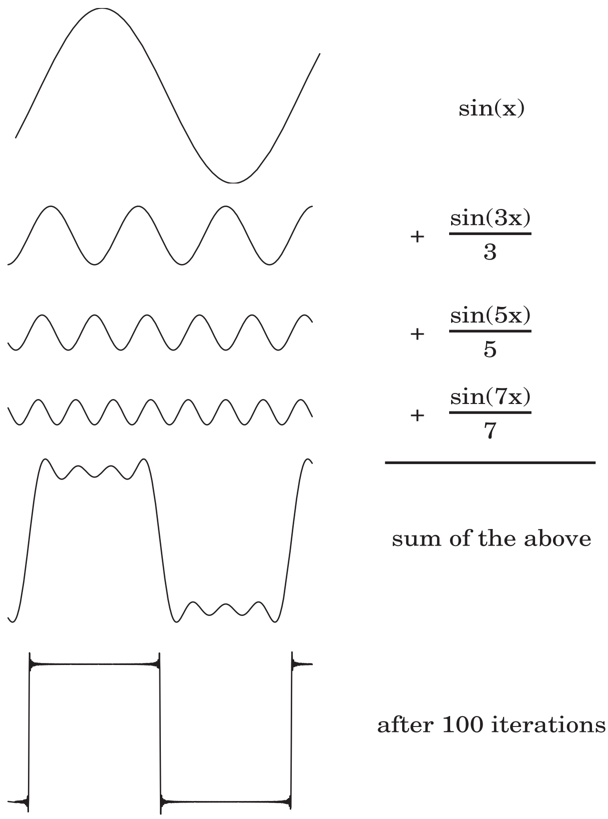

Figure 11. How to make a square wave. To approximate a square wave, add together sinusoids in the pattern

$$\frac{\sin((2n-1)x)}{2n-1},$$

where n counts the terms. The approximation gets closer as n gets higher, adding more lower amplitude, higher frequency terms. A true square wave has infinitely high frequencies.

each sine wave be shifted horizontally along the x-axis to find the best fit to f, and this best fit is measured for resemblance. Along the same lines, each sine wave must be scaled, its amplitude ramped up and down, to find the closest resemblance to the original wave, f. (Amplitude and phase are independent of frequency, so that, for a given sine wave, shifting it around and scaling it taller or shorter does not change the frequency being compared.) In summary, the DFT scales and shifts each sine wave to find the best fit, then notes which amplitude (scale) and phase (shift) were necessary to effect this best fit or closest resemblance with the original wave. The DFT is a

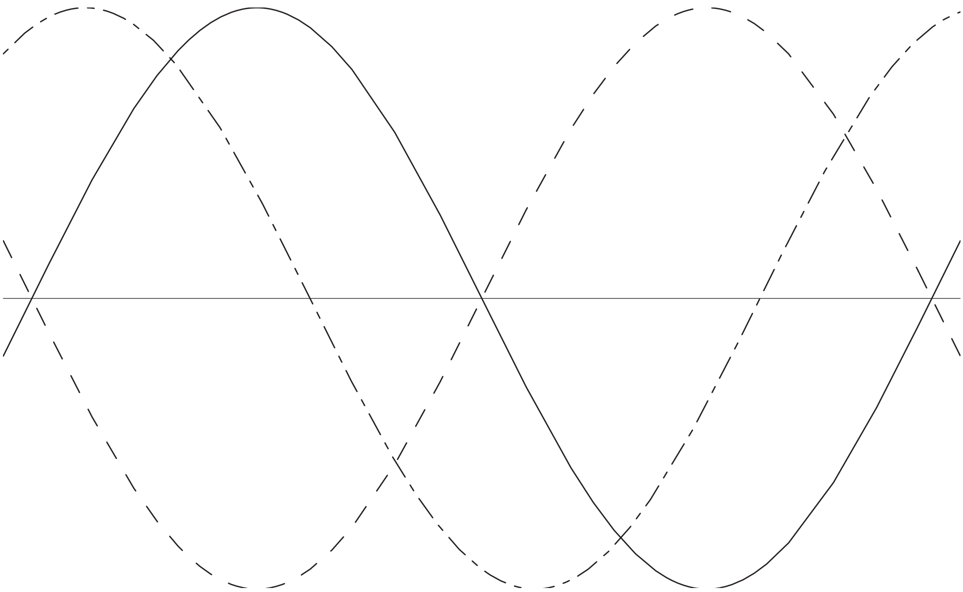

Figure 12. Phase. The solid sine wave is 180° out of phase relative to the dashed sine wave; each is equal and opposite to the other (180° is "completely" out of phase). The third, dot-dashed sine wave is partly out of phase relative to each of the other two.

mathematically precise way of calculating the phase shift and scaling factors for each compared sine wave.[58] The scaling factor is the most crucial result since it indicates how much of each frequency (compared sinusoid) goes to compose the original wave.

The exact method of comparing sine waves to the original wave demonstrates Fourier's extraordinary genius, and the utility of his method is so broad that it is employed not only in acoustics but throughout the sciences in all of the many domains of study that rely on signal analysis, from geology to astronomy to economics to the new physics. Mathematically, the nature of the comparison between a sine wave and the original wave is as follows: the two waves are multiplied and the result is integrated, which is to say, one measures how much area there is under the curve of the result. Higher absolute values indicate that the original wave has lots of energy at the frequency of the compared sine wave. Consider the following four cases.

Case 1: if the sine wave resembles the original wave, then they will tend both to be positive at the same time (for the same values of x), so that these two functions will multiply to produce positive numbers. Their resemblance also means that both the sine wave and the original wave will be negative at the same time, so again they will multiply at those times to produce a high positive number. If the original wave tends to be positive and negative in the same pattern as a sine wave, then the product of the two waves will consistently be high positive numbers, and the area under the curve of this product will be itself a high value (Figure 13*A*).

Case 2: if the sine wave tends to be the opposite of the original wave, one negative when the other is positive, then their product will be a "high" negative number, indicating that there is a lot of energy of the inverse of the sine wave (which is the same as the sine wave phase-shifted 180°). The product of the two waves will be a consistently high-valued negative number, and the area under the curve described by this product will be a large negative number. The large value indicates lots of energy at that frequency, while the negative sign associated with this value indicates the phase shift (Figure 13*B*).

Case 3: if the sine wave is much faster than the original wave, a much higher frequency, then the sine wave will go up and down while the original wave tends to stay relatively constant. When you multiply a sine wave by something relatively constant, the result will look a lot like a sine wave (scaled by a constant). Like a sine wave, it will stay above the *x*-axis about as much as it stays below it, which means that the positive area and negative area will tend to cancel each other out, resulting in a very small total area under the curve. This small area then indicates that the original wave has relatively little energy at that frequency, a weak resemblance to that sine wave (Figure 13*C*).

Case 4: if the sine wave is much slower than the original wave, a much lower frequency, then their product will tend to go up and down at about the same rate as the original function since the sine wave is changing relatively slowly compared with the original wave. Again, the up-and-down motion will tend to cancel itself out of the measurement of the area under the curve, yielding a low overall value (Figure 13*D*).

For acoustic signals, the most pressing difficulty of Fourier analysis is that it represents a wave either in terms of the amount of energy present in the wave at any given frequency but completely independently of time, or it represents the wave in terms of the amount of energy in the wave at any given time but completely independently of frequency. Either a frequency-domain representation of an infinitely long periodic wave that is not localized in time or a time-domain representation, located exactly with respect to time, but containing no explicit information about which frequencies (repetitions, periodicity) are present. This dichotomy is supplementary to the uncertainty principle discussed at the outset of chapter 2: the more precisely a wave is specified in time, the less precisely it can be specified in

A

B

C

D

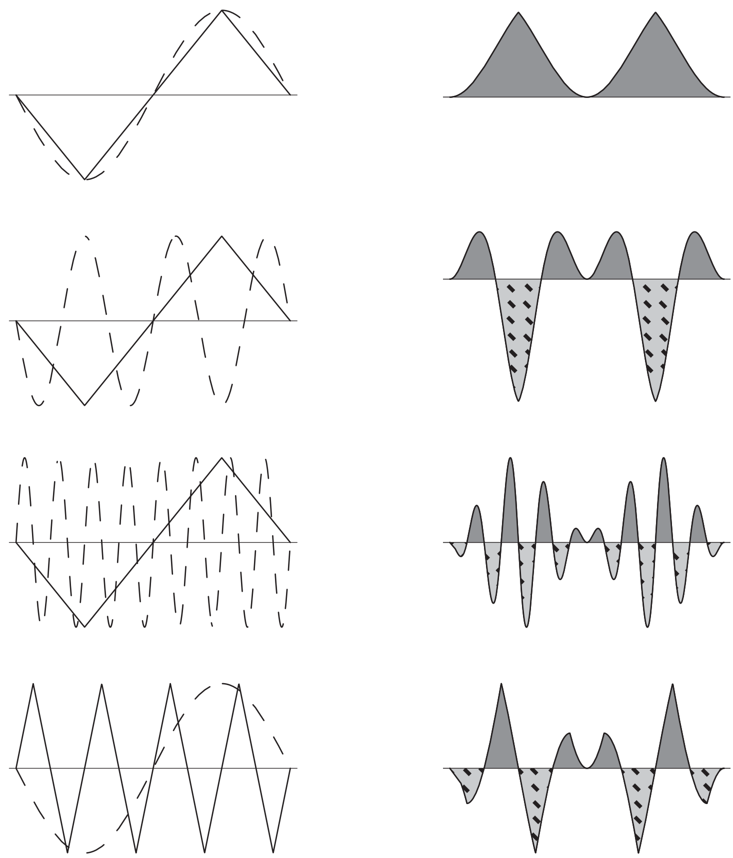

Figure 13. The Fourier method. The left column on each graph shows a triangular wave and a sinusoid *(dotted)*. The right column shows a graph of their product, with the area under the curve highlighted dark for positive area, lighter with hatch marks for negative area. *A* has only a positive area, indicating that the sinusoid in *A* is a major component of the triangular wave. In *B*, there is slightly more negative area than positive, indicating that a phase-shifted version of the sinusoid (with the same frequency) is a component of the triangular wave. In *C* and *D*, the negative and positive areas cancel each other out, indicating that those sinusoids are not components of those triangular waves.

frequency, and vice versa. A wave consisting of a single short pulse contains energy all across the frequency spectrum; the extreme case, an ideal energy pulse or infinitely short blip of energy, is white noise, containing all frequencies equally.

Representing a wave in the frequency domain describes it as a number of sine waves, each of which must be considered to be infinitely long, with no beginning or end. Such representation is appropriate and helpful in the accurate simulation of sustained, periodic sounds (strings, organ, woodwinds, brass, bowed cymbal, etc.). However, it deals only poorly with the attack or percussive portion of a sound. Because the attack of most real-world sounds is relatively short and relatively chaotic, their Fourier analyses reveal a *broadband* frequency spectrum, energy spread over many frequencies, which makes Fourier-based synthesis methods impractical.[59] (Synthesis of broadband sounds by strictly additive methods requires a huge number of oscillators since many sine waves must be added together to simulate energy spread widely across the frequency spectrum.) Psychoacoustic research indicates that the attack is the most characteristic element of instrumental sounds by which we are able to recognize the sound source: the pluck or strum of a guitar, the hammer striking the piano strings, the leading blat of a trumpet. As such, Fourier analysis and Fourier-based synthesis are not well-suited to handle these sounds. Of course, Fourier analysis has two prongs and also allows the representation of a sound in terms of time. But, while such a formulation in the time domain (i.e., as a sample) provides a completely accurate representation of an entire sound, it is a cumbersome and unwieldy tool for synthesis because it effectively provides access only to the sound as a whole without breaking it down into parts that could be individually altered before being resynthesized. Thus, a sample, which is a Fourier representation of a sound in the time domain, allows ready playback of the sound it represents but makes manipulation and alteration of that sound rather difficult. The time-domain representation does not break down the sound into separate parts, unlike the frequency-domain representation. (Technically, the time-domain representation allows time-domain distinctions, such as dividing the attack from the sustain portion of a sound. These can be manipulated separately, but the manipulations themselves are limited since the time-domain representation does not provide information that allows detailed timbral or frequency-based alteration of a sound.)

The fundamental drawback of Fourier analysis is this dichotomy between time and frequency. Fourier analysis assumes its object to be a periodic function, and it operates most effectively on waves that easily decompose into sine waves. Though it indicates the frequencies that must be summed to generate a given wave, it offers little information on the surface as to what goes on within that wave. Real-world data, sounds and other signals, often have sudden jumps, sharp peaks and valleys, chaotic beginnings and subharmonic distortions, and such aspects are only poorly accommodated by a sine-wave analysis. It would thus be beneficial to make two fundamental changes to Fourier analysis. First, it would be useful to divide a wave into parts and perform separate analyses on each. Ideally, this division should take place separately for each frequency of comparison; that is, a search for low frequencies would take for its object a fairly long section of a wave, while a search for high frequencies would divide the wave up into many smaller parts and look at each one separately. Second, it would be useful to use shapes other than sinusoids for the analysis. A wave with lots of sharp peaks might require many sine waves to build, but it might be easily and simply constructed out of a few triangular-shaped waves. The implementation of both of these refinements to Fourier analysis has led to a relatively new form of signal analysis called *wavelet analysis.*[60] Instead of analyzing signals in terms of sinusoids that repeat forward and backward, wavelet analysis uses wavelets, discrete shapes that have a nonrepeating element, effectively fixing the wavelet at a particular point in time. As such, the primary advantage of wavelet analysis is that it overcomes the dichotomy of Fourier analysis. Whereas Fourier analysis allows us to move back and forth between the time domain and the frequency domain for the entire signal, wavelet analysis combines the two domains to provide information about which frequencies are present in the signal at any given time. Unlike two-dimensional Fourier analysis, graphical representations of wavelet analysis are effectively three-dimensional, adding a third dimension to coordinate the other two. Graphs of Fourier transforms show, in two dimensions, energy versus frequency. Wavelet analysis generates a graph of energy at each frequency at each time, requiring a three-dimensional representation (Figure 14).

Wavelet analysis not only yields more useful information, but it opens many new possibilities for synthesis. It provides instructions for synthesizing a changing sound rather than assuming that the wave to be produced is constant and periodic for all time. Further, it allows a resynthesis based on waves other than sinusoids. Waves that contain much broadband energy are not efficiently synthesized by sinusoids since sine waves have all their energy in one frequency. By using a wavelet that is already broadband, the resynthesis may be more computationally efficient and accurate. In effect, wavelet-based synthesis does not need to build the timbre of a sound explicitly, as does additive synthesis, but can include timbre in the decomposed parts of the wave, timbre in the pieces themselves. (Just as Fourier analysis yields instructions for how to re-create the original signal from sine waves, so wavelet analysis generates instructions for how to re-create the original signal from a bunch of wavelets.) The choice of waveshape for the wavelet makes wavelet-based synthesis very powerful and adaptable; using a different wavelet, but in the same proportions and time structure, generates a sound with a different timbre but similar formants and other musically relevant characteristics. That is, in sound synthesis, wavelets allow very subtle alterations to a sound that do not change its overall characteristics.

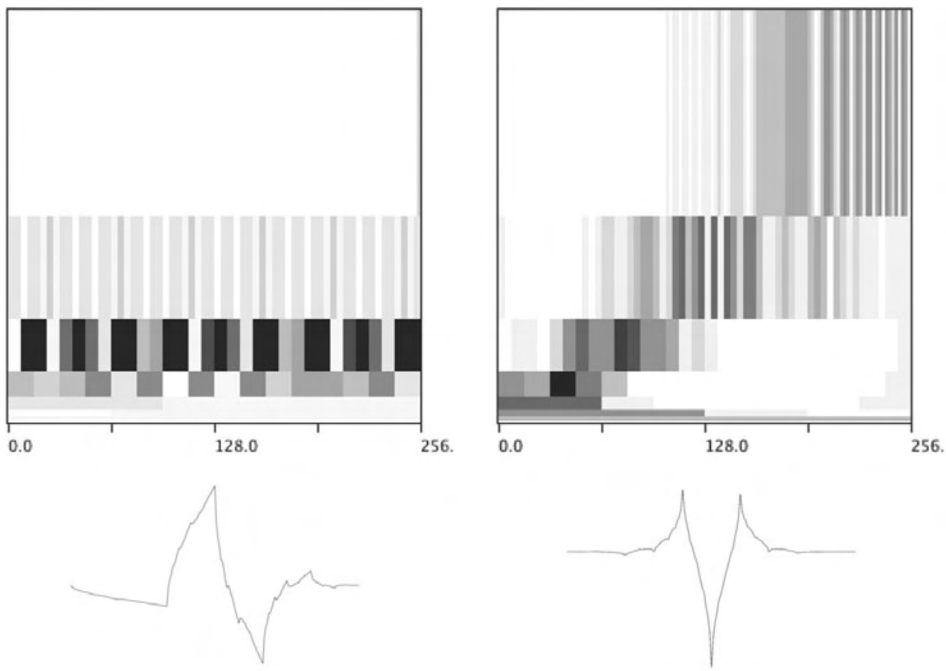

Figure 14. Wavelet analysis. Two examples of wavelets *(bottom)* and the results of analyses using them *(top)*. The horizontal dimension is time, the vertical dimension is frequency, and the gray level is amplitude, with higher values represented by darker shades. The left column shows a Daubechies wavelet and its transform of a simple sinusoid. Note the concentration of energy in a narrow frequency band (the dark horizontal band); a sinusoid has all its energy in one frequency and does not change over time. The right column shows a Coiflet wavelet used to analyze a "chirp" sound, a sinusoid shape that gets faster over time. Note the initial concentration of low-frequency energy that moves higher in frequency over time. Analysis images from Tabor.

Aside from synthesis, wavelet analysis has promising applications in the challenging area of *noise reduction*. No real-world signal is entirely free from noise; in sound applications, there is generally a hiss or buzz or some other low-level sound that one wishes to eliminate from the signal. To take an obvious example, if a recording is made to a cassette tape, then transferred to a digital format for duplication to CD, it is probably desirable to clean up the sound before transferring it to CD to get rid of the hiss inherent to the cassette tape format. Even when using a less noisy recording medium, such as digital tape, there is generally a certain amount of noise introduced by the microphones or other components of the recording chain and by the digital conversion. Noise reduction is the process of reducing this unwanted sound to allow the signal to shine through more clearly. Though it has applications in commercial recording, noise reduction is a valuable technique for signal processing generally. A message broadcast from a weak or distant transmitter may be buried almost indiscernibly in layers of random noise. To decode this message, the noise must be removed. Using a Fourier model of sound, noise reduction establishes a single threshold of amplitude, and all parts of the signal below that threshold are reduced or eliminated. Noise reduction does not generally take frequency into account, so it eliminates both low and high pitches below the chosen threshold. If, however, noise reduction begins with a wavelet analysis, the threshold can vary depending on frequency. That is, one could choose to conserve even very quiet high-frequency pitches if they are adjudged musically (or informationally) relevant while eliminating fairly loud low-frequencies if they are not taken to be part of the "legitimate" signal. In the realm of synthesis, the possibility of performing different operations at different scales, of dividing the signal by frequency before operating on it, is very powerful and has countless applications.

Though wavelet analysis offers a number of advantages over Fourier analysis, and though it does allow a reconstitution and selective alteration of the original signal, it is fairly computationally intensive. Moreover, resynthesis based on wavelets still demonstrates a direct proportion between complexity of the signal and complexity of the synthesis process. That is, more complex sounds require more wavelets that change their proportions over time more frequently. Even so, there are other uses for wavelets besides just a reverse analysis (resynthesis). One of the most promising synthesis applications of wavelet analysis, with many of its own powers and benefits, is *granular synthesis.* Granular synthesis approaches sound as very short chunks, or grains. One creates a sound by compositing these brief grains, each of which is a slice of sound that endures between two and two hundred milliseconds (2–200 ms). The individual grains may be spaced apart, abutted, or layered (added together), and the density of layering is determined by the duration of each grain and the rate at which new grains are triggered. (Longer grains and more frequent triggering result in higher density.) Each grain, though already very short (relative to human sound perception), is given an envelope: over its brief course, a grain begins silently, fades up to a maximum amplitude, then fades out to silence. There are no abrupt jumps from silence to sound, which, were they present, would cause digital distortion, pops and clicks (Figure 15).

Envelope and amplitude are the primary determinants of each grain, and grain density also determines the character of the resulting sound. But

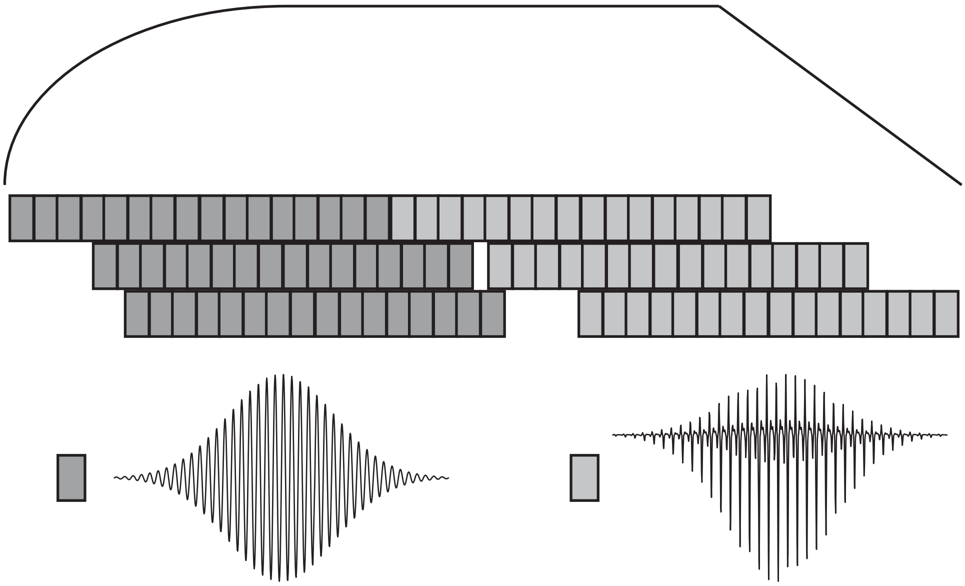

Figure 15. Granular synthesis. Each rectangular box represents a sonic grain of twenty-five milliseconds, which makes this whole sound about one second long. In this example, there are three simultaneous *streams* of grains. The two different shades represent different grains, so this sound changes character after about a half-second. As can be seen at the bottom of the figure, each grain has an envelope, so that over its duration it starts silently, gets louder, then fades again to silence. The entire sound also has an envelope, shown at the top of the figure.

there are additional subtleties in the production of the grains in relation to each other. A single grain is generally a periodic wave (not necessarily sinusoidal) that repeats at some regular frequency. As such, since each grain is generated so that it overlaps previous grains, there is a question of alignment. Do the periodic waves in a grain line up with the previous one(s), or are they out of phase? If the latter, various filtering effects will occur (comb filtering, phasing, or flanging are all possible), including possibly substantial frequency-cancellation effects. Such filtering does not add additional frequencies to a sound but equalizes the ones already present, emphasizing some frequencies while attenuating others. In Figure 15, overlapping boxes do not align with each other, which suggests that the phases of the waves within the grains may also fail to align.

The envelope for each grain—a fade-in portion, a sustain portion, and a fade-out portion—both guarantees against digital distortion and adds its sonic signature to the synthesized sound. In acoustical terms, the envelope is yet another wave that modulates the amplitude of the grain. This modulation, which amounts to AM synthesis (amplitude modulation synthesis), has the effect of adding sidebands to the grainwave frequency, spreading out the energy in a grain over a wider range of frequencies. Longer or more oddly shaped fade-in and fade-out portions of the envelope produce a signal whose energy is distributed across a wider band of frequencies as well as introducing additional frequencies into the resultant sound.

These variables—density (grain duration and grain triggering frequency), envelope shape, grain amplitude, grain phase—are particular to each grain. There is an additional set of parameters that applies not to each grain but to the sound overall, an overall envelope for the sound, with a duration, maximum amplitude, and shape, and these parameters can be applied after the grains have been generated and summed. (Figure 15 shows an envelope shape for the amplitude of the overall sound but does not illustrate the effect of this envelope when applied to the sound.) Furthermore, the parameters that control individual grains can be varied over the duration of a single sound; that is, one can assign envelopes to the parameters that determine how each grain is produced. For example, one can vary the density of grains over the course of a sound, say, by making the grains progressively longer. Or, if one simultaneously triggers them less frequently, then density will remain the same, but timbre will change as phasing effects are altered throughout the reduction in triggering frequency. Even if phase is not an issue (because every grain is generated to be in phase with simultaneously sounding ones), the alteration of density changes the sound since the grain envelope is being triggered less often, thus changing its frequency and altering its effect on the bandwidth of the grainwave frequencies. The point is that a change in one parameter, the density of the grain, makes a number of changes in the overall sound. Moreover, these changes are generally musically relevant and controllable. Basic musical elements, such as amplitude and envelope, are easily determinable, but one can also change timbre, including formant relationships, in controlled and interesting ways.

A critical factor in the sonic products of granular synthesis is the nature of the grain itself. What wave is to be used to make the grains? One can use just a sine wave for the grains, which strips the grains of their own timbre so that timbre can be constructed and controlled entirely by the synthesis parameters. Or, one can use a short sample of recorded sound, in which case the synthesis will produce a sound that resembles the original sample but will also allow additional control over the timbral and dynamic characteristics of the resultant sound. By changing the grainwave throughout the duration of the synthesis, one can create a sound that itself changes from one timbre to another smoothly while maintaining the same pitch and dynamics. A particular application of this technique is to create the grainwave by choosing a small excerpt of a sampled sound and then use a different excerpt of the same sound for the next grain, etc. By starting with a grain created from an excerpt of the beginning of a sampled sound, eventually switching to a grain excerpted from slightly later in the same sampled sound, and continuing to choose successive grainwaves by moving through the original sample, one can recreate the original sound but with control over the length of the sound and over the length of each part of the sound. A sound can be stretched to indefinite length without altering its timbre, a feat generally impossible using other methods of synthesis.[61] Or the attack portion of the sound can be retained as a short percussive moment while the sustain can be stretched or shortened arbitrarily. Conversely, by making simple operations on the grains themselves but proceeding through the original sample at the original tempo, one can change the pitch of the original sound while retaining its pace.

Aside from simple grains or ones generated from another sample, one might get one's grains from another kind of synthesis, additive synthesis or FM synthesis, for two examples. By varying the parameters of this other synthesis over the course of a granular synthesis, not only does the grain change, but the sound changes in complex ways, since simple alterations in the grain have predictable but multifaceted effects on the resulting sound. This is why wavelet analysis makes such an excellent complement to granular synthesis. Since wavelet analysis yields a representation of a sound as a sequence of overlapping events, each with its own duration and frequency but each with the same basic waveshape, these events can each be treated as a separate grain or as a brief stream of grains. This allows the regeneration of complex real-world sounds that retain a rich timbre and that evolve musically and naturally over the duration of the entire sound. Granular synthesis generally involves the simultaneous production of more than one grain stream, and by coordinating the parameter envelopes of separate streams, musically complex and interesting results are readily obtainable. Morphing, pitch-shifting, time alteration, and general arbitrary manipulations of timbre are easily realized with granular synthesis, while accurate simulation of acoustic instruments is accomplished by adding wavelet analysis. Indeed, one can take the simulated acoustic instrument and alter its sound in acoustically impossible ways while retaining a realism in the timbre.

Granular synthesis is a generalized method of synthesizing sound that incorporates a distinction of scale within the sound. The process of synthesis explicitly divides the scale of the grain from that of the whole sound and treats each scale separately by assigning separate sets of parameters to them. Depending on the exact implementation of the synthesis, there are also intermediate scales, streams or bursts of grains, with their own envelopes, shorter than the entire sound but longer than any individual grain. The scale can be extended, so that the same principle governs an entire musical phrase, to create rhythms and melodies. Even a whole piece could be generated using granular synthesis, a self-composing music that takes in parameters and puts out evolving and musically interesting pieces entirely synthesized.[62]

The distinction of scales in granular synthesis is the key to its nonlinear complexity. Each control parameter has multiple sonic effects, so making one simple change in the inputs results in complex but coordinated changes in the outputs. Altering the length of the fade-in portion of the grain envelope, for example, changes both the amplitude and the bandwidth of the resulting sound, creating stronger or weaker bands of energy around the fundamental. Triggering grains more frequently generates different phase relationships among the grainwaves to introduce phasing effects *and* raises the frequency of the signal that modulates the grainwave, which creates entirely new frequencies in the result and may even alter the pitch of the fundamental. In general, the sonic phenomena that result from granular synthesis are affected by more than one input parameter, so there is more than one way to achieve a given sonic result, each with its own sonic byproducts. This heterogeneous relationship between input and output, this nonlinearity, is most typical of musical gesture on traditional acoustic instruments: varying the angle of the bow or the amount of pressure applied to it, relaxing the muscles of the embouchure, striking the key near the fallboard, all of these gestures have complex results, which affect many aspects of the sound, but these affects are all musically coordinated. Notes tend to get harder as they get louder, the filtering effects that occur naturally in acoustic instruments vary their envelopes and cut-off frequencies with the volume of the note. These coordinated but complex variations are also built in to granular synthesis, which becomes more musical to the extent that it incorporates the nonlinear complexity of gesture.

If gestural complexity and coordination is usually lacking in synthesis, this is due in part to the strict division effected between time and frequency in the Fourier model. The distinction of scales in granular synthesis takes the place of this analytic division between time and frequency in other methods of synthesis. Granular synthesis preserves both time and frequency in the grain while allowing their simultaneous independent manipulation outside the grain. (Dennis Gabor, the theoretician who discovered the uncertainty principle for sound, postulated but did not yet realize granular synthesis in the forties as a way to maintain both time and frequency control over the sound.) As such, granular synthesis is also a means of avoiding the separation of form from content that is a typical limitation of sound synthesis. Whereas form characterizes the sound analytically, in terms of properties and values, content characterizes it synthetically as a complex relation among all its interwoven aspects. In most digital synthesis techniques, the division of time and frequency also implies the strict isolation of parameters to be manipulated. For example, alterations to the pitch of a sound are independent of adjustments to its timbre, which gives an analytic power but does not model the real world accurately. The division of form from content contributes to the linearity of the complexity in the synthesized sound, since form must be constructed adjunct to content but does not arise from it autochthonously. In granular synthesis, forms are not separated from each other sharply to begin with, as a single parameter alters both time and frequency information, or changes simultaneously and intuitively a fundamental and its harmonics, or makes smooth alterations in both timbre and pitch. These sonic properties therefore not only preserve their values relative to each other through changes to specific parameters, but such simple changes make complex alterations to the resultant sound that still preserve its character. Moreover, the relationships among the parameters are themselves more sonically intuitive, so that it becomes easy to, say, add harmonics, or adjust the phase relationship of overlapping grains to make the sound thicker.

The most interesting sounds vary, but also vary their variations, so that the frequency and bandwidth of a given formant change over the course of a sound, and even this change should vary, sometimes changing rapidly, sometimes slowly. Variable variation most effectively simulates real-world sounds and instruments, which demonstrate a kind of weighted chaos, in which random fluctuations of the sound add an infinite complexity and subtlety while maintaining a consistent and identifiable pitch and timbre. Granular synthesis allows extremely fine control over variation and over the variation of variation, as changes made in each successive grain can determine subtle variation on the order of a few milliseconds. Whereas in other methods of synthesis, constant change is controllable only by overarching envelopes that apply to the entire sound or by contrivances to overcome the inherent limitations of the synthesis method, in granular synthesis, constant reevaluation of the sound is built in to the synthesis method itself since a new grain must be produced every few milliseconds. Still, despite its nonlinear complexity and intuitive gesture-like control, granular synthesis can sound machinic or homogeneous, especially after extended listening. The kinds of parameter manipulations necessary to generate sounds that are deeply complex, that vary in subtle and surprising ways, that conform to no pattern, are tedious and difficult. Thousands of grains are added together to make a sound that endures for a couple of seconds, and the labor to specify differently each grain and all its parameters is prohibitive. Without such arduous efforts, however, granular synthesis, even augmented by wavelet analysis, begins to challenge the Fourier model but does not escape its ultimately digital quality, a sameness that belies its formulaic or synthetic origins. The infinite richness of real-world sounds can therefore be more closely simulated, without having to specify each grain separately, by introducing a small random fluctuation into the parameters that generate the sound. The nonlinear complexity of granular synthesis ensures that the phenomenal results of this random fluctuation will be neither too obvious nor too subtle. The effects of a random fluctuation of, say, the duration of the grain, are multiple and complex but do not dominate the sound, so that the overall effect is musical, as the multiple changes are musically coordinated. Ideally, the random variation would be complex enough to avoid a recognizable pattern in the resulting phenomenon, would be controllable in its broad outlines, would allow the preservation of a consistent character to the sound while adding a subtle depth, and would be completely repeatable, so that the sound designer and composer are not forced to rely on happy accident to realize their objectives. In essence, we want to defy the digital by simulating the rich depth of reality. Granular synthesis already achieves some of this by amplifying complexity, but it can be further augmented, with all of the desirable characteristics, using the technique of *cellular automata*.

Though cellular automata have applications in diverse realms, in the area of sound synthesis they are used to simulate a neurochemical process wherein individual neurons, linked in a spatial network of interactions, progress through various states. In brain chemistry, cells are individual neurons, and their states are the relative abundance of charged particles, which determine the imminent likelihood that the neuron will fire. When simulated on a computer, the state of a given neuron is usually represented by an integer value, and the neurons themselves are usually understood as laid out on a two-dimensional grid so that each neuron has specific neighbors. Each neuron, or cellular automaton, is in a particular state at any point in time. Its state at the next time, after one *iteration* of the simulated network of automata, is determined according to a set of rules that consider its previous state and the states of the cells in its neighborhood. The rules for determining the next state of a cell are the same for every cell in the system of automata, and these rules also define what counts as the neighborhood of a cell. Different rules will generate different results, that is, a different progression of states for the network of automata. For example, here is one possible simple rule: for a cell, *c*, if the state of at least two ad-

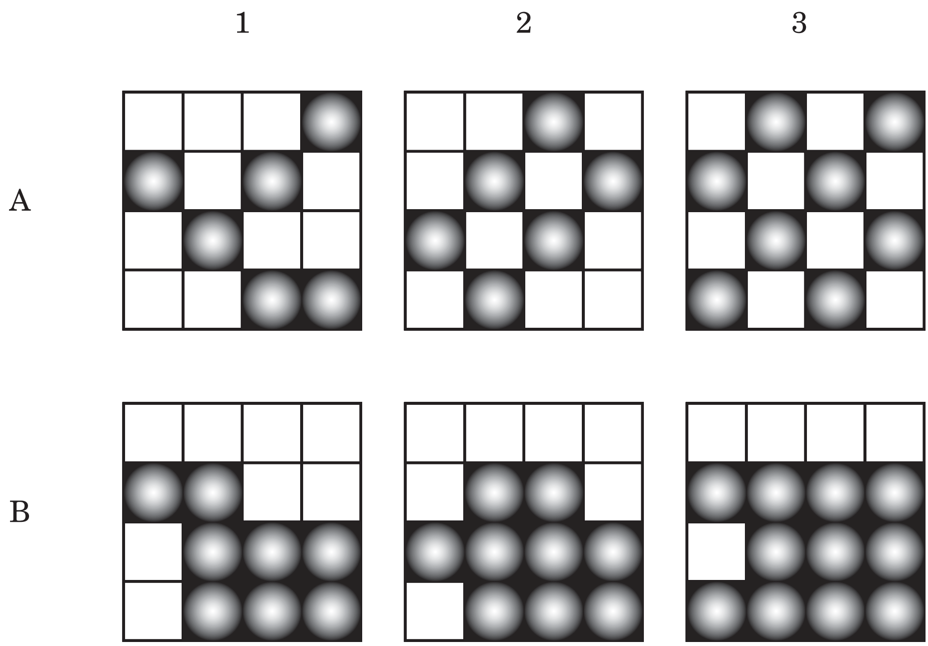

Figure 16. Cellular automata. Rule: A cell with at least two ON neighbors is ON at the next iteration, or else it's OFF. (Diagonals do not count as neighbors in this example.) A white ball (not a blank square) is ON. A1 and B1 represent two different possible starting points. Following the rule, Row A reaches step 3, then oscillates permanently between 3 and its complement, which looks like 2 but with the upper left and bottom right corners filled in. Row B progresses 1–2 then alternates between 3 and a fourth state, not shown, whose calculation is left as an exercise for the reader.

jacent cells is *on*, then the next state of cell *c* is *on*, otherwise it is *off*. This calculation would be performed for each cell at each step (Figure 16).

Notice that, in this case, there are only two possible states, *on* and *off*, and the state of a cell does not depend on its previous state but only on the states of its neighbors. In this case, the neighborhood of a cell is defined as the adjacent cells (since no other cells matter in the rule for determining a next state), but other rules might include calculation wherein a cell's next state is based in part on its previous state and/or on a wider (or narrower) neighborhood. In the example given, the tendency of the system is to fall into a relatively simple stability and mostly just *on* or *off* permanently. That is, if the initial state of the system, specified by the user, included lots of *on* cells, then others would tend to turn *on* also, since lots of cells would have at least two *on* neighbors. Whereas if the initial state included mostly *off* cells, then their neighbors would turn *off*, leading to more cells turning *off*, etc. It is also possible to imagine a circumstance in which, given the above rule, a cell (and its neighbors) would flicker *on* and *off*, changing their states every iteration. With more complex rules, more complex behaviors are possible: instead of a periodic *on* and *off*, a cell might cycle periodically through many states, in coordination with its neighbors. Periodic cycles are musically relevant phenomena and part of what makes cellular automata a fruitful synthesis tool.[63]

To use a network of cellular automata for music, one preloads the system with a set of initial states, one state for each cell. This can be done by specifying each state deliberately or by allowing them to be filled randomly. Because the cellular automata proceed according to deterministic rules, the same initial conditions will produce the same progress of states each time, allowing repeatable results. At each iteration of the system of automata, one or more cells are measured, and their states are used as parameters in the creation of music. One such parameter might determine the length of the fade-out portion of the next grain envelope in a granular synthesis, or it might determine the next pitch to be used in constructing a melody. (Cellular automata can add complexity to synthesis, composition, or other aspects of musical sound generation.) The cellular automata system is then allowed to proceed to the next iteration, which produces the next set of parameters. The overall result is a kind of controlled chaos. It is chaotic because each automaton is dependent at each iteration on many different values, so watching a single automaton changing states may reveal no obvious discernable pattern. It is controlled because the system is deterministic, producing a specific output for a specific input, and because the automata interact in predictable and typical ways. That is, given a set of rules, there are general tendencies for a system of automata. A network of automata tends to settle into small groups of cells with identifiable behaviors. One particularly useful tendency involves an initial chaos that settles into pockets of periodic (cyclic) activity. This tendency, fairly common in cellular automata systems, is a good model of the behavior of acoustic instruments, wherein the initial attack is noisy and chaotic but eventually gives way to regular periodic bands of energy. Thus, by using cellular automata to determine the frequencies of a few simultaneously generated grain streams, one can simulate the complex behavior of acoustic instruments while timbre will remain rich with plenty of microvariation. One can thereby use electronic or synthesized timbres to generate sounds that are uncannily acoustic in behavior. By perturbing the system every so often, plugging a new value into certain cells after every ten iterations, say, one can continue to add a bit of chaos into the result while still maintaining an overall consistent character.

The Grain of the Voice

Each of these three techniques—cellular automata, granular synthesis, and wavelet analysis—challenges the digital to exceed its formal limitations, to liquefy its borders in order to extend into the ears and bodies of listeners and players. This is not to say that any of these techniques escapes altogether the formality of the digital. Each is implemented in the digital domain so that each is wholly formalizable, reducible to the numbers that correspond to its manipulations. If these techniques succeed nevertheless in pushing the boundaries of digital possibility, it is by virtue of a zigzag, a choppy motion that breaks away from the linear constraints of the digital. The zigzag passes through an additional dimension, and the digital must reorganize or regroup in order to follow this leap, to trace the new form of this motion. These techniques scramble the digital, at least for a moment; they fold the data back on themselves, and the additional dimension shows up in this folding or layering. Layering puts disparate levels in contact and connects diverse scales to each other. Cellular automata gain their power and complexity not simply by aggregating simple cells but by forming geometric relations among those cells and by specifying rules or procedures that ensure the mutual influence of the cells on each other. Each cell has an inside and an outside, which are separate but interrelated domains, each with a set of rules. Granular synthesis distinguishes the inside of a grain, itself complex, from the macrolevel characteristics defined by the variable aggregation of grains and then draws intricate lines of interaction between these two scales. Wavelet analysis creates many insides, as it not only preserves a complexity in the wavelet itself, which can take any shape, but adds another dimension by stretching the analysis over different intervals corresponding to different frequencies and then further stretching it over time. An individual wavelet may have fractal characteristics, incorporating different scales in its form. The additional dimension of wavelet analysis shows up explicitly in its graphic representation, which is literally three-dimensional, or which uses color to represent the necessary additional dimension.[64] In each case, the additional dimension is not simply an analogous extension of the former dimensions, not just a perpendicular with the same linear rules that applied to the original dimensions. Instead, the additional dimensionality is won by granulating the linear, by chopping the line into variably sized partitions and then creating a texture by overlapping those grains. It is this chunkiness that extends the dimensionality, adds a palpable texture to the object, a fractal quality that makes the borders fuzzy enough to exceed their linear limits. Fractional or granular dimensions and connection across disparate scales are the hallmarks of the fractal, and, indeed, each of the three techniques exhibits properties of self-similarity. Wavelet analysis reveals how the signal is changing but also how the change is changing at different scales of time and frequency. Granular synthesis induces complex variation at the macrolevel by operating at the microlevel. The same operations are possible at both levels—pitch determination, amplitude enveloping, timbral morphing—and these operations can be repeated at the (still broader) level of structure to extend the granular technique into composition as well as sound design, thus expanding the fractal. Cellular automata produce a variation of variation, hiding patterns within patterns, as simple cells generate complexity in relation to their neighbors. Granulated sound, partitioned into heterogeneous elements, exposes its inside on its surface, submitting itself to delicate, local manipulations that repercuss over its whole body: granulation as tickling.

How can we tell in general when there is additional dimensionality, when the digital is challenged and must decompose before it ossifies again? When does the grain exceed its formal description? The musical-digital question is, do the grains become mobile and intense, do they retain an inside, or are they rather just units, parts to be stacked? Granular synthesis does not use grains only as elements; it is itself grainy, extending across dimensions, fractal. Furthermore, the grain is not merely the basic unit, not just a waveform, but is the power of synthesis, the power to assemble, to extend, to multiply dimensions. Not only granular but every synthesis employs a grain, every synthesis has its elementary particles. It is a matter of how these are assembled, horizontally and vertically, or diagonally. Granular synthesis makes explicit the granular nature of music, where sound is made of intense moments of widely varying lengths. Music is not assembled from elementary grains, its parts are not homogeneous; rather, its graininess is a matter of envelopes, layers, densities, variations, and the relations among them.

Music theorists are too often reluctant to acknowledge the granular quality of their objects. They observe the round notes, the straight stems, arrayed on a linear staff divided by perpendicular bar lines that mark off a metered time; they follow the horizontal and the vertical but cannot find the diagonal, "the musical act *par excellence*," the zigzag that makes the notes leap off of the page into other dimensions.[65] Perhaps because he is not primarily a theorist of music, Roland Barthes recognizes the musical import of the grain. He praises the creative faculty that assembles (sung) music out of fragments.

> This faculty—this decision—to elaborate an ever-new speech out of brief fragments, each of which is both intense and mobile, uncertainly located, is what, in romantic music, we call the *Fantasy*, Schubertian or Schumannian:

> *Fantasieren:* at once to imagine and to improvise: [. . .] in short, a pure *wandering*, a becoming without finality: at one stroke, and to infinity, to begin everything all over again.[66]

This gesture at a *musique informelle* is pointedly not about assembling music from prefabricated parts, an idea Barthes explicitly opposes in "Music, Voice, Language." Fragments are not created by dividing up a musical line at its joints but by juxtaposing and layering intensities, "each syllable [. . .] must be set (like a precious stone) in the general meaning of the phrase." Intensities are physical, musical, memorial material, and they reach the listener directly and immediately, moving first of all not the spirit but the body. "These figures [intensities] are not persons but little scenes, each of which consists, in turn, of a memory, a landscape, a movement, a mood, of anything which may be the starting point of a wound, of a nostalgia, of a felicity."[67] Intensive, mobile fragments are not articulated but have fuzzy borders, fractal dimension, extending into the body, into the past and future.

On the other hand, articulation, the division of a line into concatenated elements, is musical anathema, for it replaces the singular moment of meaning with the too-clear precision of conventional expression. "Articulation, in effect, functions abusively as *a pretense of meaning:* [. . .] *to articulate* is to encumber meaning with a parasitical clarity, useless without being, for all that, sumptuous."[68] One divides a phrase (analysis) in order to map it, to correlate it with cultural norms of expression, music by the numbers. Analysis provides an index that correlates music with coded emotion, places it within an established system, but in so doing, relegates that music to expressing only what is already known, what *can* be expressed. Analysis therefore encourages a music for mass culture by establishing a system of standards on the basis of which it is possible to align opinion, thus reducing music to style.[69] Standardized responses to standardized stimuli divide music into categories of genre with links to class, ethnicity, and other affiliations. Mass culture reinforces the standardized indexes that measure music, inculcating adherence among listeners so that each piece triggers a predictable response. Musical creativity becomes a matter of prefabricated assembly; every pop song is effectively a remix, combining the current samples, the rhythm of the day, the latest style.[70] Pop music producers pick and choose from a palette of available and current stylistic possibilities while pop music consumers pick and choose from the resulting genres and subgenres. The analytic index shows up also in the charts, which, according to Attali, are primarily an instrument by which the masses coordinate their tastes with each other.[71] Across cultures, throughout history, among youth and adults, musical affiliation is a significant component of style, which begins to explain the extraordinary success of the music video. The iconography of the image can be endorsed publicly where one's music may not go, an advertisement of musical affiliation. That there are a variety of styles does not contradict the fundamental principle of alignment of opinion. Coordination of opinion is as much about differentiation as association; mass culture requires only that the categories be empirically defined. Opinion in mass culture involves choosing the adjective that best describes one's feelings, thumbs up or thumbs down, as the film critics say. This kind of opinion provides the illusion of choice and autonomy, "*a pretense of meaning*," while channeling the potential creativity of aesthetic engagement into predictable and commercially viable directions. As long as you like either hip-hop or C&W, you can be targeted.

This critique of genre applies precisely at the level of the general. Analytic determinations influence many aspects of music production to aim a song or album at an identifiable market, but any given song and any given album exceed the predictable dimensions of measurable genre. This excess is an aesthetic spillover that the recording industry tries to eliminate but cannot. Some recordings simply refuse to catch on among the listening public no matter how many times they are dropped into the rotation on MTV and Top 40 radio. (These media are directly compensated by the recording industry for promoting certain songs and artists.) Other recordings become popular without major-label backing (though the labels come knocking soon enough), through word of mouth, charismatic performance, by arousing political resistance, or by "crossing over" into an unanticipated and perhaps unaccountable genre. The aesthetic overflow of a song defies any formula and allows the industry to move so that styles change and the listening public stays a step ahead of the recording industry. Even the most plastic productions—artists whose images have been constructed according to an agent's research about what "kids today" are looking for—contribute something of themselves to their records and videos. Moreover, most artists even working within a genre attempt to offer a unique voice, a sound that is their own. Genre does not entirely capture any individual song, even if its pervasive influence flows into the minute details of production, composition, and performance.

Despite his recognition that music is no longer listened to so much as accumulated, Attali optimistically announces a new direction for music: the age of composition, an era of music-creating as opposed to music-consuming. But Attali does not anticipate the grip of the digital over culture.[72] The victory of mass culture is to define choice as a choice among alternatives. That is why the digital has turned out to be such a perfect match for the music of mass culture, analyzing and correlating opinion with numerical representations of music that boil down to binary choices. The digital is analytic by nature, breaking down the music into basic units, standardizing sound recording. These units, bits, analyze sound in its minutest details, turning the music into a content-neutral form, and thus facilitating easy recycling, cut-and-paste, indexical measurement, adjustments to popular taste. Purely formal, bits are neither intense nor mobile; they are not fragments of music, but indices of amplitude. To the culture of music, the digital offers an absolutely linear smooth surface without texture, or a flawless uniformity of texture, each bit equivalent to each other. The music becomes statistical in nature, and success is a matter of finding the formula that relates the bits used to the demographic target market. Already, online CD retailers can predict which music you will like given some personal information about you. How long before this same information will allow the computer simply to generate your preferred music before your very ears? Commercial radio stations program a week's worth of music in advance, to be cued up and played by a computer jukebox, using the latest "numbers" to determine what should be played and when. MTV features numerous versions of the show where the viewers call in, or e-mail, or "instant message" to determine which videos will be played, confirming Attali's contention that the consumer's goal is to reflect most accurately everyone else's opinion.

If the mass of listeners—identified by demographers and advertisers as a young crowd getting younger—exercises any critical judgment, it is primarily oriented toward the alignment of taste: to discern, for a particular song, whether it is an appropriate kind of music to like. The reproduction of music is not geared toward opening the ear to something new but to allowing one to hear what one has already heard. The romantic notion that music makes one feel (something) is still the popular myth and the taken-for-granted reason to listen to music, but the context of playback generally prevents the music from getting through to the listener, who therefore can feel only what she already felt. For the majority of listeners, a "good" reproduction system is one that puts out a lot of bass, which has prompted personal stereo manufacturers to install circuits in their components that boost the amount of bass, sacrificing fidelity in favor of muscular or powerful reproduction. Low-frequency (and broadband and high volume) sounds mark the most obvious structural distinctions in popular music, carrying the weight of the bass drum on the downbeat and the pulsation of the bass guitar that defines the harmonic rhythm throughout the piece. Between boosted bass response and the cheap headphones or cheap computer speakers that so many listeners employ these days, very little of the actual sound gets heard and none of the subtle content of the music. Headphones, despite their close proximity to the listener, generate a misleading experience of a music that is no longer in an acoustic space as such but now within the listener's head. Not only do they eliminate the social element from music listening, to the point of isolating the listener, but personal stereos foreclose the space that would allow the appreciation of musical subtlety.[73]

Such intolerable listening conditions are tolerated precisely because listeners are not interested in the music as sound but as index. How refined does the reproduction system have to be in order to pick out the articulations, the analytic elements, the formal structures that are the most gross features of the piece? If one can hear the basic rhythmic pattern, bass drum, snare, and high hats in four-beats-to-the-bar, the rest doesn't really matter. Reassured that the phrases begin and end in the right places, that the electronic effects are up to date, that the key signature is persistent and familiar, one can simply experience the music without actually hearing much of it. One need hear only enough to recognize the genre, to parse the coded emotional expression. Much like the performer playing a digital instrument, digital music acts not as a vehicle but as a trigger, setting off preprogrammed feelings in the acculturated listener. The music never actually reaches its audience and is never really intended to. The key to mass cultural music listening therefore is not to hear the music but to be reminded of it, to hear only what one has heard before. To this end, poor fidelity may actually be a boon, as hearing less means fewer surprises, fewer challenges.

Once the formal characteristics of a piece of music are captured by the digital, much of that form can be discarded as irrelevant to the code that regulates conventional emotional response to music. MP3s (songs encoded using Moving Pictures Experts Group [MPEG] encoding, layer 3)—which eliminate more than 90 percent of the data that would be required to store the same song on a standard CD—are not only considered an adequate substitute for the CD, but audio quality rarely even comes into question. MP3 encoding reduces data to about one-twelfth the original amount, but which eleven-twelfths are being thrown out? The one-twelfth of the data that are retained have been carefully selected to preserve those most salient elements, those most notable formal features of the sound that articulate it, so that listeners know how to respond. This is, in part, why nonmainstream music stands to lose the most from data reduction techniques such as MP3 because it lacks the coded emotional forms to begin with and so places a more equal value on each part of the sound, making it difficult to determine what should be kept and what discarded in order to preserve the "essence."

Lossless reduction reduces the size of the data in such a manner that the original data can be completely restored. A lossless technique like Huffman coding fits the same amount of information into a smaller space, sacrificing ease of interpretation for data size. However, lossless techniques can only go so far, and to achieve the dramatic reductions of MP3, one must throw away some of the original data, a *lossy* reduction. Lossy reduction is rampant in musical applications and underlies the MP3 craze, as well as the minidisc format, the failed DDC (digital data cassette), and streaming media formats, such as Real Audio and Liquid Player. Though these methods differ from each other in their details, they each employ the same fundamental approach to thinning out the data representing sound. This approach is based on psychoacoustic principles, or *perceptual coding*. For example, since the ear is less sensitive to very high and very low pitches, these may be removed from the signal at the outset. If two sounds are close in pitch and one is much louder than the other, the ear cannot hear (very well) the softer sound, so why not remove its data from the signal? Likewise, when a loud sound ends, it takes a few milliseconds before the ear can adjust to detect a soft sound, so any soft sounds immediately following loud sounds can also be discarded. These principles of psychoacoustic masking justify the elimination of much data from the original signal. By reducing the overall dynamic range (amplitude compression), one can save still more data space. Few people pay much attention to stereo image, so stereo separation can be severely compromised to further compact the data. Certainly these alterations to the content of the signal can be readily detected, even by untrained ears, but most listeners claim that the differences are too subtle to matter to them. No doubt, cheap headphones and computer speakers will barely reveal these subtle differences, the loss of aura in such data-reduced music. Reduction is thus a nonissue. Only the audiophiles, discussed in chapter 1, make much fuss about the decreased quality of data-reduced music, and they were marginalized to begin with. The industry, led by pop music listeners, is heading inexorably in the other direction. From the perspective of the music consumer, the convenience and portability of the MP3 far outweigh the better sound quality of any of the proposed high-bandwidth formats.

With attention turned resolutely away from sound quality, the relationship between the technology and its purpose (to convey music) begins to slur. Music has always been technological, from the stretched strings of the guitar to the disciplined voice of the singer. (In this sense, even the most primitive vocalizing is technological as soon as it is singing; work must be done on the body to reproduce expressive sounds by intention. Expressive sound is already a discipline, already a departure from an idealized "natural.") But the recent dominance of digital technologies in the music industry ensures that musical artists now define their actions in terms of those technologies, adopting a posture that is self-consciously progressive or deliberately backward. In his exemplary article, "The Sound of Music in the Era of Its Electronic Reproducibility," John Mowitt accounts for this technology fetish as an attempt to find meaning in a music as empty as the culture it reflects. That is, consumers search for the significance of the music they hear and create but discover only that its lack of significance answers to its status as commodity: digital sound, no longer music, but only data, statistics, and numbers. "The ritual character of auratic art manifests itself in the triumphant cult of technology. [. . . T]radition is now called upon to assure individual interpreters that the meaning they are incapable of assigning to their experience is in fact an accurate reflection of the general meaninglessness of culture."[74] The technology comes to count as much as or more than the music; listeners admire the smallest minidisc player, the most bass-heavy speakers, the MP3 machine with the best LCD display. Musicians covet the latest version of a reverb machine and constantly update their gear to conform to the newest standards of interoperability and sound quality. Having saturated the market with CDs and virtually eliminated the LP, record companies—desperate for a new format to trigger another massive buying cycle and taking a *see-no-evil* stance on the public preference for low-bitrate portable audio[75]—are now introducing DVD-Audio, as well as Super Audio Compact Disc (SACD), an enhanced CD format with higher resolution and sampling rate.

Confronted with the impossibility of significance in a music dominated by digital technology, the music artist follows the path outlined by Adorno, who sketched a response to the same cultural void more than a half-century ago: fold the insignificance back on itself, turn the music into an ironic commentary on the conditions of its production. "What characterizes the work of those musicians radicalized by their relation to bit-oriented reproductive technologies is the effort to raise the technical preconditions of their musical material to the level of cultural expression."[76] By making technology an explicitly musical concern, by giving technology a voice in the music, one can exercise the dialectic of musical meaning. In some recent music, concern with technology is predominant, overtaking other traditional aspects of music, such as harmony, rhythm, and melody. There is a loose subgenre of electronic music—referred to variously as *glitch*, *clicks 'n cuts*, *microwave*, *microsound*, and other names—that manifests a relation to technology in the music by assembling the music out of characteristically technological or digital sounds. The sounds of a skipping CD, of digital distortion, of 0s and 1s arranged in patterns derived from formulas with little regard for their sonic results, of high pitches above human hearing and low pitches heard in our guts instead of our ears, all of these uniquely digital sounds are used to create a self-consciously digital music. Some musicians foreground the incredibly quiet background of a CD, or its extreme dynamic range, or its low-level resolution. Still others present technology that is not specifically digital, by building pieces entirely out of static and other broadband noises at extremely and unbearably loud volume, or incorporating sonic hallmarks of old technology into their sound, such as LP surface noise or the distinctive sound of early synthesizers. Spatial characteristics possible only through the digital manipulation of music also draw attention to the technology itself, as when a train passes through one's living room, or a cymbal flies around one's head as it decays. Equipment, digital and otherwise, stretched past its approved limits can generate sounds that reflect back on the machine itself, like the no-input mixing board (Toshimaru Nakamura[77]) and the sample-less sampler (Sachiko M), or a synth that accepts, by an accident of programming, parameters that are technically out-of-bounds. "The medium is no longer the message in glitch music: the tool has become the message."[78] In the best cases, these ironic self-reflections challenge the digital to show itself, to push against its limits, to measure up to the analog, the actual, the acoustic. These demonstrations of equipment and concepts show both the possibilities and shortcomings of digital sound technology, its strengths and weaknesses, its reach and its limits.

If the synthesizer is to become, as Gilles Deleuze and Félix Guattari suggest, "a musical machine of consistency, a *sound machine* (not a machine for reproducing sounds), which molecularizes and atomizes, ionizes sound matter, and harnesses a cosmic energy"; if it is to make "audible the sound process itself, the production of that process, and [put] us in contact with still other elements beyond sound matter"; then it must do so by challenging the limits of convention, by doing always what it cannot already do.[79] By stretching the synth beyond its defined limits, digital music makers cause breaks and gaps in the instrument itself, disintegration of its borders that allows a more effective meld with other instruments, with the listeners' ears and the performers' bodies. Working with digital music outside of the context of mass culture requires a constant challenge to the limits of the digital in order to make its borders fuzzy, to turn it from its habitual patterns to new ones, whose novelty is neither human nor machine, not yet digital or analog. Despite its tendency to reproduce the same pattern again and again and despite its perfect memory and its ideal abstraction, the digital in its structure inherently engenders a reflection on its own limits. For the digital introduces a distance between the musician and the music, a distance that mediates but that also opens a space of reflection.

Instead of a direct contact with sound vibrations, computer-based music tools place the abstract symbols and structures of sound as an intermediary between the musician and the music; a mediating distance is the rule in the use of digital instruments and compositional tools. Though the MIDI standard can represent music in terms of note values, most computer-based digital-audio tools present to the user an interface of frequencies instead of pitches, lengths in seconds instead of quarter-notes, and acoustic rather than musical symbols generally. The tools used to make digital music are frequently modeled after the engineer's studio rather than the composer's desk or the musician's instrument. One most concrete way in which this mediating distance imposes itself on the music-making process is in the delay, called *latency*, between triggering a sound and hearing it. The trigger, be it a key press or a drum hit, must be processed and interpreted by the equipment before it gets turned into sound, and this process takes time, which makes sensitive playing rather difficult. In general, the mediating distance imposed by digital instruments is an effect of the discontinuity between the digital realm and the analog-acoustic realm. Because there is not merely a transduction but a translation from one domain to the other, there is a gap. This gap places the performer, composer, and musician at a remove from the music itself. The delay can be arbitrarily prolonged, given the abstract nature of the digital data: today's button-pushing performs next week's concert. While the distance between musician and music impedes the immersive experience of playing, it also opens compensatory possibilities. The sound created can be frozen in place, studied, and manipulated at the leisure of the composer or player. The performer/composer is thus confronted by the sound as object, and the sound loses some of its organic immediacy to become something to be manipulated, tweaked, worked over. At a remove from the sound, standing over it, the electronic musician reflects on the sound, has the opportunity and the distance to hear every detail. Digital music tools allow and encourage an unending editing process, exposing every aspect of the sound to the music maker and offering a focus on arbitrarily small detail and arbitrarily large structure. The possibility of such a specific focus, combined with the inherent distance of digital music making, results in an attention to the quality of the sound, the minute details of the music that are observable only from the objective distance created by the digital tools. "Good" sound becomes an explicit directive of the electronic musician, sometimes to the detriment of good music.

With all the time in the world to make aesthetic decisions, and with arbitrarily fine control over the resulting sound, the digital musician tends to rely less on intuition and more on well-formed and deliberate standards of good sound. Decisions are made more with the mind and less with the body, as the gestures of digital music-making also demonstrate this same deliberation: the acoustical gestures of bowing, fretting, strumming, blowing, fingering, are replaced by the technological gestures of downloading, cutting, pasting, duplicating, aligning, normalizing, filtering, etc. Hours and days in front of the keyboard and mouse are spent *playing* a piece. As music-making becomes a more intellectualized and less bodily, intuitive process, experimentation too is deemphasized. Accidents and mistakes can always be corrected, which encourages musicians to try all sorts of things in the initial phase of the project, but it also allows them to weed out of the final product the experimental, anything offensive or uncomfortable, to effect a conformity to prevailing standards.[80]

"On one side there is the concrete, visible and mechanic *[sic]* universe of the traditional instruments where the body of the instrument and the body and movements of who is playing that instrument are intrinsically related to the qualities of the sound they are producing. On another side, in the era of electricity and electronics, we start listening more and more to the sounds of invisible bodies contained in the electronic components of synthesizers, samplers, and computers."[81] That these bodies are invisible is not to say that they are inaudible. The objective distance that allows the player to focus reflectively on the sound results in a music that exhibits its sounds in detail, calling attention to timbre in all its specificity. Musical instruments have always been explicit; the oboe does not disappear into its own sound but presents its body in its voice. The musician struggles with this body, experiencing the resistances and sympathies of the instrument at any given moment. Creativity is partly a matter of a concrete relation to the instrument, and picking it up and working it differently generate different sounds. This matter is given a new context with electronic instruments. The direct contact with the sonic surfaces of the instrument in the case of traditional instruments means that there is a less mediatory role for the instrument itself; feedback is more intuitive, one shapes the sound with one's body. What sorts of shaping are possible with a digital instrument? How does mediation affect creativity in music?

F O U R

Making Music

This is something very characteristic of our conventions of analysis—not only for new music, but in other areas as well—that the further we go into the microcosm, the more we have to describe what we are observing in terms of the tools we are using.

—Karlheinz Stockhausen

New Media Theory

OUR FICTIONS warn of the dangers of technology. In the typical scenario, the technology achieves an autonomy and turns against its users, whose hubris, indolence, or avarice spelled their doom from the start. In the case of the computer, its eschatologies depict its triumph over humans via a simulation so effective that it comes to produce reality.[1] George Orwell's forecast is not so much inaccurate when he titles his book *1984*; rather, he sees already in the origins of the computer its telos: a binary machine that dictates reality. "War Is Peace; Freedom Is Slavery; Ignorance Is Strength": the arbitrary reversal of the binary is the province of the computer.[2]

Piling irony upon brilliant irony, Apple chose just this image to introduce—in a 1984 television advertisement during Super Bowl halftime—their new Macintosh computer. Thousands of homogeneous, mindless drones sit before a huge screen filled with the image of Big Brother spouting NewSpeak propaganda.

(This serves to describe not just the advertisement but in many ways also the Super Bowl itself!) An athletic woman with shocking blond hair runs into the auditorium and throws a hammer at the screen, smashing Big Brother and freeing the drones, who recoil, overwhelmed by their new freedom and sudden responsibility for self-determination. “See why 1984 will not be like *1984*.” The overt symbolism—intended by director Ridley Scott working for Apple Computer and advertising firm, Chiat/Day—likens Big Brother to IBM (“Big Blue”), whose market-dominating PC was then only beginning to reach out of the office and infiltrate the homes of the “average” American. On the cusp of the computer age, as consumers struggled with their uneasiness at the prospect of this almost mythically powerful technology in their homes, Apple allayed their fears by claiming to offer a choice, a computing experience designed with the human in mind.

At last, a computer for the rest of us. Never mind Apple’s deliberate disregard for the lesson of Orwell’s fiction, which would likely caution all the more against the allure of a “humanized” computer. Never mind the irreconcilable irony of a television advertisement that uses *1984* to deliver a message of freedom through product purchase. Constructing an interface around the familiar metaphor of the desktop, and tying eye directly to hand through the innovation of the mouse, Apple rendered this appliance so comfortable and nonthreatening that in its early years, the Macintosh was frequently dismissed as a child’s toy, suitable only for the idle preoccupations of stay-at-home dabblers and grammar school teachers.[3]

However their computer is regarded, Apple’s retooling of the interface characterizes a dominant trend in computing devices, driving both the industry of digital hardware and the aesthetics of computing software. No amount of power, no degree of facility seems ever to be enough: the interface must be made both more vivid and more potent, tempting the fate depicted in those fictions alluded to above. The computing experience will not be fully satisfying until it provides a plenary reality fabricated on the computer, a Virtual Reality (VR).[4] What currently stands in the way of VR is the very interface that is supposed to present the reality; the interface resists our manipulations, gets in the way, calls attention to itself. As such, new media theorists place VR as the end of the tendency they call *immediacy*, the desire to remove all traces of the interface: “the logic of immediacy dictates that the medium itself should disappear and leave us in the presence of the thing represented.”[5]

The presence of the thing represented—if Virtual Reality aims for nothing less, then this accounts for the oxymoron in both phrases. What sort of presence would the thing represented have? It is not a question of the presence of the representation, the image on the screen, for example, since we already have that. Instead, the thing is supposed to just be there, available, right before your eyes (and nose, and fingers, etc.). No medium, no interface, nothing in between the user and the thing. Presence.

But what (represented) thing is the computer supposed to make present? Everything digital is in principle generic, repeatable, which is to say, already a representation. As purely formal but not actual, a digital object has no presence and so provides no clue as to what presence the thing represented might have. In fact, the desired presence is a phantasm, a myth propagated by an industry and a culture that dream of a wholly virtual reality. There is no presence, only a representation, which is why new media theory offers no positive account of immediacy but discusses it always in terms of privation: removing the interface, de-mediating, erasing the trace of the digital.[6] Such an effacement of the interface is said to bring the object closer to the user, to put the thing's presence within the user's grasp by removing impediments to its access.

Measured against the standard of VR, any interface will seem intrusive. The ideal of VR makes of the computer a medium, that which stands in between the user and the (presence of the) thing represented. However, once we recognize that there is no presence that might be represented, then it is not clear what the computer is supposed to mediate. Absent presence, the computer does not stand between the user and the thing; rather, the computer *is* the thing. To use a computer is not to manipulate something that is in principle independent of the computer but to manipulate something that is inherently virtual or computer-bound.[7] One uses a computer in order to do things that one can do with computers, just as one uses a chisel to do the sorts of things that one does with chisels or as one uses maracas to do the sorts of things that one does with maracas. Instruments, especially musical instruments, make possible their own uses; they do not serve an interest that could have preexisted them. Which is to say, they are expressive. A computer is an instrument, a means of expression; or, at least, so would we have it.

New media theory notes that alongside the tendency for immediacy, there is an apparently contradictory tendency toward mediation: computer interfaces feature many elements that explicitly call attention to themselves, reminding the user of the mediated nature of the experience of using a computer. Jay David Bolter and Richard Grusin point to the layering of windows, the appearance of text, icons, menus, and other interface elements on top of images that might otherwise be photorealistic. "The multiplicity of windows and the heterogeneity of their contents mean that the user is repeatedly brought back into contact with the interface, [. . .]"[8] As long as the computer is taken as a medium, these tendencies can only be understood as opposed, so that the addition of interface elements is an unfortunate but necessary limitation that impedes the desired immediacy. However, if instead we regard the computer as an instrument, then both trends can be seen to stem from the same impulse. Immediacy in regard to an instrument is not the removal of its interface, not a demediation, but the creation of an environment in which the user can express her desire with the greatest facility, the greatest ease. Likewise, the appearance of elements of the interface is not a necessary compromise that unfortunately disrupts immediacy but is a way of augmenting the possibilities offered for self-expression and doing so in a way that is unique to the computer. The interface does not stand between the user and her desires but makes possible the articulation of that desire.

Thus, our collective fantasy of the ultimate computer is poorly apprehended. From the computer as a medium, we might desire a virtual reality. But from the computer as an instrument, we desire rather a *real virtuality*. Not the presence of the thing to the user but the presence of the user in the thing. This can still be thought as a kind of immediacy; but what needs to be removed is not the distraction of the interface but the gap between the user's desire and the accomplishment of that desire. This is precisely what computers do for us: they save labor, they facilitate work, they help us to realize our desires. As expressive, they are instruments of the will.

Taken to its extreme, this image of the ultimate computer is no less frightening than the VR fantasy it supercedes. For the computer, seemingly unlimited in its dominion, is employed not only to take over the labor of the body, but also the labor of the mind. No doubt, the computer has been thus far most helpful in saving users from having to retype manuscripts, resize images, perform complex calculations, monitor highly chaotic or highly boring situations for change, lick postage stamps, and go to the library or the mall. But it is increasingly employed also to help determine the very motivation for those manuscripts, images, calculations, status reports, communications, and desires for information or goods. Computers now offer suggestions of "other movies you might enjoy" based on a statistical analysis of your viewing habits as compared with others who are statistically similar to you. Computers can provide a critique of your writing style, can offer a template for proper fictional narrative development, can propose a suitable mate, matched to your desires. Ultimately, the computer will get to know you so well that it will be able to make all of your choices for you: what to have for lunch, what music to listen to, what career to choose. Chris Beckett's science fiction story, "The Marriage of Sea and Sky," imagines a computer that ghostwrites, in his own style, whole chapters for its author/owner; we are indeed heading that way.

This nightmare of a world where creativity is left to the computer suggests the difficulty of the territory to be navigated in the ongoing development of digital machines. By upholding the notion of the computer as an instrument, we may be able to continue to maximize its usefulness while holding at bay the threat of a whole-scale absorption into the digital. Instrumentality offers its own ideal, an image drawn from the world of music, where instruments have taken a most specific and essential role: not merely means to an end, they generate their own ends. What is this ideal relationship of the musician to her instrument? What formula describes the contribution of each to the musical result?

Old Immediacy Theory

"He was a natural, born to play the piano, and when he was on the concert stage one felt as though the piano itself was welded to his body. Musician and instrument were one."[9] This quotation, a fan's description of Arthur Rubinstein in performance, outlines a certain ideal image of musical genius. There is first of all the mythic ascription of a natural order, according to which Rubinstein was fated to play the piano. His relationship to the piano, however practiced, however hard won, was first of all natural or innate, already there in him from birth. This natural or even supernatural relationship to the instrument is reiterated in the description of the intimacy of Rubinstein's physical relationship to the piano. Though it is somewhat comical to imagine his attempts to make music with a piano "welded to his body," nevertheless we take the point: there was a kind of direct contact between musician and instrument, a way in which the instrument simply got out of the way and allowed Rubinstein an immediate access to the music. Playing the piano for Rubinstein was a gesture as simple, as thoughtless as lifting an arm and scratching oneself might be for the rest of us. It is true that Rubinstein projected an air of utter effortlessness in his playing; he sat over the keyboard executing the most technically challenging maneuvers with relaxed aplomb, a serene, even childlike look on his face, delighting in the music exactly as does a member of the audience. He seemed to be watching his fingers dance over the keys as though they weren't even his, charmed and surprised by the beautiful music emanating from the instrument before him.

Rubinstein is by no means unique in this relationship to his instrument. Rockers will undoubtedly recall Jimi Hendrix's similarly effortless command of the guitar. Admirers refer over and again to his ability to meld with his instrument, to sing through his instrument, attaining an unmediated access to the music. Though singing as an ideal of immediacy is dubitable in light of the deconstructive critique of full presence, we can still feel the force of the claim. Hendrix's guitar was as comfortable, as automatic a means of expression as voice and lungs; the guitar for Hendrix is not an obstacle that stands between him and the music but simply a vehicle of expression. Like Rubinstein, Hendrix played in a manner both wholly absorbed by his music but also completely comfortable there, coaxing from his ax whatever note, whatever sound he desired.

In both cases, the comfort or relaxation is accompanied by an absorption, a total immersion in the music that blurs the distinctions between musician and instrument and appears to take over or occupy the musician's body, at least for the duration of the performance. Immersive genius is not always so relaxed. Glenn Gould was so close to the music that it contorted his body; he carried his own piano stool from one studio to another, which placed his nose only a foot or so above the keyboard. From this unusually low position, he would get even closer to the music by hunching down into the piano, seemingly embracing the keyboard with his shoulders. Thus seized by the music, he was compelled often to hum along while playing, much to the frustration of recording engineers, who were charged with minimizing Gould's off-key whining in the recording.

Improvising pianist Keith Jarrett not only hums along while he plays, but frequently moans, yelps, and shouts to the music, apparently involuntarily. His body also is gripped by the music; so much so, that on occasion, he comes to face the wrong direction, away from the keyboard, or crawls so far under the piano as to defy gravity, holding his body at an acute angle, balanced on his fingertips. As improvisation, Jarrett's immersion is understood as unadulterated expression, wherein his will becomes equal to the music that results. He has merely to think the sound and it is produced before him. We might make similar claims about Itzhak Perlman, who appears to rise from his wheelchair, drawn up by his violin, which seizes him as he plays.

Readers can no doubt supply many further examples of musicians whose immersion in the music is so complete that they become possessed by it. But musicians are not the only members of this cult of genius. Any endeavor that principally involves the body invites a total participation, an absorption wherein the doer and the task become one. Sports heroes are often believed to have a supernatural bond with their field of play; the bat or club becomes an extension of the body, the player's senses are also extended to see what is happening on the court or the field even where the eyes do not point. Michael Jordan displays an effortless grace, a command over the basketball court, the ball, and his own body, subordinating time and space to serve his basketball-ish ends. He knows intuitively where the other players are, and even where they will be, without having to look.

If the immersed genius gives himself over to his activity, if he abandons himself to his immersion, then it is not surprising that this ecstatic loss of self frequently blurs into madness. The immersed genius is also the mad genius, succumbing completely to a madness he cannot escape. One is as much possessed by genius as possessing it. Ed Harris, producing, directing, and starring in *Pollock*, shows us the moment of Jackson Pollock's genius: having worked for some time with canvases laid flat on the ground, Harris's Pollock, standing over such a canvas, absentmindedly dribbles some paint onto the wood floor of the barn where he is working. He glances down at the dribbles, whereupon the lightbulb turns on over his head, the extra-diegetic music swells, and Pollock's body goes on autopilot. For three minutes, the camera moves constantly, suggesting the frenzy of his genius, the foment of creativity, and maintaining a frame that includes both paint in motion and Pollock in motion, but (almost) never a full view of either painting or body. Harris wants to effect the melding of artist and paint, dribbling, spattering, hurling, and flicking all as one. The filmic cliché for this scene of creative genius would be a kind of sex-narrative, wherein Pollock, in a continuous montage of activity shots, would expend his creativity to the utmost, spilling the paint as his seed, to finish, finally, slumped in a chair, a cigarette dangling from his lips, while the music fades to the sound of gentle rain against the barn roof. To his credit, Harris avoids this cliché, instead twice interrupting the montage of painting activity with shots of Lee Krasner, played by Marcia Gay Harden, who speaks to Pollock over a diminished musical bedding track, while Pollock himself remains silent and vaguely self-satisfied. His silence in the face of Krasner's remarks—one regarding his current business arrangements with Peggy Guggenheim and the other a direct acknowledgment of his genius ("You've done it, Pollock. You've cracked it wide open.")—suggests that despite these interruptions, Pollock continues to paint, if not on the canvas then at least in his head and, more important, in his body. For this scene attests, above all, to the way in which one is seized by genius. Pollock's motion is simultaneously deliberate and spontaneous, willful and reckless.

Fearing the loss of our heroes, we bestow on them a genius out of the reach of ordinary folk. We do not want to know about the thousands of hours of excruciating exercises necessary to develop an able technique. We would rather believe that artistic greatness is a gift from the gods, bequeathed on the meek and unwilling, who bear their gifts as a burden. Thus immersion is thought to be a transcendent state, a mythical connection with the realm of the aesthetic Idea, that descends on those whose souls are already so inclined, ready if not quite willing to hear the call. John Coltrane believed the hype, thinking of himself, as he approached his early death, as a demigod, a superhuman with extraordinary creative powers. Because we also believe the hype, we fail to notice the ordinary genius in which each of us participates every day. If immersion is indeed a mark of genius, then each of us has her genius, exceptional and mundane: a genius for eating, walking, talking, reading, writing, love-making, driving, and sleeping; we become wholly absorbed at times by these activities, losing ourselves in their flow, smearing the borders of the body to include what lies beyond the confines of the flesh. One theory of hypnosis holds that, far from being an exceptional or exotic state of being, it is merely the prolongation of those moments of absorption into which we fall constantly throughout our daily tasks.[10] As such, the immersion we ascribe to musical genius is not unfamiliar to the rest of us, and an examination of this immersion may have implications that reach far beyond the world of music.

What goes on, then, in this moment of pure expression, this immersive condition? We can note immediately the ambiguous role of the subject in this immersion, as the musician seems to be at once completely possessed by the music and also not responsible for it, "welded" to the instrument and standing apart from it as if in the audience. This ambiguity derives from a paradox of the will involved in immersive music-making: for to achieve the effortlessness of immersion, the will must will its own annihilation. Immersion demands that the musician get out of her own way, submit herself to the music without interference. One must will the loss of one's self, the dissolution of the will, to find an equanimity that will just let the music be, let the music come, without the need to force it along. Some musicians speak of *floating*, allowing the music to carry itself forward by its own momentum, just as some authors, orators, and musicians might be said to *channel*, to let the work speak through them, so that they are present and not-present at the same time. The immersed musician is possessed, body and soul, by the music, which suggests the first of four models to help make sense of immersive music-making.

Model I: Spirit Possession

Given our (Western) insistence on self-identity, this paradox of the will appears initially inscrutable. How can the musician make the music without trying? How can the musician be apart from herself while also making music? Ethnographic sources provide a first model that may help to unravel the nature of immersion and its relation to the will: spirit possession. As a model of immersion, spirit possession seems immediately appropriate since one way to understand immersive music-making is precisely as a possession by the spirit of the music. In *The War of Dreams*, Marc Augé examines the role of the subject during spirit possession: "The [person possessed], dispossessed of himself or, to be more precise, of his body, is not enigmatic but absent." "Through her mouth—but not through her voice, which is transformed and made unrecognisable—it is someone else who expresses her and addresses her to other than herself, even if the latter make up a collectivity of which she is part: in relation to them, her possessed body is now no more than a mediation or a medium."[11] To forge a more stark contrast with dreaming, in which the subject remains present but passive, Augé emphasizes the total absence of the host in spirit possession, stressing in particular that the host has no memory of what happened in her body while it was possessed. Though he notes the performative aspects of the return of the host to her body at the end of the spirit possession, his insistence on the total absence of the host/subject during the possession resolves too quickly the paradoxical relation of the host to her own body. For there is in spirit possession, as in music-making, a willful effort by the host to summon the spirit, to enter the state of immersion in which the will annihilates itself.

The person to be possessed is not spontaneously gripped by the possessing spirit, which would enter the host's body suddenly from out of nowhere. Rather, an often arduous process is endured in order to summon the spirit, which must be *willed* into the body of the host. This process, a ritual tradition, may be laborious and painful; in any case, it includes techniques that attempt to isolate the subject from her own body, techniques that either focus concentration to an immobile point or defocus it until the self becomes incoherent. To separate the host from her body, she must be contracted into a maximal density or spread so thin that she vaporizes. Such an extreme state calls for extreme measures: psychotropic drugs are ingested to disorient the host, induce a semi-sleep, or alternately provoke a fascinated total involvement of her concentration. Rhythmic drumming or music pervades her senses, creating a seamless background that fills the host's subjective space, blanking her concentration or possibly shutting out distraction. The host may meditate, regulate her breathing, chant a mantra out loud or to herself, or dance wildly. Her body may be subjected to pain or soothing, poisoned or deprived of food. In every case, focusing or defocusing, the result is to place the host in an extraordinary relationship to her own body, to open a gap through which the spirit can pass into the body, pushing the host's consciousness into the background.

Eventually, however, all of these techniques can be discontinued. At some point, the spirit enters the host, who need then no longer will or summon the spirit. The host can absent herself, simply allow the spirit to speak through her and in her, without having to make any particular effort. While Augé analyzes this immersion as an absence of the subject, in the case of immersive music-making, the host (the musician) is not altogether absent, even if he is in some sense beside himself. For unlike the host possessed by a spirit, the musician remembers—at least as a kind of bare empirical memory and as an overarching affect, a breathlessness, a lightness of being—he remembers having been there. The musician, to the extent that he remains at all self-conscious, stands by while the music happens, observing his body and his comportment to the instrument and the music. There is in both cases the necessity for a summoning of the spirit. Although many musicians may rely on drugs, techniques of the body, or habits of concentration, for the most part, summoning the spirit of music involves the ritual playing of one's instrument, playing and listening.

Model II: Intellectual Intuition

No doubt, the binary of presence and absence is too schematic to account for the problematic role of the musician in the immersive condition. If the musician gets out of the way by relinquishing her will, giving herself over to the spirit of the music, this is also the moment at which her will becomes equal to the music being made. An immersed musician is one with the music, so that body, mind, instrument, and sound are perfectly aligned, ideally coincident. There is at this point no difference between what the musician wills and what music gets produced. As though, by opening a gap between the musician and her body, another gap is closed, the gap in time and space that normally separates the musician from her music. The will annihilated is reborn in the music, or *as* the music; the will becomes equal to the infinite subtlety of the sound, and the musician wills even the noise, even the accidents that befall the music. Immersed in the music, she devotes her entirety to it, wills it completely. "I couldn't play a wrong note," says the jazz soloist after an especially good night. This is not to say that any note would have been correct, but rather that nothing stood between musician and music, that the musician was able to will everything happening there in that moment. No longer defined within the confines of a willing subject, the will inheres in the music itself, becomes equal to its production. What does it mean to suggest that the will becomes equal to the willed?

Models can be easily multiplied, and the reader is invited to think through the becoming-equal of will and willed in relation to Friedrich Nietzsche's eternal return or Søren Kierkegaard's knight of faith; these contemporaries attempt to guide the will through an essential and determining paradox. Nietzsche's eternal return demands that the will become equal to everything, that the whole of existence be willed, but this is tantamount to willing even the accidental, *especially* the accidental, that which defies every will. Likewise, Kierkegaard's knight of faith must will what cannot be accomplished by the will and what is only accomplished by the will's desperate and irresolute failure. The tortuous paths pursued by Nietzsche and Kierkegaard disrupt the Hegelian logic that ends inevitably in stasis; these anti-Hegelians mandate a paradoxical will that does not resolve into a synthetic unity. Prior to Hegel, before the end of history, it was possible still to believe in the future of history. For example, Jean-Jacques Rousseau imagines a return to nature that is neither paradoxical nor eternal. This state of nature is nothing but the immersive condition, the concrete possibility of the equality of will and willed.

It is Immanuel Kant, however, who most directly addresses the question of becoming-equal, not as a general component of an ethico-ontology (eternal return), nor as a life's ethical project (knight of faith, state of nature), but as a specific form of experience, a question of epistemology. In *The Critique of Pure Reason*, Kant examines the possibility of a knowledge that would be equal to its object, a direct experience of things as they are.[12] The first critique, an investigation of the limits of reason, is concerned primarily with questions of epistemology: how we know the world and what we can know of the world. Crucial to Kant's project is the question of how our experience relates to the things that we experience. Near the outset of the book, Kant considers whether all experience must be mediated by sensation, whether our experience of things is always an experience of them as they appear to us, a *sensible intuition.* Or, whether there is not the possibility of an experience of things as they are, rather than as they appear to us, a direct apprehension of the thing by the intellect rather than by the senses, which Kant calls an *intellectual intuition.* Kant summarily responds to his query negatively: there is for human beings no intellectual intuition.

He reasons thus: To experience a thing *as it is* would be for the experience and the thing experienced to be the same. In intellectual intuition, there is no difference between the experience and the thing; the experience would be *equal to* the thing experienced. But, if there is no difference between the experience and the thing experienced, then the experience would include the entire thing, even the very existence of the thing; not only would an intellectual intuition apprehend the qualities of the thing, it would be equivalent to the thing's existing. In other words, to experience something in an intellectual intuition would be for that thing to come to exist. Kant asserts that this is simply not how the world works; we do not bring things into existence by our experience of them. Rather, the world and the things in it are given irrevocably, unalterably, and we have no choice about how they are given. Perhaps God has an intellectual intuition, such that whatever He imagines comes to exist as soon as it comes into His imagination. But humans have no such power over the world. In fact, says Kant, a person does not even know *himself* in a direct apprehension; even your experience of yourself is mediated by parts of your thinking apparatus that make self-experience possible.

Immersive music-making fails to fit into Kant's scheme of experience and serves as a provocative counterexample to his analysis. In immersive music-making, the will and the willed *do* become equal, the musician's experience is no longer distinct from the music that gets made. Desire is immediately manifest as production, unmediated by an imaginary object that desire is supposed to reach for. An immersed musician has an intuition that is precisely intellectual in the sense Kant outlines; the musician experiences the music without intermediary, without the instrument, the body, the senses getting in the way. This is not to say that instrument, body, and sensation simply disappear. Rather, they no longer mediate, they no longer cause a friction that would stand in between musician and music. Musician, body, will, instrument, sound, and context operate as a single machine, a singing machine that makes sound with one will. Nevertheless, the role of the subject remains problematic because perspective does not just disappear. The musician's experience is still localized in a time and a place; the will does not become equal to an objective reality of the music independently of the unique situation of the musician. The will affirms the whole of the music along with a perspective. As such, two musicians playing together can both be immersed, can both become equal to the music without necessarily becoming equal to each other, without losing the distinction between them.

Undoubtedly, models I and II confuse the matter more than clarify it. The analysis of immersive music-making thus far misses the point of each model. The sketchy reference to ethnographic research on spirit possession was supposed to demonstrate the absence of the subject, but an immersed musician is not exactly absent, for there remains a singular perspective, which remembers and which willfully affirms the entirety of the sound. Kant's consideration of intellectual intuition shows that sensation is an irreducible mediating element of experience, but immersed music-making somehow retains sensation while insisting on an impossible immediacy. Let's add some additional confusion.

Model III: Projection and Temporality

At first glance, the paradox of the will gets much of its intractability from a temporal illogic. For the will to become equal to the willed, the two terms would have to revise their usual temporal priority. Normally, the will precedes what it wills, since willing would otherwise be futile. In the case of immersed music-making, the will and the willed are coincident. This tension can be alleviated in part by noticing that willing here is not necessarily a matter of willing something in particular; that is, the will of the music is not a desire that something in particular happen. It is rather a *will to music*, a will that is the coincidence of desire and production. Such a will wills not only the to-be-determined, music not yet produced, but also music here and gone. A will that embraces proactively and retroactively. How do we will what has already happened and what is already happening? How can the will be equal to what is yet to come?

To investigate the temporality of this paradoxical will and the temporal status of the immersed musician, Heidegger offers valuable tools in his subtle and thorough analysis. His notion of projection *(Entwurf, entwerfen)* from *Being and Time* merges past, present, and future in a will that precedes the distinctions of presence and absence and makes sense of the melding of musician and music. Projection, the futural component of temporality, crosses the divide between Divisions I and II of *Being and Time*, and thus it also crosses the divide between the analyses of inauthentic *Dasein* and authentic *Dasein*. Heidegger does not take the passage of time for granted, as though time were a neutral and objective entity that is only secondarily related to human existence. Rather, *Dasein*, the sort of being that is being-human, must bring about its own future, participate actively in the passage of time. This participation has two modes, authentic and inauthentic, both of which are relevant to the issue of immersion.

Inauthentic, *Dasein* finds itself in a world full of things. But *Dasein* does not simply stand inertly as one thing among these other things. *Dasein* is the sort of thing that understands itself, and it does so through its relations to the things in its world. As such, these relations, of world and things to *Dasein*, are not value-neutral relations. They are not like geometrical relations or purely physical relations that have only a formality but no value content. Rather, *Dasein*'s relations to the things in its world are fully valued in the sense that things matter to *Dasein*, and *Dasein* understands itself in terms of the way things matter to it. Heidegger characterizes these relations with the term *for-the-sake-of-which*, where things in the world are ultimately understood by *Dasein* as being in some sense for *Dasein*'s "sake." (The world in general has the character of *significance*, from which the *for-the-sake-of-which* is derived.)

How can things be for *Dasein*'s sake? If things were static, they could never matter to *Dasein*. Only because things can be otherwise can *Dasein* make sense of desire; only because things have possibilities for being other than they are can they matter for *Dasein*. It is thus a fundamental aspect of *Dasein*'s way of being in the world among things that it understands itself and these things as having possibilities. And it is this structure—a structure of understanding whereby *Dasein* relates itself to things along with their possibilities—that Heidegger calls (inauthentic) *projection*. *Dasein* projects itself onto its world of things, projects itself onto the possibilities given by those things and its relations to them, thereby opening for itself a future.

At the risk of being overly schematic, note the ready applicability of Heidegger's analysis to music-making. In chapter 1 the investigation of listening to recorded music revealed that in each sound is already implicated the possibility of that sound's future. Every sound, and especially music, has a sense of direction; noise, the implicated reserve of sense, projects sound into its own future, so that the future is already there in the sound currently being produced. What holds for the fundamental structure of *Dasein* holds also for the act of listening. The immersed musician, at once listener and player, wholly given over to the music, plays not only this here note but also those yet to come. Willing the entirety of the music, the musician reaches with his will even those subtlest extremes of noise, the domain of the implicated, and so wills the accidental, the undetermined, notes not yet played. How could one play even the noise without relinquishing one's self as a point of origin, for noise is by definition that essential element that is not subject to control? Losing herself, the immersed musician forges a contact with the entirety of the sound, not just the pitch, rhythm, dynamic value, etc., but every peak and valley in the waveform, the shape of the harmonics, the subtle distortions, all the noise from which sound is drawn. Absorbed by the music, the musician projects the music onto its possibilities, plays those parts of the music that remain implicated but plays them as implicated, massaging the music's future in its present, retaining the indeterminacy of what is to come by adding her own indeterminacies.

The implicated reserve of sense inheres in all sound, as its momentum. Noise is a sonic universal. Likewise, inauthentic projection is a universal structure of *Dasein*. *Dasein* does not project itself occasionally onto this or that possibility but is always projecting itself in order that it may have a future at all. Heidegger emphasizes that projection is not a question of a particular possibility but the very possibility of possibility. This notion of universal possibility seems inadequate to the willed affirmation of the entirety of sound in immersive music-making. The will to music does not merely keep open possibility per se but realizes a necessity, discovers in immersion the next sound that makes the maximal sense of what came before while holding in implication the maximal sense of what is yet to come. The immersed musician lives at the bleeding edge of the music, seizing in each instant on the one possibility that will keep the music going, that will drive it forward with such force that it determines its own time, casting off the restrictions of meter and harmony that would constrain it. To discover the singular specificity of immersion, we must consider projection in its authenticity.

As inauthentic, *Dasein* is fallen into the world of things. Always and irretrievably fallen, *Dasein* understands itself in terms of those things and their possibilities; *Dasein* takes its cues from the things around it. But, for the most part, those things and their possibilities derive primarily from convention: taking its own possibilities from the possibilities of the things around it, *Dasein* tends to do "what one does." One eats with a fork, one reads a book, one drives a car. *Dasein* understands its possibilities and hence itself in terms of those possibilities ordinarily given, in terms of the world of things.

By contrast, authenticity would be a matter of *Dasein*'s taking its cues not from the world of things, but from its ownmost self, finding for itself its ownmost possibility. Where can *Dasein* look to find its ownmost possibility? Heidegger proposes that by confronting the possibility of its death, *Dasein* discovers this ownmost possibility. For death is not only an end to *Dasein*'s life, not only the elimination of *Dasein*'s future but, since past, present, and future are all modes of *Dasein*'s being, death is also the end of *Dasein*'s past and present. In death, *Dasein* has no related-ness, an absolute nonrelation, its whole world is taken away. Thus, in being-toward-death, *Dasein* confronts the possibility of its having no longer any possibility, it recognizes its utter finitude, and is stranded by this recognition, left entirely to itself. In being-toward-death, *Dasein*, completely without relation, can draw its possibilities from nothing but itself, for it has nothing but itself. There, in proximity to its death, *Dasein* finds only its ownmost possibility, and this discovery characterizes *Dasein*'s way of being that Heidegger calls *authentic.* The authentic projection of being-toward-death differs from inauthentic projection: Heidegger uses the term *anticipation*, or *running-ahead* of itself to describe authentic projection. In being-toward-death, *Dasein* runs ahead of itself, projects itself onto its ownmost possibility and then inherits or takes over that possibility from itself. This bootstrapping is how *Dasein* brings about its singular future, how it becomes who it uniquely is.

Music also lives perpetually under the threat of its own death, in the face of its imminent dissolution. Musicians know this better than anyone, though astute listeners can hear it as well. Music holds itself in a precarious balance that may fall apart at any instant. In fact, music is ever falling, constantly breaking apart, turning into noise as fast as it is articulated as sound, and it must ever and again be caught, restored, and revitalized by the musicians and their instruments. This perpetual falling and recovery is the unique momentum of music, whose felt motion is only this sense of imminent dissolution and perpetual recovery. Music is not a succession of static elements but a threatened inertia gathered into a fragile cohesion and held together only for an instant by the noise from which it is drawn before immediately falling back into that noise. Immersed in the music, entwining her own life with that of the music, the musician also confronts the imminent death of the music, and in so doing, discovers in each instant its ownmost possibility.

At the limit of its own dissolution, ever on the brink of exhaustion, the music bends itself toward its next moment. Only a will that affirms whatever the next moment may be, only a will wholly given over to the music can coax from the implicated reserve of sense the essential next sound. If its possibility is there in its noise, implicated, then it should be emphasized again that this is not a predetermination, not a next note already fixed by the present one. Rather, the singular situation, musician, music, instrument, history, all together determine only in the moment of dissolution the next note that will restore, at least for another moment, the integrity of the music, an open-ended integrity that falls short of a final unity. It is as though the music must be nearly overwhelmed by the noise that threatens it with incoherence in order to discover in that noise the next coherence that keeps it moving, keeps it sensible for another beat. Being-toward the death of the music, the musician discovers that ownmost possibility, that next sound that keeps it vital, breathes life into sound for another halting moment. Only the immersed musician can hear that next sound, for only the one immersed in the music feels its fragility, is bound up with its fate, and can thus hear the singular possibility that the music gives to itself.

Lest this invocation of the grand abstractions of Martin Heidegger feel too remote from the concrete but obscure practice of immersive music-making, consider the analogous affirmations of improviser and composer Cornelius Cardew.[13] In his short monograph, *Treatise Handbook*, Cardew offers numerous provocations to those who would think about the lived experience of playing an instrument. He proposes seven "virtues" for musicians, including those of selflessness, identification with nature (to "steer a course" by both leading and following the current), and, most crucially in relation to Heidegger, the acceptance of death as "music's fatal weakness and essential and most beautiful characteristic—its transcience *[sic]*."

Model IV: The Faculty of Music

An unspoken question asserts itself in these three models: Who is making the music? The three models presented thus far render problematic the usual suspects who would answer this question. If the most "natural" answer is to say that the musician makes the music, then it is no longer clear who this would be. The musician gets out of her own way, but whose "way" is this? As a subject, the musician is absent or perhaps in attendance but passive. In any case, the immersed musician does not "intend" the music, if that means to think it in advance of making it happen. The musician's responsibility is to be carried along by the music, though certainly he offers something to its momentum. Perhaps it is the musician's body that makes the music; the absent musician gives himself over to his training, allowing his body to do what it will. The body is capable of a great deal, and the musically trained body can play challenging pieces with little guidance from the musician. That is, a musician can think about something unrelated or carry on a conversation while her body plays the instrument, often with extraordinary proficiency. However, when the musician simply abdicates, allowing fingers, arms, lips, and feet to do as they have been trained, the resulting music is decidedly perfunctory. The body is a creature of habit, but habit reproduces only what has already been produced. Though it can effectively "go through the motions," the body is unable on its own to invest the music with that drive that gives it a sense of direction, that elevates it to a genuinely creative endeavor. The music it creates may be competent but will not reach the point of expression. The musician who just allows his body to do what it will cannot be immersed in the music, for he is not even engaged by the music; the one who lets his body play is not putting himself on the line, not tying his own fate to the imminent death in the music, and so fails to draw out the ownmost possibility of the music in the moment.

It is at least accurate to say that the world is responsible for making the music. This response is compelling because it takes account of the way in which the musician is not acting in isolation, as an originary source of the creative sound being produced. Rather, context plays a significant role in music-making and to give the world credit acknowledges the diverse sources from which music gets generated. Immersive music-making is frequently described in holistic terms: becoming one with the music or the instrument, tapping into the forces of the universe, etc. Still, to identify the world as the place of music-maker is to rest content with a solution so generic as to lack explanatory value. If the world makes the music, how do we account for the individual training of the musician, his influences, his mood, his unique techniques? Why, if the world makes the music, will two musicians playing the same instrument in the same place on the same night play completely differently? To answer the question of responsibility for music-making, we need something that accounts for both the specificity of the situation, the musician's training, habits, and mood, and for the context, the opening onto the creative, the forces of the universe. We need an agent that is, like music, both habitual and spontaneous, personal and cultural. The notion of a *faculty* responds ideally to these criteria. What would it mean to have a faculty of music?

The doctrine of the faculties was ultimately rejected by Enlightenment thinkers because it lacked explanatory power. To answer the question of how we are able to reason by citing a faculty of reason seems only to beg the question. The introduction of a faculty provides a label for phenomena that remain otherwise unintegrated and unexplained. Moreover, inasmuch as the faculty pretends to account for the phenomena to be explained, it masks their lack of explanation and discourages further investigation. In the third chapter of *Difference and Repetition*, "The Image of Thought," Gilles Deleuze proposes that the doctrine of the faculties was rejected too summarily by Enlightenment reason, and he attempts to restore a doctrine of the faculties that promotes investigation of their associated phenomena while providing an explanatory power. Using Kant's image of the faculties as a foil, Deleuze offers such a restored doctrine, giving to each faculty an independence and autonomy that establishes its sovereign domain while also creating a place for it within human activity.

Kant identifies three faculties, the faculties of sensation, understanding, and imagination. The Kantian model draws an image of thought, explaining the mechanism of thinking in terms of these faculties. According to this image, a selfsame object presents itself to the faculties, each of which evaluates that object. To the extent that these evaluations agree, the object is properly recognized, and thought has taken place. Deleuze refers to this as the model of *common sense*, since the faculties act on an intuition that is *common* to them all in order to make *sense* of the world by correctly identifying it. When the faculties disagree, the resulting uncertainty prompts a further evaluation by the faculties until they attain an accord.

Deleuze's principal objection to this model is that it apprehends thinking in its most banal moment. If thought is a matter of recognizing objects in the world, then this is a thought without creativity. Recognition does not confront thought with a problem that engenders a productive solution, calling thought to its most difficult exercise, but instead demands only deduction, where the greatest risk is not the challenge of thinking but the possibility of error. Contrasted with this image of thought as a common sense modeled on recognition, Deleuze proposes a truly creative thought, a productive thought, whose success is never secured and which does not even know how to start. Deleuze reiterates Artaud: "To think is to create—there is no other creation—but to create is first of all to engender 'thinking' in thought."[14] Such a creative thought does not coordinate the faculties around a self-identical object, for it does not take identity as an assumption. Rather, each faculty acts spontaneously and independently.

Spontaneity here does not indicate that the faculty operates haphazardly or without any order. Rather, Deleuze's emphasis on the spontaneity of a faculty is an insistence on the sovereignty of its domain, its unique ability that defines the uniqueness of human experience. For example, if reason is spontaneous, then this does not imply that it is arbitrary or has no general habits or characteristics. The spontaneity of reason means that ultimately reason is its own arbiter. One can train one's faculty of reason by studying (law or philosophy perhaps), or by exercising it deliberately and self-consciously in relation to problems that present themselves, or by writing and critically examining that writing. As such, reason varies from culture to culture and individual to individual, for these habits of training also so vary. Whatever arguments might be ventured in support of a given reason, it is finally only the faculty of reason that can decide what counts as reasonable. There is no other appeal that would outweigh the judgment of the faculty of reason, which alone determines the reasonable. Reason is thus spontaneous in the sense that it is governed by no higher authority, no dogma that would determine outside of the faculty of reason what is reasonable. Reason generates the reasonable by its own spontaneous activity. It is an irreducible exercise of a faculty.

Deleuze grounds the spontaneity of each faculty by identifying its sovereign domain: each faculty has its unique object, that which only it can apprehend. The understanding has the *cogitandum*, that which can only be understood (and not sensed, imagined, or spoken), and the *cogitandum* sets fire to the understanding, sending it on its spontaneous and productive journey. It is this very process that is understanding, the dynamic motion of a spontaneous, creative understanding rather than a static arrival at a complacent point of understanding. To understand is not to gain a complete and finished view but to generate something new in thought. Sensation has its *sentiendum*, that moment of sensation that can only be sensed. If thought is difficult, if it is never finally secured but must always be started again, perpetually rethought, this is because the encounter with the *sentiendum*, the *cogitandum*, the *phantasteon* (of the imagination), the *loquendum* (of the faculty of speech) is never guaranteed. It is difficult to seek out these sparks, these moments of the faculties, precisely because they can be apprehended uniquely only by the suitable faculty. Once it sets sensation aflame, sparks its ignition, the *sentiendum* is exhausted, covered over by the movement of sensation and is thus, in another sense, insensible. The *loquendum*, the spark that ignites the faculty of speech, disappears each time it launches speech into action, cannot itself be spoken though it is essential to the happening of speech. One never knows how to find again these sparks of thought, these moments that engender thinking in thought, but one *must* find them in order to elevate thought beyond the banality of recognition to the point of originality, to the point where thought discovers its ownmost possibility.

The faculty of music accords well with this restored doctrine of the faculties. In light of Deleuze's analysis, we can recognize that fundamental to immersive music-making is a spark, a moment of pure musicality, the *musicandum*. The *musicandum* is that momentum of the music that connects it to past and future, pushing it forward by virtue of its asymmetry. The *musicandum* is not exactly heard or felt or even produced in the music; it exists at the limit where a passive sensation and an active playing collide. It is both played and felt, an accord of musician and music, that defines the domain of the faculty of music, the organ uniquely suited to the passion and action of the *musicandum*. This faculty is spontaneous, it deals in problems; it does not so much recognize and assent to the musicality of the sound, as it responds to it, plays with it. Music poses a problem—how to engender the musical in music—and the musician addresses that problem at each instant, apprehending the *musicandum* with his faculty of music. Immersion in music is now understood as the process wherein the musician gives himself over to his faculty of music, where the faculty of music becomes responsible for making the music, grappling with it, called forth and sent ahead by the *musicandum*. Though this raises many additional questions, theoretical and pragmatic, it also explains the paradox that has persisted through the analysis of immersive music-making: given over to her faculty of music, the musician is both absent and wholly present, an observer standing to the side of the music and the very flow or sense of the music itself. The faculty of music joins the musical extremes of displacement and dispersion.

We can also readily understand both the habitual and the spontaneous in regard to the faculty of music. The formation of habits is the principal means of musical training: habits of the body playing an instrument, habits of motion in the music, habits of interaction with other musicians, habits of listening to, buying, and discussing music. The training of the musical faculty that produces these habits accounts for the cultural and personal specificity of music, the existence of genre and style. The faculty of music is educated by a culture, which offers categories of musical style, iconic composers and one-hit wonders, and also by a personal history, a mentor, a radio station, your older sister's record collection. Nevertheless, these influences do not finally determine the specificity of the faculty of music, which retains a spontaneity that is the province of each faculty. Only the faculty of music ultimately decides what is musical, and it makes this productive judgment not according to any prior logic but only according to its sovereign determination. The faculty of music has a vocabulary, a set of habits, but its gift is always to reach beyond this vocabulary, to exceed its own habits.

Still, the standard objection to the doctrine of the faculties applies here: why a faculty of music, and why not, then, faculties of biking, goldfish-swallowing, or limerick composition? Shall we just introduce a new faculty to explain each human behavior or talent? Perhaps the risk of multiplying faculties into the void cannot be eliminated, but the criteria of spontaneity and habit help to determine when a faculty is in play. Amidst its many relations to poetry, rhythmic or repetitive activity, aesthetics, mathematics, etc., music retains an autonomy that delimits its domain apart from these other phenomena; despite its fuzzy borders and lack of a center, the notion of the *musical* makes sense of itself, generating a negotiable territory using landmarks that appeal as much to the "natural" (neurophysiology, the mathematics of consonance) as to the "cultural" (what counts as musical talent?, where and when does music get made?). In general, faculties cannot be admitted uncritically, but where there is a spontaneous determination of a territory, *there* is also a good candidate for a faculty.

A further test of the legitimacy of a faculty is to measure the strength of its implications. What difference does it make? Both passive and active, present and absent, the faculty of music reorients the understanding of music-making generally. It unites composer and performer, improviser and interpreter, guitarist and trumpeter, African musician and Indonesian musician, and finally listener and player. For each of these roles draws on this same faculty, each attempts to effect the same relationship to the music. This may be most perplexing in the lattermost example, since the player and the listener appear to be at opposite ends of the music, one actively producing it, the other passively enjoying it. Their mutual reliance on the faculty of music reveals their fundamental commonality. Both listener and player seek to immerse themselves, to give themselves over to the music, so that it takes a hold of their bodies, their feelings, their spirits. To listen to music is as much a practice as to play it, and music listening requires a cultivated talent, the more refined as the more practiced. Music listening is also therefore an activity, an active engagement with the music, though it is a paradoxical activity, one that attempts to relinquish its willful responsibility in favor of the ambiguous responsibility of the faculty of music. "[I]f the listener does not have anything done to him, since the composer has not arranged things so that everything is done *for* him, the responsibility for *how* he hears or sees is placed firmly on the functioning of his own perception."[15]

The members of a musical ensemble relate through this faculty, which exists for each of them as it does for their collectivity. At the limit of habit and spontaneity, the faculty of music is both individual and shared. It is a faculty that is not located in a particular dimension of the human being, not in the mind, or the body, or the history, or the instrument, but is dispersed throughout these parts and also into the space of sound. It does not end at the limits of the body or of the instrument but extends as far as the music itself, diffusing at its limits into the background of noise, becoming a part of everything there, of history and of the future.

Uniting amateur and professional musician, beginner and accomplished virtuoso, the faculty of music dispels the myth of immersion as a destiny of genius, to replace it by the still provocative notion of the *musicandum* as the spark that fires every moment of music. Wherever music is made, the faculty of music is engaged, which is to say that the musician is immersed, if only for a moment, or for a series of disconnected moments. Immersion is not a magical state of being, attainable by the greatest musical geniuses; it is only the sustained condition of an engaged musical faculty, not necessarily easily achieved, but also not simply out of reach for the lesser musician. To keep the music going, to draw out of it its ownmost possibility, the *musicandum* must be perpetually rediscovered, saving the music from its certain death. Immersion is the most successful discovery of this impulse, but music can also be carried forth in fits and starts, the creative in a dialectic engagement with the habitual.

Experiment, Experiment, Experiment

Compared to the player of composed music, the improvising musician has certain advantages vis-à-vis immersion. *Im-pro-vise*, *not-fore-see*. Not knowing what is to come next, refusing foresight, the improviser is unrestrained by a predetermination of the music and is thus freed to let the music choose its ownmost path. Wholly improvised music, or *free improvisation*, provides no criterion for determining a wrong note since any note is acceptable, which means that the free improviser has by default the experience of "no wrong notes." It may seem that the whole discussion of immersion—the emphases on creativity and spontaneity, the will that wills what is not yet determined, the insistence on the autonomy of the music over the musician—has been skewed in favor of improvisation. How much more difficult it is to discover the music's ownmost possibility when the correct note has been specified in advance. How can the musician become one with his instrument when a score stands between him and the music, mediating his experience of it? The improvising musician need only let herself go, to become wholly immersed in the music, let her faculty of music roam free.

On the other hand, if there are indeed no wrong notes in free improvisation, then there would seem also to be no particular risk, nothing hanging in the balance. Play this note or that note, or don't play at all; why would it matter in a free improvisation? Improvisation would be a matter of nonchalance, and there would be no way to discover the ownmost possibility of the music for there would be no threat to its coherence, no imminent death. In his insightful analysis, John Corbett complicates this image of improvisation. "Since the performer does not *know* for certain what will be played going into the performance, since the music is by definition undefined, the risk of failure, of complete collapse, is everywhere present."[16] Without the safety net of a score, the improviser suspends himself over an abyss and must build his own musical support if he is to stay in suspense. The imminent death of the music is that much closer, breathing down one's neck, for one does not know what will come next. Playing composed music, the musician can rely on her trained body to play the appropriate phrase, thus staving off the death of the music even where she does not imbue it with an immersed vitality. The improviser on the contrary must perpetually invent, can rely on nothing learned, for the only criterion of life in the music is creativity.

Corbett identifies three risks specific to improvisation: stagnation, insanity, and completion. Stagnation is the threat that the music will never get going, never go far enough, stick to the mundane, the already-played, the tried-and-true; to stagnate is to produce nothing but only to reiterate what has already been. Music instruction rarely encourages learners to play the unfamiliar, to attempt where they cannot succeed, so stagnation is surprisingly common even (especially) among highly skilled musicians who are only beginning to improvise. We are uncomfortable playing the unforeseen; not knowing what comes next provokes a significant anxiety. Beyond anxiety, the risk of insanity threatens to carry the musician too far, past the breaking point, to where she can no longer function properly. An improvisation that leaves the musician not just altered, but deranged, so far decentered as no longer to have a self to return to. This extreme may exceed the usual boundaries that circumscribe the musical, spilling from sound to noise to motion, until the improvisatory performance crosses a line where the body is extended beyond the limits of its healthy perpetuation, losing its ability to go on. Such a risk is probably overstated, as, for all its violence, only rarely does music leave the musician truly dysfunctional. There are more frequent minor insanities, where the musician is so carried away by the music as to lose track of time, or the audience, or the other players, or her body's alimentary or narcotic needs. Still, it is not a matter of coming back home but of getting out just far enough. The risk of completion is the most subtle and the most difficult to avoid. Habits of performance, thousands of years of the European musical narrative call the piece back home, inviting the musicians to close the journey, curtail further risk, give in to the relief of a final resting place. Derek Bailey documents the temptation by improvisers to return to the comfortable, the known. For example, composer Earle Brown discusses how his composition challenges its performers: "They would start quoting the repertoire they know best and I've always tried to provoke the musician to go beyond his habits."[17] Certainly there are greater dangers, and the journey may well outweigh the return to the starting point. Still, as Corbett insists, to return each time, to close the circle is to submit oneself to too many codes, offer too many answers where there should instead be more questions.

These risks may be inevitable, and fortunately so, for only by submitting the music to risk can one discover its greatest promise, its furthest creative dimension. Such discovery remains difficult, despite the risks, because it is not clear how even to begin to im-pro-vise. How do we fail to foresee, or rather, how do we succeed at not foreseeing? (Once again, the paradox of the will.) It is insufficient merely to avoid advance planning; in fact, without deciding in advance what will be played, one tends to play precisely what one already knows, or in any case, what one's body already knows. The already known must be deliberately and methodically short-circuited, disrupted by techniques that prevent its recurrence. "The way to discover the undiscovered in performing terms is to immediately reject all situations as you identify them (the cloud of unknowing)—which is to give music a future."[18] To improvise is to discard what has previously been done, to insist on the new. To surprise herself, to produce something that has never before been produced, the improviser resorts to practiced methods.

Method: musical process. Chapter 2 discussed Steve Reich's reliance on musical process. His compositions establish conditions under which a process is set in motion, and its progress, which generates the sounding music of the piece, occurs outside of the control of any human agent. "Pendulum Music" specifies that microphones be suspended above the speakers that amplify their sounds. The microphones swing back and forth, and each time a microphone passes directly over its amplifier, the resulting feedback blares throughout the listening space. The simple harmonic motion of the swinging microphones establishes a rhythmic pulsing of feedback noise, which becomes more constant as the microphones slow down and eventually stop, suspended directly over their corresponding amplifiers, to fill the auditorium with the drone of microphone feedback.[19]

Another Reich composition plays two identical looped tape recordings simultaneously. Because the two playback machines do not operate at identical speeds, the tapes slowly drift out of sync with each other, blurring the articulations of the recorded sound, from a chorus, to a reverb, to an echo, to a stuttering series of phonemes, until they eventually realign, having gone full circle. Though neither of these examples is specifically improvisational, improvisers frequently rely on a similar spirit of musical process to help avoid the production of the already known. An improviser might choose a random pattern of notes and then play it in various permutations of scale or tempo, or by doubling each note in the pattern on successive passes, or by skipping notes, etc. Treating himself as a pattern-generating machine, the improviser sets up rules and then blindly follows them, allowing the process to determine the music.

The intermediary role of the body can be helpful in constructing improvisational processes. One can treat one's body as a machine, establishing a pattern of fingers instead of notes, so that the musical production is wholly an effect of the body's motion. Or one may construct the process by appeal to external elements: attempt to copy every phrase the saxophone plays but in reverse, or try to play what the drummer *is about to play*, or play a phrase based on the letters in the names of the band members. Let your eyes wander through the audience; play a phrase by choosing successive pitches corresponding to the estimated income bracket of each person in row 3. In each case, the outcome of the process exceeds any foreknowledge of it; the musician manages to not foresee even when the productive algorithm is known in advance.

Method: inject randomness. Some of these processes avoid the already known by including elements that are sufficiently outside of the musician's control to generate something different every time. Keith Rowe—an improvising guitarist who has been at the center of the scene since the sixties with arché-improv group AMM—uses a shortwave radio to introduce the unpredictable, the unforeseeable, into his improvisations. He turns on the radio at his whim during a performance, accepting whatever sound might be broadcast at that moment, though he may also change the channel to find something he considers suitable to the musical context. Complicating this intrusion of the random, Rowe generates all of his sounds through the pickups of the electric guitar that lies on the table in front of him while he performs. The guitar pickups alter the sound in unusual ways, and even if Rowe himself is sufficiently familiar with the effects of this technique, the audience is usually surprised by the ways in which the guitar responds to various stimuli. To intensify the meaning of the random in his improvisations, Rowe attempts to exercise a precise control over every other element of his performance: most of his motions are deliberate and masterful to a fault rather than careless or haphazard. Not only does he place objects in and near the guitar strings with the refined precision of a virtuoso, but his timing, volume, and timbral choices are exact and calculated. Even leaning forward to grab equipment is a patient and delicate motion, minimizing the uncontrolled squeaks from his chair caused by the shift of his weight. All of this control dignifies the improvisation as legitimate music and allows a focused attention on the subtle timbre, the unforeseeable, the previously unheard.

Robin Rimbaud, who records and performs as Scanner, uses equipment to tune in to frequencies that carry private cell phone transmissions, which he incorporates into prepared music during his performances. This technique includes the random not only to testify to the fluid continuity of digital media but to highlight the confusion of public and private brought about by the cell phone. Cell phone technology is possible only by virtue of wireless transmission, which in theory allows the user to carry a private space out into the public environment. Scanner demonstrates how thin this division is, how unprotected is the shield of privacy surrounding the cell phone user. As such, he tends to choose and broadcast conversations that sound most intimate, most personal, not only because this forbidden fruit effectively titillates the audience, but also because these conversations most obviously disrupt the private/public division that cell phones purport to preserve. We hear in his performances not only what is unknown but what is not supposed to be known. Moreover, Scanner risks a great deal, including the possibility of finding no good conversations to listen in on, and even the chance of a lawsuit or other legal intervention.[20]

Method: play games. Something like a combination of process music and randomness, ludic music generates itself by treating the musicians as instruments, directed according to the rules of a game. John Zorn's "Cobra" is probably the most well-known example, where improvisations are created and controlled by cards handed out to the players. Trey Spruance, who participated in some of Zorn's musical games, describes the obsessive detail that separates the players from their own musical decisions, forcing them to play what they have not foreseen:

> It's a game and everybody plays with and against each other. Categories of calls (musical choices) can be made by each player, and they have to get the prompter's attention, who in this case is Zorn. Then he holds up the card and everybody recognizes what the card is—that card indicates what that

person called, by pointing to his mouth and then holding up a corresponding number. Once you have Zorn's attention and you've made that call he'll grab the card, hold it up, and then you indicate to him which players you'd like to see do that, if it's a call that requires you to specify who's going to play. Once that's understood the music that's been going on gets cut off as soon as he brings the card down; then you embark on a new sound.

There are six categories of calls that you can make: mouth, nose, eye, ear, head, palm, and those are the hand cues that you use. The mouth cues have four permutations for instance, and the head cues have three permutations.

There are different categories of sound instructions that are indicated by the first hand signal that you do—you point to your eye, which is one category of four calls, your nose, which is a category of three calls or your mouth. There are five categories and then you can hold up one, two, or three, four, five fingers. Each one of those has one type of manipulation of the sound. Like one category has these things called events, where a number of events that will occur can be whatever you want . . .

There's nothing in Cobra that indicates stylistically what is going to come out—except for in the complicated part of the piece which is called the "Guerrilla Systems." In which people put on the headbands, and whoever is wearing the headband is in control. In this part of the game there's one call that can be made in that's called "Sensing," which is where whoever makes the initial call has to start playing in a very recognizable musical style. Then his two spotters in the squadron he's signaled out of the group have to play in a contrasting style—a musical style that's recognizable and conflicts with the original style. But that's the only time where the kind of music to be played is specified.[21]

This obsessive detail programs the players and disrupts their sense of routine, denying the familiar. Each musician is forced to change directions at a moment when he might otherwise have played something comfortable, his musical decisions at the whim of the other players. The sounding music is constructed by a process that makes a pawn of the musician but, in so doing, draws from her a unique voice. The game itself functions as a musical element, primarily by redirecting the musical contributions of the players into unforeseen territories.

Consider a recent recording by Bob Ostertag, "Say No More." The process begins with individual musicians recording improvisations in the studio. These improvisations are transferred to a computer, where Ostertag cuts them up into small snippets, which he arranges to form his own musical compositions.

Eventually, the musicians are called back together, this time as a group, and are instructed to play, as accurately as possible, the compositions assembled from the snippets of their original solo improvisations. This task is technically impossible, as some of the computer arrangements involve layering or speed or stamina that human players cannot achieve. The effect both twists the idea of improvisation—by assigning it a permanence and reproducibility that the very notion of improvisation generally eschews—and forces the players to play what they cannot so as to produce the unforeseen. The pieced-together compositions borrow elements of the solo improvisations but assemble them to break the improvisational habits of the players, who ultimately play parts that are at once uncannily familiar and perturbingly strange.

Method: alter the instrument. Corbett identifies standard technique as a means of placing a distance between the player and the music. By eliminating resistance, "[s]tandard technical facility is [. . .] a strategy by which the instrument and performer are both denied a certain kind of presence in the performance [. . .]"[22] Generation of resistance is essential to creative improvisation; the body must be made to feel awkward in relation to the instrument, the known must be un-known. Corbett describes techniques to generate new resistance as a redisciplining of the body, the forced or methodical abandonment of old techniques and the adoption of new ones. At some point in the musician's training, the instrument ceases to offer an adequate resistance. The interface between player and instrument becomes too smooth, and familiar patterns are so comfortable as to discourage the invention or investigation of any other possibilities. To escape the trap of their own training, some improvisers alter their instruments, taking them apart, adding pieces on, and in general ensuring that their practiced playing techniques are either untenable or will generate unfamiliar results. By adding resistance to the instrument, new paths must be forged, new ideas generated. Examples abound, and Corbett offers a short list. Additional examples include Greg Kelley, a member of the Boston Sound Collective, who disassembles his trumpet during a performance, playing each part, not only with his lips and breath, but also by rolling it around on and tapping it against various surfaces. Also consider the cellist, Frances-Marie Uitti, who constructed a special curved bow to allow her to play combinations of notes impossible with an ordinary straight bow.[23] Confronted with a no-longer-familiar instrument, the musician generates novel and surprising results even when applying familiar technique.

Method: make mistakes. "Indeed, I have found solo playing to uniquely permit me to perform entire concerts formed from an elongated and somewhat ironic series of sonic, technical, behavioral and musical blunders."[24] A whole concert of mistakes might be taxing on the audience, but, then again, what would a mistake be in such a context? The improviser generally welcomes mistakes, the intrusion of the unforeseen, for a mistake is the production of the accidental. Jazz has been facetiously defined as the repetition of the wrong note. But it's not so easy to play a wrong note; the trained body steps in to thwart attempts to circumvent its habits. Another variation on the paradox of the will: how to make a mistake on purpose. One can establish a context or take certain actions to cultivate and nurture mistakes; one can attempt something that one knows one cannot do, play faster than one is able, play from memory what one does not quite remember, exceed one's abilities. The improviser attempts the impossible, or at least the improbable, secure in the knowledge that the attempt will fail and in the hopes that the results will be of musical interest.

In the studio, the musician generally has the option of doing another take, an option increasingly unlimited as digital recording media become cheaper and ubiquitous.[25] Early recording technologies allowed only one take, as the plates to make records were too valuable to waste on repeated mistakes. Now, not only can one record over and over, but one can keep exactly those parts that work, redoing whatever does not work. Multitracking allows the producer to keep the bass while doing the vocals over. Random-access editing allows the mixing engineer to select the best parts of each take to assemble a final version that sounds like it was created in one pass. Older editing technologies associated with analog taping—punching in and out—allowed the musician to record over a previous section of the music, at least a few times, as long as the engineer was nimble enough to hit *Record* at just the right moment. A very short segment of sound was difficult to align properly, especially because the recording heads were not in the exact same spot as the playback heads, meaning that there was a time difference between what was being written to tape and what was being read off of it. Newer digital technologies allow the isolation, down to the hundred-thousandth of a second, of the exact starting and ending points of the section to be rerecorded. In fact, the sound can now be moved around, duplicated, stretched, or otherwise altered, until it fits perfectly into the prerecorded section. There is no longer any such thing as a mis-take, since it can always be "fixed in the mix." In this sense, the recording studio is antithetical to improvisation, wherein the process itself has a value over and above the produced sounding result. The methods for disrupting foresight outlined here are not means to ends but are themselves the music.

To act such that one does not know what will happen. This echoes uncannily a definition offered by John Cage, not of *improvisation* but of *experiment.* To experiment, says Cage, is to do something the outcome of which is not known in advance.[26] His definition contrasts with others, scientific experiments that proceed by hypothesis. To test a hypothesis is precisely to know the outcome in advance; one may not know the specific outcome, but one knows the limited set of possibilities that define confirmation or refutation of the hypothesis. His music can be considered experimental, says Cage, only if experiment is a matter of not knowing in advance what will happen. His compositions are experimental just to the extent that they open onto the unknown, the unforeseen.

These convergent definitions make all improvisation experimental but also connect the not-foreseeing of improvisation with the experimentalism of music generally. Experiment is the improvisational tendency of all music, the way in which every music-making event risks something, tries something that may fail, for the outcome is unknown in advance. Creativity in music is not a question of choice, as Pierre Boulez would have it, but of the new, the singular or unique.[27] The immersed musician does not know what will happen, and so risks everything, however unlikely are the more extreme outcomes. (One reason for the marginal status of improvisational music is that the music industry discourages risk, as risk makes a poor investment. Ageing pop stars play their greatest hits, Britney Spears dances through the same routine every night, even the Kronos Quartet rehearses the same canned humor in consecutive concert halls. Risk in such cases is minimized: a mis-step, bad timing, technical difficulties; very little is wagered and so very little can be won, affirmation has no chance.)

Affirmation must affirm even the accidental, the unplanned, the undesired. Which is to say, failure is not merely a risk but an essential moment of experiment. Experiment entails failure. The faculty of music has failure built in. Given Cage's definition of *experiment*, failure is not a matter of falling short of some desired goal, specified in advance, but can only be judged after the fact or perhaps in the fact. Improvisers admit to the inevitability of the curve: the intensity of the music waxes and wanes; sometimes it's there, sometimes it falls flat. This cycle of success is not incidental nor does it indicate a lack of practice or ability; it is the process by which the music reaches its occasional intensity. A whole night of success, night after night of musicality, is an industry myth that attempts to rehumanize the plastic appearance product of the pop star. Music does not operate at 100 percent. It moves only in fits and starts, glimpses, sparks that arc painfully across impassable gaps, music on the verge of death, miraculously resuscitated only to lapse back into coma, music as soap opera, music as melodrama.

The artist sets out to fail, knows that failure is an inevitable element, really a dimension of success. What project would succeed without a hitch?

Only one wholly practiced, planned in advance to the letter. But what to do with this failure? The successful artist does not fail to fail, includes failure in his method, but not always in the product. The product may be the result of many failures, and all of these discarded attempts are implicated in the final result, just as the improviser implicates the paths he does not take, includes them by negation. To select one path from among the many, to hone one's art, to make a choice for an outcome known in advance, these do not destroy the spirit of experimentation but complement it. The faculty of music is both spontaneous and habitual; if its spontaneity is a matter of experimentation, then its habit comes not just from a lack of experimentation but from a positive element, another creative force. The faculty of music does more than tap into the new and original; it calls on history, training, and practice. This habitual dimension of the faculty of music, this complementary aesthetic pole to experiment is *editing*.

Though they represent opposed poles of the aesthetic process, editing and experiment are difficult to pull apart. They tend to fold into each other. Experiment is not accomplished by haphazard shooting in the dark, just as the spontaneity of the faculty of music is not a matter of randomness or illogic. Experiment is refined, practiced, technical, methodical; as such, experiment is a matter of careful editing, choosing with deliberation and forethought the right conditions, the right variables, to make the experiment most effective at generating the new. Often, the realm of experiment is confined to the subtle, while the grossest elements of music performance are predetermined by a score or some other constraint: controlled experiment. This constraint, which may extend also into the subtlest aspects of music, is the domain of editing. Though it refers to a preexisting condition, editing should not be defined, as it often is, as an operation on an already formed material, as though editing were not in itself creative but "merely" pragmatic; as though the editor is the one who steps in to temper the unbridled genius of the master. Editing is the intrusion of habit, self-consciousness, deliberation at any moment in the creative process. It is the accumulated residue of history. The writer is already editing as soon as she begins to write, choosing one word or phrase from among the many possibilities. This is too schematic, for it is not as though experiment generates possibilities that are then selectively eliminated by editing. Rather, editing and experiment overlap at the creative moment, which realizes a tension between habit and spontaneity.

One way to understand the mutual implication of editing and experiment is in the similarly divided paradoxical self of the immersed musician. To the extent that the musician is absent, given over to the whim of the spirit of the music, he is an experimenter, tapping into a creativity that immanently determines its ownmost path. To the extent that the musician remains centered, contributes himself to the produced sound, influences the music being made, he is an editor, drawing on a history of decisions and deliberations. This schismic schema misleads in that it suggests that the two selves, and the corresponding roles assigned to editing and experiment, are separable, at least in principle. But the immersed musician does not necessarily retain some overseeing consciousness that makes snap decisions regarding the music to be made; even the editor is lost in the music, given over to its spirit, and his difference from the experimenter is only the force of habit, the weight of history that asserts itself in the music. Symmetrically, the experimenter is not a purely external force, a universal stream that the immersed musicians taps into, but is itself a habit of the musician, whose training, whose centered self calls forth its experimental possibilities, to make of them a second nature. Spontaneity and habit as mutually dependent, a continuity of creativity.

Perhaps the difference, to the extent that there is one, is best understood in terms of temporality. Experiment is a leading edge, a forward motion, a blurry line dividing present from future and inhering in both at once. Editing is rather an accumulated past contracted in the present, the weight of this past as it leans into the line of experimentation. Under the pressure of the past, the ragged edge of experiment liquefies, breaks down as it surges ahead, only to become brittle again in a new contraction of editing. The accumulated past that constitutes the present force of editing is an accumulation of experiment, experimentation amassed. Editing is the residue of experiment, just as experiment is the leading edge of editing. Editing is thus a sedimented experimentation, experimentation layered upon itself. Editing offers a character, a definition, while experimentation gives editing its character, both by defining its boundaries or limits and by extending them through a continual process of experimentation. Experiment thus edits editing, while editing determines the domain of the experiment.

At its concretion or conclusion, the result of the interplay of editing and experiment is known as a work. When it is being produced, when the experiment is vital, the produced sound is not yet a work, for its boundaries are open and fuzzy; the lived experiment refuses any potential limits, opening the sound onto whatever accident may come along, affirming the incidental and inessential. Once it has been committed to record, or score, or memory, it is necessarily a product of editing, and this allows its definition as a work. A work may be experimental, in the sense that it produces an unforeseen outcome, and artworks all have such an experimental dimension. A work can experiment, but this is never the same experiment as the one that produces the work, even when these two things are materially equivalent.

One popular view assimilates the difference between experiment and editing to that between improvisation and composition. Such a view holds that the composer and the improviser are doing the same thing, but the composer has a chance to correct his work and tweak it until it is just right, while the improviser is stuck with whatever issues from his ax at the moment.[28] There must be some truth to this simplification: the composer definitely has an opportunity that the improviser does not. Each chooses sounds, but the composer gets to consider her choices, examine them, try out different possibilities to see what works, alter, add, delete, cogitate. If this is the difference between composition and improvisation, if improvisation is extemporaneous composition, then improvisation would offer no attraction but the spectacle of a musician so talented as to be able to produce adequate music on the spot. Improvisation would be a novelty act, tantamount to plate spinning or lightbulb swallowing. Once the novelty wears off, who wouldn't prefer to hear the more considered, more carefully chosen music, free of boring passages, well-balanced, properly crafted?[29] After all, the composer can retain the innovation generated by experiment, so nothing is lost in the composition. Except the risk.

Surely this simplification misses the mark. The composer does not begin by improvising, even if experiment lies at the heart of both activities. And the improviser does not set out to compose on the spot, even if the completed work bears certain formal similarities to a composition, or in some cases, could be mistaken for a pre-composed piece. The improviser has a certain freedom not available to the composer and takes advantage of this freedom to place himself at maximum risk and to tempt failure at each point. The composer has compensatory freedoms and attempts to balance the music's risk with a recovery that ultimately returns to stasis. The composer tells a story, the improviser lives through one.

It may be the case that the composer relies more heavily on editing while the improviser's art is primarily one of experiment. But these roles are complicated, for to compose music is always a matter of experiment, as the composer tries this and then that, composes only what she does not know in advance, in order to hear whether it works. The composer does not know what she will put next until she has put it there, considered it. Does each note flow from the previous by an immediate intuition, or does each note attempt something, to succeed or fail? Composers write the way the rest of us do, by writing. Moreover, improvisation is also a process of editing, though in a different time frame, an editing of style, of technique, of habits and ways to break them. For the essence of improvisation is always to strive for a kind of freedom, to refuse any path already chosen. The improviser, aiming for the experimental, includes much editing in the work, all of her training, all of her experiences as a player have refined her style, contributed to her vocabulary, and so shape the choices she makes in the moment of experiment, an experiment born of editing. But so does composition at its core aim always to free itself from any rule, to choose itself in all its parts. Adorno's concept of a *musique informelle*—a music that generates itself according to its internal dynamic, music without a form imposed upon it, but whose structure is an effect of its ownmost possibility—unites composer and improviser, for each desires nothing more than this, that the piece should spill forth from its inherent necessity, that it should decide again at each moment to take the next step. Adorno, who generally dismissed improvised music as facile, unsophisticated, and primitive, elevated the essential moment of improvisation to a principle of composition.

The Resistance of the Instrument

Immersion; improvisation; experimentation. We were looking for the role of the musical instrument in order to consider the computer as an instrument. Analyzing immersion, we noticed that the instrument does not mediate, does not stand between the musician and the music. Neither does the instrument disappear, for it remains integral to the music, offering itself to the musician. What sort of offer is this? It offers to the musician a *resistance;* it pushes back. The musician applies force to the instrument, and the instrument conveys this force, pushing sound out and pushing back against the musician.

Paradoxically, the instrument cooperates by resisting. In its body and its parts are weight, tension, inertia, and only by leaning into these forces of stasis does the musician feel the instrument press back against her, demanding her continued response to keep it in motion. When he plays, Hendrix's guitar does not disappear, for he feels it, and feels in it, meeting its maximal demand. If the string does not bite into the fretting finger, if the reed does not buzz against the lips and tongue of the clarinetist, if the piano key does not demand a specific minimal force before it travels to the bottom of the keybed (a properly regulated piano action requires about twenty grams,[30] I believe), then there will be no music, for without resistance, the instrument slips out of the musician's hands and falls silent. The skin of the drum transfers energy back to the drumstick, back to the drummer; the vibrating column of air in a tuba pushes back against the player, as the heft of its metal gives the musician something to play with. There must be a friction between musician and instrument, specific points of contact where the hard surfaces of the instrument meet the soft flesh of the musician.[31]

For his part, the musician resists the resistance, which is to say, he employs technique. We said earlier that technique is supposed to overcome the instrument's resistance, or at least to minimize it. This is incorrect. On the contrary, technique is designed to place the instrument's resistance in contact with the musician, to allow him to feel the many dynamics it offers of force and sound. Neither does technique maximize resistance, but it encourages the most efficient meeting with the instrument's resistances. Technique aims to feel and work in the resistance offered by the instrument. To learn an instrument is to learn in your body the dynamics of its resistance. Once established, technique becomes a matter of habit; but while it is learned, at its limit of refinement, at the edge of the musician's ability, technique is experiment, feeling the subtlest shape of the instrument, the tiniest texture of its response as inseparable from the timbral minutiae of the sound. It is this subtlest edge that distinguishes a merely good instrument from a superior one and, likewise, a merely good player from a master. This also suggests how the musician never finally masters the instrument but ever challenges himself to work within a further register of its resistance.

The produced sound results from the struggle of the musician in relation to the instrument's resistance, a technical struggle. Not just any resistance is productive. An accordion with buttons that stick, a woodwind with a split reed, stripped drum lugs that won't tighten, these faults resist the player's efforts to use the instrument in its usual way, but, though they may make for an occasional interesting or creative moment, for the most part they limit the possibilities inherent in the instrument and prevent music from being made.[32] Faults such as these do not open possibilities but close them off; they do not engender creativity but deter its exercise.

Defined by its resistance, the instrument does not just yield passively to the desire of the musician. It is not a blank slate waiting for an inscription. Likewise, the musician does not just turn the instrument to his own ends, bending it to his will against whatever resistance it offers. Rather musician and instrument meet, each drawing the other out of its native territory. The instrument itself has a potential, a matter to-be-determined, and its use is always in relation to its own character as well as to the desire of the musician. Music does not result from the triumph of the musician over the resistance of the instrument, but from their struggle, accord and discord, push and pull. Neither music nor instrument is predetermined, set in a specified direction from the beginning. Rather, the instrument presents a leading edge of indeterminacy, which is only defined progressively in the playing of the instrument as resistance is excited into oscillation or pushes back as pressure. The instrument's resistance holds within it its creative potential, which explains why improvisers focus so explicitly on aggravating the instrument's resistance. (Many of the improvising methods described above are designed to force the instrument to resist.)

Resistance therefore is not a refusal to conform to the musician's desire but is rather the condition of a problem, a musical problem. Like every good problem, the musical problem does not preexist the conditions of its expression. That is to say, the instrument is not employed instrumentally toward some end independent of the instrument itself. The problem is as much in the instrument, in its resistance, as it is in the musician and in the music. The resistance of the instrument is the problem it poses to the musician but also the precariousness[33] of the music embodied in the material forces that define that resistance. It would not be problematic if it did not threaten the music, impose itself on the musician; a problem one can safely ignore is not much of a problem. Left alone, the instrument returns to its static equilibrium, a death that threatens the music around each note, at the bar line of each measure, at the resolution of each cadence. The instrument is the accumulated inertia of resistance, the concrete material wherein the forces of resistance are held.

The musician approaches the instrument with a desire but not a desire for something in particular, only desire itself, desire waiting to be shaped, desire for music. The instrument confronts this desire with a resistance that also waits to take shape, responding in the moment to the applied forces of the musician. The instrument resists the creative impulse, pushes back against the musician, problematizing her desire and forcing her to make tactical maneuvers, right there where the music is happening.[34] At the meeting between musician and instrument, a problem is determined, and its progressive determination is only the generated sound of the music. The process taken as a whole turns (undetermined) desire into (determinate) expression, and the instrument can be defined as a machine for this purpose, a determination machine that uses resistance to turn desire into expression.[35] Resistance is thus a transdimensional conveyor, from virtual to actual, turning desire into sound. It is neither the stone nor the chisel but the force at their meeting, the point where desire becomes expression. This process has no conclusion, for the problem is never solved once-and-for-all: produced sound is always accompanied by noise, an area of indeterminacy that poses the problem again for the next moment.

This is why, despite the liaisons between the two concepts, we prefer the notion of immersion to that of immediacy. The instrument does not mediate and the musician does not strive to make it disappear into immediacy; the aim is not to bring musician and music into a contact without mediary. The material instrument contributes its creative potential to the act of music-making, a potential held in the materiality of its resistance. The material reality of the instrument is not accidental or unfortunate, to be dispensed with or overcome by technology. The dream of immediacy forgets the effort by which desire is forged into expression, the friction essential to this generation. Fantasies of future neurotechnologies imagine an instrument that "channels" the desire of the musician, an instrument that requires no technique but only a will to make music.[36] As though singing were not already technique. As though desire were already expression and need only be released from its captivity in the human mind. However, this image is misconceived, for there is no music without resistance and struggle. To move from desire to expression requires an effort and is never guaranteed short of this effort.

The notion of an effortless production is the error that damns not only the image of musical genius but also the image of the ideal computer. As discussed above, VR aims eventually to substitute for the entirety of the user's reality. In most formulations of this fantasy, the user is primarily passive, witnessing a seemingly real world generated on the computer. This aspect of VR emphasizes the computer as a medium, placing the user in the position of an observer. Media theorists, who perpetuate this medial view of the computer, treat the interactive dimension of computers as an ancillary element, where interactivity puts the *new* in new media. That is, the computer is understood as "medium plus interactivity"; the usual theories of media are applied, then modifications are made to account for the interactive dimension. Thus approaching the computer, media theorists are ill-equipped to understand it, for the computer is first and foremost a tool, an instrument, rather than a medium. Taken to its fantastical extreme, the computer as medium provides a complete, simulated world to a wired observer. Augmenting this fantasy to accommodate the computer as instrument, the ultimate VR not only provides a world of passive sensation but simulates the activity of effortful expression. The computer becomes so integrated with our selves, facilitates our actions to such a degree, that eventually it anticipates and carries out our desires. Certainly this extreme—the computer as extension of the self—is less theorized than the computer as immersive environment. But as it stands, the computer is undoubtedly a facilitator, a labor-saving device, and it is subtly but definitively imagined as saving progressively more and more labor. The officers on the bridge of the Starship Enterprise (in its various incarnations) never have to press more than three buttons to retrieve any required datum. Extensive modifications to hardware subsystems can be made in under two minutes. ("Reroute power from the hexadilithio matrix to the starboard shield assembly." "But, Captain, that's never been done." "Well, you'd better get started then." Twenty seconds later . . . "She's ready to go, Captain, but I don't know how long it will hold.") This single fictional example is inadequate, but it suggests the transparent interface in our collective imagination. We fantasize without thinking it through that computers will eventually simply respond to our will, do our bidding, even though current interfaces inevitably balance power against simplicity.

Computers extend our memory, storing and recalling complex and highly organized sets of data. Computers extend our bodies, enabling the disabled, providing hands and eyes at a distance, telepresence, virtual avatars, and other distant projections through technology; the mouse's scroll wheel at your desk can move heavy objects or pan cameras on the other side of the world. Computers already extend desire into expression, choosing which films the user might enjoy, calculating the best contrast and brightness values for a photograph, passing a sound through a set of filters to enhance its "excitement." In general, computers facilitate expression, helping us not only to accomplish goals set in advance but also to determine those goals, to decide what we want. Eventually, the fantasy goes, computers will effect the immediate presence of our desires in the world, taking over the effort of turning desire into expression. The computer, which already saves effort, will eventually save all effort, leaving us to a life of pure leisure.

Much has been made of the abandonment of the corporeal in cyberspace. Computer users leave their bodies behind, or maintain only a minimal corporeality when they enter virtual worlds. The resistance of the material world—formerly essential to creative expression—is subsumed by the computer and by the analogous small motions that constitute the materiality of computer use (mousing, typing, scanning the screen, etc.). The computer simulates resistance, or rather it simulates the symptoms of resistance, the icons of resistance, but not the resistance itself. This facility does not go far enough, as even these small motions of hands and eyes are onerous and must be replaced by voice commands, eye-movement direction, better mouses, and even mind control. It is not just a question of an environment in which the body becomes superfluous. The computer must anticipate the user's desire, meet her halfway by automating as much of the work as possible. Resistance should be decreased to the point where no technique is required.

Of course, this is as ill-conceived a notion as musical immediacy. Desire is not yet expression, and art is generated by the process of conveyance, in which desire is turned into expression. If computers remove the effort from this process, then expression will fail, becoming generic, the expression of the programmers perhaps, but not of the computer user. To become an expressive instrument, to allow the generation of ideas, the computer must not disappear, neither into the sensation nor the desire of the user. On the contrary, the computer must become resistant, it must become a machine for posing problems. The key to creative computer use is to make these problems genuine, problems of determination. This is especially tricky because the computer is a realm of already complete determination. It is not defined by the ambiguity and complexity of the physical and material; despite the popular jargon, there is no room for the virtual on a computer. Everything is already defined, mapped out in advance, planned according to VLSI chip design and optimized operating system calls. How to make a productive problem on a computer, a problem that does not disappear in its solution, a problem that demands the new of its solvers: this is no easy task.

In his study of computers as (music) compositional tools, Michael Hamman notes a rare tendency for the computer to act something like a musical instrument. He distinguishes two domains of computer use, the *symbolic* and the *semiotic.* In the symbolic domain, the computer environment (meaning primarily the program in use but also the interface design, hardware, and operating system) determines in advance the kinds of objects that can be manipulated, and (in music-making programs) these objects generally correspond to well-understood musical objects or concepts (tempo, pitch, note length, dynamic value, etc.). Though symbol-oriented tools may ease many compositional tasks, they generally do not challenge the user to invent new techniques or concepts since the object space itself is already one of intimate familiarity. A compositional computer program that presents to the user a staff and allows her to place notes on it is a prime example of symbolic manipulation, streamlining a familiar activity by computerizing it but otherwise leaving it unchanged. More generally, the computer commonplace of cut-and-paste, whatever convenience it might offer, resides squarely in the symbolic domain, for it allows the user to operate on familiar objects, or analogs of them, in familiar ways and so does not challenge the meaning or conventional use of those objects. Hamman notes that owing to the familiarity of the symbolically represented objects, they are easy to manipulate, so the interface tends to disappear. The symbolic domain involves relatively little mediation but is as such an infertile ground for new ideas.

The alternative to symbolic manipulation is what Hamman calls the semiotic dimension. To extend into the semiotic, a program must allow the user not only to manipulate objects whose meanings are predefined and familiar but also to generate new meanings, to create objects that are unfamiliar. Most computing environments provide predefined symbols, or a set of presets, so that the user need never take on the responsibility of effortful creativity. However, some programs go so far as to demand a semiotic comportment, such as the program, discussed in Hamman, which allows the user to manipulate a number of variables that are interrelated by sound-generating algorithms using formulas that are complex and nonlinear.[37] The value of a variable determines some aspect of the character of the produced sound, but it also determines the weight and function of the other variables. Continuous alterations to one variable may yield continuous alterations in the produced sound, much as sliding a finger up the fret board of a guitar will continuously change the pitch of the sounding note. However, alterations to a second variable change not only the produced sound but change also the effect of the first variable, which now makes a different sort of continuous alteration in the sound. The user of such a program has no choice but to experiment in order to find sonically satisfying sounds or sequences but also in order to develop a sense that is both embodied and conceptual of how the interface relates to the sound. A trumpet player learns to find those thresholds of breath pressure, embouchure shape, lip tension, and other subtle, embodied factors that determine the points at which the sounding note will jump up or down by a certain interval. This knowledge can be described, but no description will ever teach another player where the thresholds lie. It is a knowledge gained only by embodied learning, and this is what Hamman desires from computer programs that are to aid creative processes.

How would a semiotic program operate? Nonlinear and complex relations among variables can establish a domain of possibilities that is not easily conceptualizable, has local discontinuities, and even exhibits occasionally chaotic or pseudo-random behavior. Patterns may be detected here and there, but no global pattern can be abstracted, so that the overall operation of the computer-instrument must be learned only by trial and practice, just like an acoustic instrument. One way to encourage such practice is by providing interface elements that allow for a rapid alteration of many different variables independently. (Consider the Meta-Instrument project, which allows the simultaneous manipulation of thirty-two independent variables, for a total of over half-of-a-trillion possible settings.[38]) The user must become practiced at the interface, and the lessons will be learned as much by the body as by the mind or, rather, in general, by the faculty of music. Only a software-hardware system that offers a rich sound palette, alterations both subtle and gross, and an intuitive relationship between gesture and sounding-result will encourage the sort of practice it takes to master such an instrument. Complexity is not therefore an adequate mechanism to reach the semiotic domain, since not only will too much complexity deter actual use of the instrument, but an artificial complexity will only cripple access to the sounds without necessarily adding any possibilities. Semiosis is a matter of potential; as Hamman says, it is a question of being able to create meanings. And this means to create what has not already been determined.

Computers do not lend themselves easily to a semiotic employment. The abstraction at the heart of computers, in which everything is turned into bits with hard edges, discourages subtlety and intuition in favor of intellectual rules. By abstracting the data they represent, by allowing the manipulation of abstract objects, computers effect a relationship that is also abstract between user and object. Symbolic manipulations are disembodied, so they are readily made linguistic, amenable to teaching by telling; you can instruct someone over the phone as to how to perform a symbolic manipulation on the computer. By contrast, semiotic manipulations cannot be adequately described but must be interactively witnessed, played with. To learn a semiotic interface is to learn to play an instrument: by offering resistance, it also offers possibilities of determination. The question is what the computer offers to determination; is there a leading edge of indeterminacy, a problematic zone of resistance? Indeterminacy would seem to be entirely lacking on a computer, since the limits of its possibilities are inscribed in its hardware and further narrowed by its software architecture. That is, once the algorithms are established, the relations between variables and results are wholly determined, and the space of possibilities is set in silicon, mapped out in advance. Hamman proposes that this ontological fact is secondary given the epistemological condition of nonconceptualizability. Because we cannot know the instrument, or only in our bodies, therefore learning and making music with it is a truly creative act.

One consequence of the relative unsuitability of the computer for semiotic usage is its similar inappropriateness for improvisation. A symbolic interface effectively diminishes or eliminates the possibilities for improvisation because the computer is unable to surprise its user. There is no possibility of the unforeseen because the possible manipulations are predetermined by the software and known prior to their implementation. If one can make mistakes at all, they tend to be useless and unproductive mistakes. The mistakes only become interesting when the computer is challenged beyond its predetermined capabilities, when its predictable character breaks down to generate digital errors, overloads, buffers filled with garbage, stuttering, etc. Unfortunately, these errors are usually handled within the program and discarded before they reach the interface, generating an *exception condition* that can be skipped or else crashing the system altogether, beyond recoverable results. Nevertheless, there are a number of artists who exploit these errors in their work, finding those points at which the program no longer works as expected. There is also a large community of artists who improvise with laptops; many such artists resort to designing their own software in an attempt to augment the semiotic potential of the computer and open possibilities for the unforeseen of improvisation.

Note that, to the extent that it is employed semiotically, the computer feels more mediate than in its symbolic usage. Frustrating the user by posing to her a problem of determination, the computer seems to stand between her desire and its expression. Just as in the case of the musical instrument, this is a mistaken impression. As the site where desire becomes expression, a semiotic interface is essential to that process, not just a necessary mediary but a creative element that contributes its own character to the result. As Hamman points out, an interface that offers no resistance is one in which the user only performs actions that are known, that are already familiar. A well-designed symbolic interface will disappear, cease to get in the way, but this ease is purchased at the price of creativity. To generate the new requires a resistance, the interface must push back, make itself felt, get in the way, provoke or problematize the experience of the user, who, confronted with a problem, innovates in order to solve it. The outcome is unknown; the experience is experimental; the process is improvisatory. To describe this alternative as a semiotic dimension is somewhat ill-conceived, as meaning is by no means the only thing that might be invented, but also affect, percept, play. Indeed we must get beyond symbols whose meaning is preinscribed, for there are ways to circumvent or exceed those symbols, ways that are not specifically about creating new meaning (unless *meaning* is very broadly construed). What we desire is that the program behave in ways that are intuitive without being obvious, consistent without being predictable, accessible to beginners and rewarding to experts.[39]

Taking a cue from the musical instrument, it is clear that what the computer needs is a resistance, a problematic resistance that, when pressed by a creative desire, turns that desire into expression, generating the new. This formula, not so easily said, is nevertheless much more easily said than done. For though the computer certainly resists the desire of its user, it does so with a rigidity, a fixity that tends only to demand conformity rather than engender creativity. In order to do things with a computer, one must use it according to its prescribed options, and no other usage is the least bit productive. The computer's resistance is predefined by the reigning architecture. It is not a pliable material resistance, with a leading edge of indeterminacy, but a fixed logical resistance, in which every response is calculable, repeatable, and determined in advance.

This is the character of working with a computer. The user must know what she wants in advance, and her ends must be understood in terms of the things the computer is programmed to provide. Digital technologies always demand a similar conformity. The user of the remote control must not only conform physically to the remote's layout of buttons, its axis, its limit distance from the box to be controlled, she must also conform to its way of thinking, its methods of breaking down tasks into steps and then stepping through them. First turn on the receiver, then the television, then the DVD player. Then start the DVD player, wait for the menu to appear, then adjust the sound options by choosing the menu item devoted to them. The user must also be programmed. Inserting a page break on a word processor requires a particular combination of keystrokes; other methods of getting to the next page, such as a series of carriage returns, don't work as well, since later editing may change the formatting of the text so as to require more or fewer carriage returns. No doubt, every technology demands that its user learn its appropriate operation. But computer technologies are especially rigid because of the abstraction at their core.

At the proper caress, the stiffness of the computer begins to soften, at least temporarily. To coax more from the computer than it is initially prepared to offer, one must still conform to its standards, its limitations, but there are ways to bend its suitability to one's own purposes. Programming—which encompasses a whole range of activities, high-level, low-level, specialized environment programming, etc.—seems like the obvious path to genuine innovation on the computer, allowing it to do new things, things it could not have done before.[40] Whether or not such alterations can be considered fundamental or merely ornamental is a matter of perspective; computer skeptics will scoff at the supposed wonders of programming, claiming that it still does only the meager sorts of things that computers can do. Those who believe in its creative power claim that programming opens vast worlds of possibilities and proves that the potential of the computer is unlimited.

Whatever possibilities are opened up to the computer programmer, programming still differs fundamentally from a creative engagement with a musical instrument. For the programmer always knows precisely what he is aiming for. Programming is not an open-ended task where one sets out with a desire and improvises along the way. There is no moment of dabbling, no experiment, except inasmuch as one tests to see if one's code "works." It is true that any complex program is developed to some extent while it is being coded. The design process is coincident with the build process, and design is altered, new code written, old code amended or discarded until it works and works well. But even when the goals are determined along with the process itself, they are always thought out first and implemented second. Every line of code is directed toward a particular end, and the program succeeds or fails strictly according to whether that end is achieved.

This observation about programming characterizes in general the difficulty of pushing the computer in the direction of the (musical) instrument. Almost everything on the computer is the result of an initial decision by the user, made independently of the computer. Almost every action on the computer is made toward a particular goal and can be judged successful or not on that basis. One intends to type a *y*, and to type something else is not the basis of a creative moment of improvisation but a simple failure. One sets out to create a database that contains a catalog of one's record collection, and every move along the way either advances toward that end or is an utterly superfluous waste of time. By contrast, setting out to make music is an open-ended proposition, and all sorts of things will count as success to the point where it is no longer a matter of success or failure. But setting out to accomplish something on a computer has always a specificity that carries with it its own criteria so that the computer is rarely a site of experimentation. Rather, the computer is primarily an editing machine. If it offers a resistance, it is only the clumsy resistance of its stiff interface. Any creative resistance comes from the material itself, and the computer generally mediates one's access to that material.

This also explains why it would be futile to search for a faculty of computing (analogous to the faculty of music) that would be the self who computes in the moment of its activity. If the resistance is in the material, then the appropriate faculty would be relative to that material; there are diverse expertises associated with disparate activities at the computer: computer gaming, layout design, Web design, digital photography, database maintenance, word processing, networking, hardware repair, interface design, sound manipulation, security, typing, scheduling, communications, etc. Not that each of these activities implies a faculty that governs its masterful application; in fact, only rarely does the computer demand the sort of absorptive engagement in which one extends one's self much beyond the usual limits of the body. (Beyond the bodily extensions of mousing and typing, one is rarely called forth in an immediate manner by the computing device, even if the material becomes engaging. As such, there is perhaps, if not a faculty of computing, at least an aptitude for it, a way of thinking in terms of data presentation, ergonomics, interfaces.)

The computer is an editing machine. This suggests, following the above analysis of editing, that the computer is an accumulated residue of habits, that the conformity it demands is a matter of forming habits. Certainly, the computer offers a fantastic consistency; it responds identically to similar conditions, operates the same way from one machine to the next, and one day to the next. But habits do not form from nothing. Habits have a history, a series of experiments folded onto one another. Programming comprises one dimension of this history of the computer, to the extent that programming succeeds in pushing the boundaries of what the architecture can do; but it is really the history of the architecture itself that includes the most drama. To view this history, we must step back until the digital turns fluid, a history of flows and breaks, acceleration and deceleration, data passing from place to place, program from form to form.[41] The liquid history of the digital is almost guaranteed by its abstract nature, which both etches the rigid ideality of its edges but also ensures its universal communicability, its universal form that persists over time, from generation to generation. Anything on a punch card could be put on a DVD. The same programs that ran in the sixties will run on the computers of the twenties to come.[42]

New architectures are effectively experiments; it is never clear what they will be able to do until they are released on a population of programmers, hobbyists, end users, vertical markets, etc. Designing a new chip is a process of trial and error, lengthening the number of stages through which the data are processed in order to allow an increase in raw processor speed or trading heat dissipation efficiency for a smaller die size. These incremental improvements are then further balanced against bus speeds, caching mechanisms, other input/output considerations, motherboard layout, energy use, etc. Various factors fit together like a puzzle; some designs can be rejected while still "on paper," whereas others must simply be attempted before they reveal their deficiencies. Combined with an operating system (with its own various enhancements, optimizations, subsystems, device drivers, etc.) and a set of peripheral hardware, the computer exists as a living experiment, its limits unknown until tested and pushed. Despite its most rigorous definition, the computer presents to those who know where to look a thin leading edge, the edge of the not-yet-determined. Indeterminacy is never a finite quantity, else it would not be indeterminate, which means that it can be exploited toward unpredictable possibilities. The computer only demonstrates its capabilities over time and in practice.

The fluidity of the digital is evident especially in the microcosm of sound synthesis. Each generation of synthesizer overtakes the next, not in a series of discontinuous leaps but in a jagged fluidity, a variably viscous solution that moves through time and place carrying the digital along with it. Digital data, abstract to begin with, can connect easily across distance and time, and these tools can even plug in to each other directly, given the abstract continuity of the digital: "Any selection of algorithms can be interfaced to pass data back and forth, mapping effortlessly from one dimension into another. In this way, all data can become fodder for sonic experimentation."[43] Digital instruments remove sound from its concrete time and place. It can be stored indefinitely, reproduced exactly on command. The instrument does not produce the music from its concrete body but from its abstract program. Digital sound is abstract from the start and so is connected to former sounds by the fluidity of data rather than by the material solidity of mechanical vibration. Even playing digital instruments is less a matter of inscribing on one's body the gestures that have been developed over hundreds of years than it is a matter of reinventing one's own technique, adapting the abstract sonic possibilities to the naturalized gestures with which one approaches an instrumental interface or a computer.

Precisely because the digital institutes a uniformity, reduces music to form, digital instruments are connected across space and time, collected into a continuous liquid mass. The mutual abstraction of digital instruments provides a historical continuity that is invisible in the domain of the actual. The digital ties instruments into a lineage so that the instruments themselves describe a linear progression or a number of such progressions. Electronic music evolves or progresses mostly by adding possibilities but rarely by eliminating them. Each successive synthesizer opens new possibilities for the generation of sound without closing off the old ones; the latest synth can do everything its parent did and more. One can often feed the settings for an old synth into a new one to get the same sound.[44] Each version of a software product comprehends the previous version while adding and improving.[45] In the acoustic realm, there is no such clear notion of progress as new cellos and tablas are simply different from old ones, not necessarily more capable. Even if there are occasional (and contested) improvements to acoustic instruments, these alterations do not usually add to the possibilities without also changing other ones.

This continuity of the digital is not only due to its universal abstraction in the binary digit. The structure of data as well as the structure of program code is inherently modular, reusable, translatable, scalable. Data on a computer are organized into standard structures, as simple as an integer in sixteen bits or as complex as a record in a database, with text, numbers, dates, custom fields, and other data, all standardized and comparable to other fields, transferable to other databases, manipulable according to its structure irrespective of content. Programming, in the most concrete assembly language or in the most abstract high-level language, is broken down into subroutines, small chunks of code that perform small tasks on a small set of data, which can fit into any number of larger programs. For instance, one subroutine might take as input two strings of letters and concatenate them, outputting one longer string. Such a task is performed constantly in programs that deal with text, and a single subroutine could be used again and again without alteration. Object-oriented programming languages, increasingly popular since the late eighties, enforce a strictly modular design, but reward programmers with code that is completely reusable, readily alterable, and easy to debug. Just like the bit but at a broader scale: sharp divisions of structure make possible a universality or generalizability that reinstitutes a continuity from context to context.

Synchronically, the computer is frozen, its possibilities entirely predetermined and inscribed in its hardware and software. But diachronically, over time, it behaves like a fluid, everything digital connected to everything else through the magic of abstraction. Perhaps this picture of the progress of the computer provides a less cynical understanding of the industry's constant push toward the new. The endless cycle of latest models, the built-in obsolescence of the personal computer is not simply imposed on the image of the computer by a capitalist culture that sees technology as the salvation of continued growth. Rather, the drive of incessant progress is inherent to the nature of the digital. Any given hardware is instantly obsolete, for its edge of indeterminacy has already been honed to a minimal breadth by testing, by requirements of compatibility with earlier software, by habits of usage that are not economically wise to alter. The possibility for innovation, the excitement in making computers lies always in the next one, for in the course of progress, the computer begins to show its fuzzy edges, to offer itself to the determination of the artist-engineer.

This high-contrast history of the computer, in repose and in motion, demonstrates a marked inadequacy when compared with the musical instrument. For in music, the new is not just new right now, not just new relative to older music, but new as such, what Nietzsche calls the *untimely.* Music, live or on record, can continue to inspire, to surprise, to invent itself, regenerating the new at each hearing. By contrast, computers have the character of being wholly associated with their own time. Not only are digital sounds identified with the era of their production, but computers in general are affixed to their era, almost as though they simply cease to function when new technology replaces them. Is it even possible to make a digital device untimely? This fantasy substitutes for the debunked fantasy of VR. We must recognize the futility and self-defeat of striving to minimize effort. (This is not to say that research to that end should cease, rather that we should come to understand the nature and goal of this research differently.) Instead, let us call for a computer that can surprise, an interface that challenges the user, that reveals itself only slowly, determining itself in concert with the user, who learns as she goes. Bring on the day when we will play the computer as an instrument, though by then, the computer may well play us.

This page intentionally left blank

Notes

1. Sound and Noise

1. Just as there is a lower limit to human hearing around fifteen Hertz (Hz, vibrations per second), so vibrations faster than twenty thousand times per second (20 kHz) are so high in pitch as to escape detection by human ears.

2. Readers should bear in mind that throughout this book technical discussions are often simplified. For example, the amplitude of the sound wave generally does determine the perceived loudness of the sound, but loudness is also influenced by many other factors, including the sound's pitch, duration, location, source, and the other sounds in the environment.

3. Of course, *wavelike behavior* must be given a formal mathematical definition, but a huge variety of phenomena have regularities, which is the basic criterion for what falls under the Fourier theorem. Annual rainfall and the stock market and the distribution of stars in the sky all have regularities and are thus amenable to investigation by the Fourier theorem. Just about anything that moves up and down (or back and forth) can be subjected to a Fourier analysis. One restriction on its applicability is called the Dirichelet condition and specifies that the wave submitted to a Fourier analysis must not be fractal, the amount of variation in any given interval of the wave must be below some finite limit. In practice this is rarely a problem, as real-world phenomena are measured to a certain limit of resolution and thus are not usually represented by fractal descriptions.

4. We will see in chapter 3 that the Fourier theorem also has limits to its usefulness in analyzing and generating sounds.

5. One further property of waves is *phase*, which is relevant primarily when two waves are being compared. Imagine two sine waves of the same frequency and amplitude. If they reach their peaks and valleys at the same time, they are in phase. If they are staggered, then they are out of phase (see Figure 12). Phase affects perception by contributing to timbre, but it also functions as a key element of location of sounds in space. Phase and amplitude differences between our two ears are contracted into a sense of location of the sound source.

6. *Timbre* generally refers not only to the consistent character of a sustained sound but also to the way that a sound changes over time. The small screech when a violin string is first excited by the bow is characteristic of the violin and is considered an essential part of its timbre. In this sense, timbre cannot be taken to be independent of duration. Note that this wrinkle in timbre does not invalidate its definition in terms of the Fourier transform. The entire sound wave, from the opening screech to the closing fade into silence can be subjected all at once to a Fourier analysis, described as the sum of simple regularities.

7. Noise-canceling headphones operate on the principle of out-of-phase cancellation. They measure the wave in the ambient space near the listener, then generate an equal but opposite wave, exactly out of phase with the ambient wave. When added together at the listener's ears, these two waves produce a null wave, no net change in pressure, hence also no sound. This process is much easier at low frequencies, which have long wavelengths, meaning that the amplitude of the wave changes little over a short distance. Since high frequencies have short wavelengths, they vary dramatically over a short distance, which means that the wave to be cancelled would have to be measured at the same point in space as the cancellation wave is produced. This kind of space-time precision is difficult to achieve and requires exact timing and low tolerances for error impractical in a consumer device. It is possible, in principle, to cancel any sound, to build headphones that completely eliminate the sounds of the external world.

8. *The Absolute Sound* is an audiophile journal for the critique and promotion of high-fidelity music reproduction and its associated equipment. Absolutism is not merely a name: "We try to discourage our staff of reviewers from paying much (if any) heed to other publications since their work, lacking an absolute or any other editorial 'philosophy,' cannot be worth a close study" (Pearson 1996).

9. It would seem that the technology of home-based playback systems would eliminate aura from music, since, following Benjamin, aura disappears precisely when the distance between observer and work is closed. What distance remains when the artwork is in one's home, at one's disposal? However, the audiophile, despite the ready availability of the recording, continues to revere the work of music, to hear it as though from the insurmountable distance of history. The audiophile acts as though a symphony orchestra were performing in his living room, with all the awed respect for the music due to such an occasion. *Aura* is thus an appropriate term for what the audiophile wishes to coax from the recording.

10. The introduction of the score certainly goes some way toward bestowing the status of *work* on the piece of music. Note that just as the recording allows a strict distinction between signal and noise, so the score effects a similar distinction by leaving out timbre altogether. Only the most gross aspects of timbre are included in the score, such as the instrument to be played and certain recommendations in terms of dynamics and overall feeling. For the most part, the score relegates timbre to the moment of performance, which is why it does not yet constitute the artwork in itself: the performance would be the work, while the score only provides a kind of template, an instruction as to how to generate the work. For a detailed and insightful analysis of the history, ontology, economy, and aesthetics of the score, see Jacques Attali's fantastic book, *Noise: The Political Economy of Music.* For further thoughts regarding the relationship between the score and timbre, consult Jean-Charles François's thoughtful and concise article, "Writing without Representation, and Unreadable Notation."

11. Quoted in Pearson 1996.

12. Reviewers sometimes describe the character of a recording or piece of equipment by pointing to a location in the hall: "the sound of the Sigma 6 digital-audio converter was forward, placing the listener in row three."

13. David Denby relates the story of being transfixed by an AM broadcast over a transistor radio of an old scratchy recording of Caruso's voice (Denby 1996, 64). Some audiophiles have noted with surprise that music often sounds really good on the relatively poor stereos in their cars.

14. This antiobjectivism is prompted, in part, by the fear that the entire industry of audio equipment review could be supplanted by mechanical devices to judge accuracy. The audiophile press is profoundly distrustful of equipment specifications and measurements.

15. The notions of *percept* and *affect* employed here are borrowed from Deleuze and Guattari's *What Is Philosophy?*, especially chapter 7, "Percept, Affect, and Concept"; however, this borrowing is rather loose, and the concepts used here do not correspond strictly to their usage. In fact, the present chapter owes a great deal more than that to Deleuze's work, including the foregoing discussion of contraction as the basis of (sound) sensation. In *Difference and Repetition*, chapter 5, "Asymmetrical Synthesis of the Sensible," Deleuze offers a theory of sensation holding that every sensation is a difference of differences, a nested series of differences that must be crossed in sensation, and as they are crossed they are erased or covered over by a static quality. While Deleuze's account of sensation in *Difference and Repetition* is notoriously abstract, I have tried to connect his abstract account to concrete aspects of acoustics and psychoacoustics, and in so doing, have undoubtedly added to and departed from the theory he offers.

Note also the oblique reference to Deleuze below, where I make use of the connection he establishes between implication (the holding-within of the nested series of intervals of difference) and ethics. This connection operates through Deleuze's resolute abstractions and thus comes across in this present chapter as itself somewhat underexplained. Please refer to *Difference and Repetition* for a more complete articulation of these obscurities.

16. Quoted in Pearson 1996.

17. Quoted in Young 1992.

18. CDs have a sampling frequency of 44.1 kHz. This means that, in theory, they can record sounds up to 22 kHz, but to be safe, engineers generally filter out frequencies above 20 kHz.

19. Ironically, even the industry itself is now beginning to criticize the limitations of the CD, primarily to pave the way for the next music storage format. As of this writing, it is not yet clear what format will replace the CD, and competition is brewing among various possibilities (Super-Audio CD, DVD-Audio, and others). Each of these proposed replacements for the CD offers a higher storage capacity, which means that it is capable of storing sound recorded at a much higher sampling rate and at a greater resolution. Consumers must be convinced that what they currently have is inadequate, if they are to buy the new format. Currently, there is little momentum for any new format, since the clearest threat to the CD right now comes from lower quality recording media, such as MP3. It turns out that for mainstream listeners, CD quality is better than they need, and the industry will have to find other ways (such as media convergence technologies) to prompt consumers into buying new gear and new media.

20. Preliminary research is available online in Oohashi et al. 2000. Many other engineers and artists support this claim with anecdotal and experimental evidence; see David Blackmer's comments online, for example.

21. Sloboda 1994, 96, refers to this experience as "floating."

22. Equicentral, for contraction articulates or separates as much as it draws together.

23. Those who have experienced the best ensemble performance will recall how the band becomes one instrument, a music machine. Bill Evans's trio is noted for such a meld.

24. Leonard Meyer, who writes about the perception of music, recognizes that "understanding implicative relationships is a complex and subtle cognitive activity. And it is an activity of our whole being, not just that artificial abstraction, the mind. The many facets of the human nervous system, physiological changes and adjustments, motor behavior and the like, are all involved" (Meyer 1973, 113).

25. Hence, Meyer chooses in his earlier work the term *expectation* instead of *implication.* He stops using *expectation* to avoid reference to the cognitive state of the listener and also to mitigate the difficult idea of simultaneous contradictory expectations. See Meyer 1973, 114–15, fn.

26. Quote in Sloboda 1994, 163.

27. Hindemith identifies compositional genius with the ability to envision a piece in its totality beforehand, or to provide an "ultimate congruence" (1952, 63), while noting that this vision of a complete musical form, "illuminated in the mind's eye as if by a flash of lightning" has not the clarity of specific notes, but the obscurity of an implicated totality (61).

28. There is a third diminished dimension, that of the difference between two listeners or between the two ears of one listener.

29. Quote in Deleuze 1994, 244.

30. The "lo-fi," pro-analog phenomenon is so pervasive as to have taken over the rock music industry. The senior vice-president of artists at Columbia Records notes, "Tape hiss, guitar-amp noise, low-level garbage. Five years ago, we would have cleaned all that up. But today, the prevailing wisdom is to go lo-fi and let that noise become part of the music." This is in the service of trying to "capture a less digital sound" and goes hand-in-hand with embracing "incidental noise and incorporat[ing] it into the mix to achieve a *heightened sense of reality*" (Chun 1995, 36).

2. Sound and Time

1. This suggests another semiotics, one based on a hermeneutic circle. Each participant in a conversation bears a different relation to the subject matter, but these variations do not necessarily form a hierarchy of knowledge. Is this tantamount to Hans-Georg Gadamer's notion of *wirkungsgeschichtliches Bewußtsein?*

2. "This does not mean that any *f sharp* in the six hundred and twelfth measure of the final piece would have been determined in the very first flash of cognition [. . . But i]n working out his material he will always have before his mental eye the entire picture" (Hindemith 1952, 61). Hindemith refers to the intuition of a whole piece at once as a "vision," the genius's "gift of seeing" a "complete musical form" or "photographic picture" in the "mind's eye." As Hindemith certainly knows his way around sounds, one can only assume that the persistent use of the visual trope is an artifact of linguistic habits shaped by millennia of modeling thought in general on the faculty of vision. "Ah, I see."

3. Organist Lionel Salter quoted in Bailey 1992, 26.

4. It is perhaps John Cage, Karlheinz Stockhausen's inspiration, who most persistently attends to the rhythms of noise, by reminding listeners that we hear even what we do not listen to.

5. Consonants are thus misnamed, for their irregular and nonrepeating vibrations are far less consonant than the steady and agreeable accord of frequencies in vowel sounds.

6. Stockhausen 1989, 109; Barthes 1985, 284.

7. See Gabor 1946 and 1947.

8. The Fourier representation of a discontinuous periodic function demonstrates a kind of distortion known as "overshoot" (Gibb's phenomenon) where the frequencies of the sound near the discontinuity become particularly imprecise. Sudden changes in a sound are most noisy.

See chapter 3 for a more thorough examination of the inadequacies of the Fourier analysis in relation to the temporality of sound.

9. The pitch of a sound gets lower when it is (recorded and then) slowed down. Slow down a recording of, say, a single sustained note on the French horn, and the pitch will drop along with the speed. When the fundamental pitch of the sound slows to around twenty cycles per second (20 Hz), it is so low that it is no longer perceived as pitch. Instead, one can hear the individual pulses, each of the twenty cycles in a second. Further deceleration renders these cycles more distinct and allows us to perceive in magnified form the subtle shape of each cycle that makes the sound uniquely that of a French horn.

10. Quoted in Stockhausen 1989, 91; subsequent quotes in this chapter will be cited by page numbers in the text. Lacking ready technology, Stockhausen does not attempt this project of speeding up an entire piece into the span of one second. However, John Oswald (1996) has since completed such a project using various live performances of The Grateful Dead's "Dark Star" as source material.

11. There are experimental data analysis systems that represent data aurally, taking advantage of certain abilities of the ear which the eyes may lack. For instance, the ear can monitor many sounds at once, as long as they are separated into distinct frequency bands, and so can hear subtly correlated changes in a diverse set of data. The ear is also able to recognize patterns, such as logarithmic regularities, that might escape visual detection. See Fischetti, "The Sound of Data: Virtual Acoustics" (1993).

12. See Schoenberg 1984, 116.

13. This discussion of the sociomusical implications of the organization of the orchestra echoes and elaborates the opening paragraphs of Brian Eno's "Generating and Organizing Variety in the Arts" (1981), wherein he compares the nineteenth-century orchestra to a military organization. Eno traces the effects of this rank-and-file organization on the possibilities for variation in the music, noting that the orchestra discourages variation, partly by presupposing trained musicians, trained to adhere to the lead of the conductor.

14. Schoenberg holds that ideas, which lie behind the music and motivate it, are universal, so that only style changes from one era, period, or genre to another. Secondary qualities of music change over time, but the essence of the music remains the same. Adorno calls this attitude "naïve," arguing that both style and idea are much more complex than Schoenberg acknowledges (Adorno 1967, 150.) Adorno gives the impression of Schoenberg as a doddering old man, almost an idiot savant, who writes music with genius but cannot say the first intelligent thing about it.

15. See the remarks by John Backus and others in Christopher Koenigsberg's section on "Scientific Commentary" in his Web site on "Stockhausen's New Morphology of Musical Time."

16. One can understand quite a bit, if not everything, about *timbre* and *pitch* by studying the wave described by the compression and rarefaction of the air. Such an object of study yields successively less about the domains of *rhythm* and *form*. Even timbre and pitch are not thoroughly explained by air pressure. It is often noted that a picture of a waveform, even a spectrogram, is hardly translatable into sound by human eyes. Pitch is understood in most musical traditions not as frequency relations in waves but by reference to harmony, and timbre is not the superposition of waves but instead draws instruments into families and determines the critical psychoacoustic properties of an arrangement. The entire field of psychoacoustics exists only because a spectrogram is generally a poor indicator of what a person will actually hear, as the relationship between the sound waves that reach the ear and the perceived sound is extremely complicated and often even unpredictable.

17. Steve Reich: "When I pick up a gong-gong or an atoke it tells me that *it* plays a certain kind of music, that *it* has a certain history" (1974, 58).

18. Quoted in Corbett 1995, 229.

19. The connection between word and sound is famously labeled *arbitrary*. Is this a misunderstanding? Every word has its history, and the absence of an origin does not render the sound arbitrary. The history of a word, including its sound, inheres in the language and is heard there. From across a busy street, the muffled rhythm of a few words is usually enough to betray which language is being spoken.

20. Nelson Goodman's *Languages of Art* (1976) is the standard point of reference regarding questions of identity in relation to works of art. The question of the identity of the work of music in an era of composed timbre is especially acute and has been addressed by numerous theorists, including H. Stith Bennett and Jean-Charles François.

21. Quoted in Adorno 1999, 114.

22. "It is the listener who, once the meter has been recognized, creates the 'generative process that gives rise to a modest time-point hierarchy'" (London 1993). Quote in text from Zuckerkandl 1956, 168–69, as quoted in London.

23. Neurologists have discovered that we hear meter in two phases, first the complex process of aligning our hearing with meter (entraining) and then the relatively simple process of maintaining that alignment (continuation). See, for example, London 1993, §8ff.

24. Recall the Fourier theorem, which shows that any periodic waveform can be represented as the sum of some number of sinusoidal waves. In other words, every sound is made of sine waves of different pitch and intensity.

25. See Deleuze 1994, 19.

26. See Deleuze and Guattari, "The Geology of Morals," in *A Thousand Plateaus* (1987 [1980]).

27. Models of evolution that treat perception as passive and the evolving creature as only reactive are thus seriously flawed. Creatures operate on their environments, which resuscitates a variant of Lamark's theory. Perception does not develop to correspond with preexisting structures of the milieu but itself structures the milieu to make distinctions within it. An animal adapts effectively by making a difference in its body correspond with a difference in its milieu, where neither had existed before.

28. Regarding Schenkerian analysis, consider Figure 6. The idea is to reveal the fundamental structure, always strictly in accord with the rules of counterpoint. Melody, matched to harmony, descends from the third scale tone to the root, 3-2-1. (Sometimes, but not in this figure, it descends from the fifth scale tone.) Harmony, aligned with melody, goes from tonic (I, the root), to dominant (V, the tension), back to tonic (I, the end!). Ultimately, one reduces an entire piece to a structure similar to the reduction of these few bars, a whole piece as a two-part harmonic motion: I-V-I. "Schenker's main innovation was the suggestion that music is made up of more than one layer. Schenkerian analysis attempts to show how the music that you hear is a decoration of a simpler layer just below the surface. As is explained in *The Fundamental Structure*, Schenker proposed that an analysis can uncover successive layers deeper and deeper below the surface until a very simple layer that underpins the whole piece is found" (Pankhurst 2001).

Rhythm, accent, ornament, dynamics, etc., are wholly elided. Of course, the point is not the ultimate product but the process by which one gets there, and Schenkerian analysis must grapple with much complexity in the course of revealing the underlying simplicity of a piece. On the other hand, the method of Schenkerian analysis presupposes a number of principles of music composition peculiar to the European art music tradition; the farther from this tradition one strays, the less applicable becomes this method of analysis. It is a significant limitation of Schenkerian analysis that it is so rigid as to accommodate primarily a single musical tradition. This limitation becomes an ethical failing when Schenkerian analysis is presented as a general method of musical analysis without making explicit its substantive, ethnocentric assumptions.

29. As Freud remarks in his preliminary consideration of the psychological characteristics of perception, "consciousness and memory are mutually exclusive" (Freud, in a letter to Fliess, 1985, 208).

30. "Popular music is not really about 'being heard,' but rather about 'being heard again'; and 'being heard again and again and again' is what really popular music is really about" (Buchanan 1997). Quotes are from Adorno 1999, 152; also Cavell 1971, 18.

31. Quote from Sloboda 1994, 175.

32. Quote from Boulez 1986, 93. See also Wim Mertens 1983, 16f.

33. This general form applies far more broadly than just within pieces composed in sonata form and can be found in rock music, jazz, indigenous music, and elsewhere. Deleuze and Guattari (1987 [1980]) complicate the role of musical character in "Of the Refrain" from *A Thousand Plateaus*, where they examine the relationship between musical character and music narrative. Motifs represent characters in a narrative ("Peter and the Wolf"), but motifs also impose character on the music through a changing repetition that outlines the character of the work over the course of the entire piece.

34. Composer Wim Mertens (1983, 101) suggests that the lack of an overarching structure means that each moment of the piece takes on meaning as sound per se rather than in relation to its context.

35. Though my discussion here will draw primarily from twentieth-century European art music, timbre has been stretched throughout music making, from post-rock to cool jazz, New Guinea to Appalachia, to new technologies, new instruments, new musics.

36. Brief explanation: Every pitch corresponds to a particular frequency. Two different pitches are related by the ratio of their frequencies, and this ratio determines the interval between the two pitches. A ratio of 2:1 is an octave; 3:2 is a fifth; 5:4 is a third. Starting from a chosen frequency, one can tune an instrument by determining all pitches using just these intervals (octave, third, and fifth) corresponding to just these frequency ratios. The problem with this tuning system is that the instrument will be perfectly in tune for only one key (such as "the key of E"), while in some other keys the instrument will be dramatically out of tune. This works well enough for music that rarely changes keys, but leading up to the baroque period, music became increasingly chromatic, using many different keys and more dissonant harmonies. From the classical period onward, instruments have been tuned in a tempered system, where no key signature is purely in tune, but neither is any one scale very far out of tune. Most instruments are tuned in an equal temperament, where the octave is divided into twelve equal steps each with a ratio of $\sqrt[12]{2}:1$ so that every interval is an irrational ratio, hence slightly "out of tune" (except the octave, which comes out to 2:1, since $(\sqrt[12]{2})^{12} = 2$). This disagreement with perfect tuning is what so troubles Young, who hears in *pure* tunings a perfection that instantiates without compromise an ideal in the real. "To me, the harmonic series represents the truth, to put it simply, and what I have tried to demonstrate in the Dream House and in some of my other works is that you can play the actual truth itself, and that it sounds much better" (Young quoted in Palmer 1981, 55).

37. Quote from Mertens 1983, 26. Rational tunings sound distinctly different from tempered tunings. Whereas a chord or timbre built from irrational numbers will never "beat" in a constant, unwavering meter, a chord made of rationally tuned intervals will pulse at exact and specific frequencies, creating sum and difference tones that will also be exactly the same each time and for all time.

38. See Boulez 1986, 178.

39. Quote from Mertens 1983, 29. The culmination of the Dream House project is the permanent installation that currently lives in the apartment underneath La Monte Young's own, on Church Street in Manhattan. Here, Young has set up equipment that plays a single continuous and complex chord, based on whole-number ratios, which is never turned off. Time is effectively denied access to this room, where even the lights, designed by Young's wife, Marian Zazeela, do not change. The turtle pokes his head out of his shell.

40. Quoted in Palmer 1981, 56.

41. It should be noted that many critics and some of Young's early collaborators accuse him of petty selfishness and egotism because he hoards his early recordings, refusing to allow them to be released. Ongoing legal battles have yet to wrest those tapes from La Monte Young, who claims to be the "sole" composer of the music recorded therein, despite the explicitly cooperative nature of the project. Young's desire for an unequivocal control over those recordings and his claim of sole authorship stand in stark contrast with his rhetoric to the effect that there is no such thing as a single performance of these pieces, only an occasional instantiation of an eternal sound. I am not aware of Young's response to these compelling accusations of hypocrisy.

42. Quoted in Palmer 1981, 56. See also Mertens 1983, 32.

43. According to Reinier Plomp (1993), we prefer certain intervals (chords) because the harmonics of their notes tend to overlap exactly. For example, all the harmonics of a note are already present in another note an octave lower. And half of the harmonics of a given note are shared by the note down a fifth. Such intervals thus sound relatively pleasant and smooth to the ear and, along with the third, form the basis for the Western musical canon, as well as many other musical traditions. Other intervals, with fewer overlapping harmonics, are more rare in music and tend to sound rough and dissonant.

44. I am glossing an important point here about just intonation (nontempered tuning), which is that there are many different tunings using whole-number frequency ratios. One can tune an entire instrument by starting at a specified frequency, say A = 440 Hz, and jumping around from that key in octaves (2:1 frequency ratio) and fifths (3:2). (Using only jumps of octaves and fifths, all the standard pitches of the chromatic scale can be reached, so that every note can be tuned using only these two intervals.) The resulting "three-limit" tuning—so called because the third pitch in the series of overtones generates the interval of a fifth; it is a fifth above the second overtone or octave—sounds wonderfully harmonious in the key of A but very out of tune in some other keys, especially harmonically distant keys, like E♭. A "five-limit" tuning also allows jumps in thirds (5:4 ratio, representing the fifth overtone) and represents a better compromise, as it is closer to being in tune in more different keys than three-limit. La Monte Young doesn't care for the number five but explores in his drone music the sounds of ratios entirely absent from the Western musical vocabulary. He and his musicians practice playing and singing simultaneous sustained notes with demandingly precise frequency ratios such as 189:98 and 288:147, each of which is tantalizingly close to an octave (2:1 ratio), but not exactly. To find and sustain tones in these ratios requires extraordinary technical and aural ability from the performers, though Young claims that, with practice, at some point one comes to feel in one's body when one has found the exact pitch.

45. John Molino, quoted in L. Young 1987, 7. In addition to the acoustic and psychoacoustic basis for rational tunings, there is also a physical basis. Instruments produce sound by making some medium vibrate. The medium might be air (woodwinds, brass, organs), strings (piano, stringed instruments), metal, wood, or skin (mallet instruments, drums, other percussion), flesh (voice), and specialized media (water, hybrids). (Of course, instruments almost always vibrate mixed media, and this vibration extends through the body of the instrument and player, into the room and spectators.) Most instruments impose physical thresholds on the vibration, by fixing the ends of the string, enclosing air in a tube of a certain length and shape, vibrating a cymbal radially up to its edge and back. These constraints define the parts of the material that can vibrate, and usually guarantee that they will be integer divisions of a fundamental quantity. Because the speed of vibration in a medium is indirectly proportional to the length of the vibrating object, so is the frequency of the tone produced (since the frequency just *is* the speed of vibration). Harmonics are thus rational. (Or at least, they are approximately rational. Theories of acoustics, like all scientific theories, are reductive approximations that presuppose certain ideal conditions and materials. Actual materials behave slightly differently from the ideal for a variety of reasons. In practice, the harmonics of a piano string are not strict multiples of its fundamental, and pianos are therefore tuned using a compensatory "stretch" tuning, wherein high notes are tuned slightly sharp of the ideal so that they sound more harmonious when played simultaneously with low notes.)

46. In *What Is Philosophy?*, Deleuze and Guattari note the import in painting of *l'aplat*, that flat or blank area that serves as a background but also as the invitation of cosmic forces into an artwork. Young's music, and minimal composition generally, thrusts this background to the fore. It is one of the powers of drone music to reveal most immediately these cosmic forces.

47. Quote from Cage 1961, 10.

48. Quote from Stockhausen 1989, 88.

49. For a philosophical treatment of this theme of repetition without original, see the introductory pages of Deleuze's *Difference and Repetition* (1994). Also see all the other pages of Deleuze's *Difference and Repetition*.

50. Young cites neurological evidence for the effects of repetition on the mind. "[W]hen a specific set of harmonically related frequencies is continuous or repeated, as is often the case in my music, it could more definitively produce (or simulate) a psychological state since the set of harmonically related frequencies will continuously trigger a specific set of the auditory neurons which, in turn, will continuously perform the same operation of transmitting a periodic pattern of impulses to the corresponding set of fixed locations in the cerebral cortex" (L. Young 1987, 6). Young's appeal (as well as that of Plomp, see note 43 in this chapter) to a naturalized corporeal aesthetics, where the body is innately prepared by virtue of its universal structure to enjoy certain kinds of sounds, must be tempered by the recognition of overwhelming cultural, historical, economic, and circumstantial factors. There is plenty of evidence to show that, for instance, the octave is a nearly universal interval in the music of every culture. But that octave is divided in various ways, which diversity cannot be explained in terms of neurological or physiological characteristics.

51. Adorno points out that serialism excludes repetition from the series in order to bring it back with greater force as the principle of the piece. When constructing a series of elements (pitches or timbres or durations, etc.) no value may be repeated until all of the values have been used. In Schoenberg's serialism, for example, the series consists of some ordering of each of the twelve chromatic tones in the traditional Western scale. In Schoenberg's system, to compose a piece from such a series, the composer must use these twelve tones in order, and no tone can be repeated until all the others have been used. "In serial music this dialectic is taken to extremes. Absolutely nothing may be repeated and, as the derivative of the One thing, absolutely everything is repetition" (Adorno 1998, 284 n. 7).

52. Quote from Reich 1974, 9.

53. Young, quoted in Palmer 1981, 52.

54. See Reich 1974, 10.

55. Ibid., 25. In the late sixties, Reich began experimenting with electronic devices to generate sound at exactly regular intervals, which helped him to realize certain algorithmic compositions derived from precise mathematical divisions of time. One of the ways Reich manifests the compositional process in the sounding music is by making the process extremely gradual, which requires very fine distinctions, as notes move by milliseconds within beats. Most musicians are incapable of dividing a single beat into, say, 120 parts, whereas machines can do this easily. However, after composing and performing a few pieces for his custom-built pulse machine, Reich put it on the shelf to collect dust, precisely because it was too mechanical and left no room for the piece to come to life.

56. Quotes from Reich 1974, 50, 11. For example, the tradition of European art music places a huge emphasis on the existence and authority of the score, which supports the notion of an ideal version of the composition. Students of Western music spend a great deal of time learning to analyze scores and perhaps too little time actually listening to the singular event of performance. Music theorists universally acknowledge the priority of actual sound in their analyses but tend all too frequently to rely on the score as the ultimate test of a theory.

57. Alvin Lucier plays with the interface of sound and space in most of his compositions. In one piece, blindfolded dancers move about a room guided by a sonic geography; they follow the peaks and valleys of sound created by multiple sound sources, whose waves interact to create complex moving shapes in the room. In another piece, Lucier spreads sounds out in traveling hyperbolas, which tingle the listener's body as they move through her space. Early in his career, Lucier forged more intimate connections between body and sound as he used the amplified pulsations of his galvanic skin response to vibrate loudspeakers sitting atop drums, which would then beat under the influence of his thoughts and feelings. The audience could "hear" Lucier think of the color blue, or the sensation of fear, or his mother.

58. See Attali's (1985) "Chapter Four: Repeating."

59. Quotes from Adorno 1998, 183, 184, 188, 189.

60. Quote from Adorno 1999, 148, my emphasis.

61. Quote from Adorno 1999, 12. Murray Dineen locates a fundamental opposition between Adorno and Schoenberg in this regard. Adorno believes that truth in music is always a matter of its relation to the culture it reflects so that music must change constantly to keep up with its society whereas Schoenberg holds that musical truth is eternal and only the surface of style changes over time.

62. Quotes from Attali 1985, 11, 29.

63. Quote from Adorno 1999, 148.

64. See Schoenberg 1984, 116.

3. Sounds and Digits

1. Heidegger makes truth more a matter of ontology than of epistemology. As the revealing of the world, truth is an event, something that happens. And we do not participate in truth by aligning our belief with reality but by witnessing its unconcealment; the world, alight, before us.

2. Heidegger uses the German, *Gestell*, to refer to this way of human being that sets off or sets upon the world. In keeping with some of its native usages, this term is usually translated by the neologism *Enframing*, which captures the sense of *setting off*, as well as suggesting the way in which this concept is not incidental to human being but is a fundamental part of the way humans comport themselves in the world. That is, setting upon the world is part of the frame within which humans behave. I have avoided this somewhat awkward and oft-debated standard translation, but readers should note my unorthodox choice and recognize that the resulting interpretation of Heidegger's critique of technology is skewed to further the ends of this chapter.

3. See Heidegger 1977, 23.

4. The digital is now the mass cultural paradigm of technology, so that older, "pre-digital" technologies, from tweezers to plastic, are rarely called *technology*.

5. The code according to which today's computers operate is called *binary*, because the smallest logical unit, a bit, can have one of two values, generally referred to as 0 and 1. Though binary logic is almost universal in digital technologies, there is no reason in principle that a computer could not take as its basic unit an element that could have one of three possible values (ternary logic), or four (quaternary), or any arbitrary number. The current prevalence of the binary is a historically contingent result of the technologies available during the development of the computer, technologies that behave as binary gates, allowing or preventing the passage of electricity. Ternary or other nonbinary systems would require different sorts of hardware to implement. It is notable, though, that while nonbinary systems might offer advantages in terms of rate of calculations or density of storage, they are logically equivalent to binary systems and offer no advantage in principle. A binary system can perform the same computations as a ternary system.

6. Technically, many parts of the computer distinguish not between the presence or lack of electricity but between one voltage level and another. Or, as will become apparent below, between a voltage level that falls between two thresholds and another level between two other thresholds. What is digital about this situation is that however it is materially instantiated, it can still be thought of as on or off, 0 or 1. The means of representing these two values are left to the engineers, who determine which physical method to use according to the engineering requirements of the application.

7. Each of the terms represented by the acronym ASCII (American Standard Code for Information Interchange) is characteristic of the digital in general. Below, I explain how the digital is a standard and a code, is inherently information, and facilitates its interchange. That all of these digital characteristics are especially pertinent to America is an intriguing proposition left to a more sociological analysis.

8. Walter Benjamin famously argues a similar point about the experience of watching a film. In a film, he says, the perspective has already been chosen by the director, so that each member of the audience sees the same object, and we consequently identify with the camera more than the actors. Following this logic, the subject of a (hypothetical) purely digital experience would identify with a digital perspective and a binary logic. On the Internet, we ourselves become digital and, as such, generic and repeatable.

9. In their chapter, "The Geology of Morals" from *A Thousand Plateaus* (1987 [1980]), Deleuze and Guattari explain double articulation, beginning with the image of a lobster, articulated twice and each time asymmetrically. The lobster has one large and one small claw, and each claw has one large pincer and one small. The present essay owes a great deal to Deleuze and Guattari's chapter.

10. Otl Aicher, in his book on design, stresses that the ascent of handedness left one side of the brain underutilized, which excess fueled the development of language and analytic thought in early humans (1994, 23). Handedness, and its implicit asymmetry, are essential, if not inviolable, human traits.

11. Though it must be understood that 0 and 1 are not the numbers (zero and one) that we usually associate with those symbols but are defined by their role as binary digits, unlike (digital) 0 and 1, the difference between the numbers zero and one is by no means simple.

12. Further examples abound. The difference between pixel-based Photoshop and vector-based Illustrator (image-editing programs from Adobe) boils down to the question of how they divide their objects into parts. Photoshop represents objects as a bunch of points (pixels) distributed on flat layers while Illustrator represents objects as a bunch of line segments with start- and endpoints (vectors). In either case, the object is divided into parts (points or lines) and each part is assigned specific values.

13. An IP address is an Internet protocol address, a four-part number that, something like a street address, identifies each node on the Internet, including each attached computer. Clicking a link on a Web page sends a message to a Domain Name Server (DNS) with the Universal Resource Locator (URL) of that link; the DNS uses a look-up table to find the IP address of that URL, which it passes along to the server, which in turn sends a message to that IP address requesting data. The four parts of the IP address specify the location pointed to by the link, in a hierarchy that hones in on the intended node. The message sent also includes a return IP address, so the responding server knows where to send the data back to.

14. Double articulation applies not only to the binary but to other means of representing number. Numbers are generally written using digits, each of which occupies a place and represents a value. Even the most brute representations of number—such as the concatenation of symbols that Kurt Gödel employs in his incompleteness theorem—rely on at least two distinctions, one of place and one of value.

15. Does the finger begin at the knuckle, or the wrist, or the neural nexus? Fingers are attached to their neighbors not only by a web of flesh but by a neurophysiology that links them together and permits no immaculate cleavage.

16. There are a number of different ways of specifying the color of a point in a digital image. In this example, a color is specified by mixing together, as might a painter on her palette, different respective amounts of red, green, and blue. The percentage numbers do not indicate what part of the final mix each color occupies but rather how much of each color is mixed in relative to a fully saturated amount of that color. One can use between zero and 100 percent of each of the three colors, with each number chosen independently. Zero percent of all three is no color, or black; 100 percent of all three is full saturation of all colors, or white.

17. The digital generally operates in more than one dimension, and it can have a different resolution in each dimension. Digital sound has a time resolution determined by the sampling rate, as well as an amplitude resolution, determined by the number of bits used to measure each sample. (These resolutions are not strictly achieved in digital sound representation because practical matters, such as jitter and sample-and-hold drift, get in the way.) Likewise, digital photography divides an image into pixels of a certain size and assigns each pixel a color and intensity. Visual detail finer than this size and more subtle than these color and intensity distinctions is simply left out of the digital representation.

18. In *Difference and Repetition* (1994), Deleuze analyzes this force as the *virtual* and examines its relation to the actual. The colloquial usage of *virtual* to refer to anything that happens on a computer could hardly be more opposed to Deleuze's concept.

19. Whereas in a quantum computer, qubits (the quantum counterpart to bits in a standard computer) are not distinct and have no measurable or definite value, at least not until they are actually measured. This calls into question whether a prepared state of entangled qubits can be said to represent anything at all, whether representation can happen with an indeterminate form. By dint of their indeterminacy, quantum computers may have a power not just faster but entirely beyond that of traditional computers. Ordinarily, to use a quantum computer effectively requires, at some point, collapsing the indeterminacy into a determinate state, which would then represent pure form just as does a standard computer. But there may be a use of quantum computing that leaves the qubits unmeasured, that allows them to continue to represent only ambiguously, and hence exceed the usual formal limits of computation. (Note that quantum computing is a technology in the early stages of development. Qubits have been temporarily created in laboratory conditions, but so far this research only proves the potential of the concept and commercial applications are a long way off. Most quantum computing to date is on paper or else simulated on traditional computers.)

20. Even more common: select from your database just those people whose surfing habits suggest that they are middle-income suburban foreign car owners, and send them all an e-mail, custom tailored to their interests. This is easy for computers not just because they can store and manipulate a lot of data at once, but also because every datum is separate, every value exact, every judgment final. Give a computer a digital criterion, and it can apply it in every case, without fail, and without ambiguity.

21. This raises again the specter of the digital's danger: a process guided by a formal standard is not subject to the intervention of human goals, since the goals have already been determined in the form. To follow a standardized procedure or to manufacture a part according to specifications with small tolerances means that the producers themselves have little to do with creation of the product, which is instead a result of the process. Innovation becomes less likely, as processes are broken down into steps, so that few people have an overview, and individual steps are performed not with a human goal in mind but only with a specification. Originality, variation, aura all fade in favor of replication, tolerance, and suitability. Processes are judged according to their degree of conformity to the standard rather than the use to which their results are put.

22. Isn't this the dream of the virtual, to dispense at last with actuality and live in a world that is both preservable, transportable, robust, etc., as well as rich and full, inexhaustible and (comfortably) surprising? Imagine, an "undo" function for real life.

23. Lev Manovich analyzes this inherent mutability briefly on page 304 of his book, *The Language of New Media* (2001), in the chapter on cinema and the digital.

24. This translatability is not merely theoretical but is put to extensive use. There are systems to monitor data as sound, which allow human operators to hear differences that might escape visual or statistical detection. The Macintosh program, Metasynth from U&I Software, allows users to create new sounds by manipulating and "listening to" images.

25. Consider the controversy surrounding network television coverage of the millennial celebration in Times Square: some networks digitally excised an image on a billboard behind the televised journalists and replaced it with a digitally superimposed network logo. This operation was performed in real time and was undetectable to the viewing audience. Such selective editing occurs with increasing frequency as digital tools proliferate: radio and television stations compress their programming to make it shorter and allow room for more advertisements; photographers, video artists, and filmmakers touch up their images, collapsing, as Manovich points out, the difference between photograph and painting; entire scenes are digitally created or re-created, with photographic realism, often in real time, and in general without any acknowledgment of the unreality of the portrayed situation. The virtual melds smoothly into the actual, unremarked.

26. *Indicate* is, like *digital*, an etymological descendant of *deik-*. So even are *dictate*, *teach*, *index*, and *judge*, to say nothing of the entire *dictionary*. All of these words have in common a showing or saying, a presenting.

27. Hegel often refers to the *hic et nunc*, the here and now, as substitutes for the *this*. Note the etymological connection between *hic*, here, and the root of *haecceity*, here-ness.

28. A digit exists at once in the abstract and the concrete. The question of whether an animal has digits is measured by its extension into the abstract. A body part only becomes a digit when it can be used to point, to refer to something outside of the animal, and therefore to distinguish between the immediacy of sensation and the abstraction of inside and outside. A dog's snout is closer to a digit than is its paw, for a dog points with its snout but never its limbs or claws. (In fact, a pointing dog points with its entire body since the double articulation necessary for pointing does not inhere in the snout by itself but only in relation to the horizontal axis along its back and the difference between snout and tail.)

29. *Token* is yet another word rooted in the Indo-European *deik-*.

30. It is true that every actual instance of the digital requires an actual difference, a difference that has an inside. The difference between adjacent pixels on a monitor or magnetic bits on a hard disc is substantive, it has an "inside," which is why discs are sometimes unreadable and monitors blurry. But, to the extent that these are understood as digital data, there is only a formal difference between the two values, a difference that is nothing but the distinction of opposition. The digital is pure form and so replaces internal difference with just another external difference, it folds form back on itself.

31. The airplanes that shattered the twin towers thus struck a blow against not only the corporate capitalism that the towers represented as symbols of commerce but also against that other element of globalization, information technology, so closely tied to the binary digital. See Baudrillard 1983, 135f.

32. Confined to their own plane, digital representations can never differ except formally. Even when two digital things are different, even when a copy is imperfect, or when two digital things are wholly unrelated, their difference is still something digital. This means that comparison is always decisive, two digital things are always either exactly the same or not the same, and if they differ, we can say exactly how much and in which parts. But this also points once again to the great limitation of the digital. Digital difference is never really all that different; it's just more of the same, more of the digital. The digital is confined to a plane, restricted to 0s and 1s, and it can never, without external aid, leap off of that plane and into the ever-more-subtle world of the actual.

33. In digital representation, the specification of an original, as opposed to a copy, must be contrived by adding something extra to the digital data. Digital watermarking is a technique by which an encoded message or signature is interspersed among the data of a digital image or sound so as to be deeply embedded but also undetectable except by means of technologies specifically designed to read the encoded signature. The SCMS copy bit is a code that is added to digital representations of sound that instructs SCMS-equipped technology to refuse to copy the digital data representing the sound. Public-private key systems are cumbersome means of (mostly) guaranteeing authorship of a document or restricting access to it.

34. Proponents of the Internet and other digital technologies need hardly argue their case; the Internet has long ago escaped the confines of the academic and military enclaves that birthed it and, with the exception of those marginal social groups mentioned above, has a universal support from mainstream and corporate culture. Nevertheless, Internet boostering is not uncommon, either in its defense or as zealous celebration.

35. Evidence of this utopian attitude toward digital technology is not hard to come by, as such praise is ubiquitous in popular culture. Gordon Graham offers a critical perspective, but details some of these utopian promises in his book, *The Internet* (1999).

36. Whatever liberation the Internet offers, it has thus far succeeded in spreading and enforcing a universal mass culture. Internet access has become the touchstone by which technologies are measured and standardized. The result is a homogenization of computer technologies: the Windows operating system, the Microsoft browser (Internet Explorer), standard refresh rates and resolutions of monitors, standard ports for peripherals (USB, IEEE 1394, DB9 serial ports, SCSI), standard keyboard layout, etc. Based on these technological standards are further standards of design and aesthetics: layouts of buttons, pull-down menus, frames, etc. With universal technologies and a standard "look-and-feel," computer use also tends to converge onto a common terrain, despite the diversity that rhetorically, at least, defines the spirit of the Internet. (Microsoft: "Where do *you* want to go today?" Apple: "Think Different.") Not only do we all use the same browser and word processor, but we shop in the same places (Amazon.com, Outpost.com, eBay.com) and gather information in the same places (CNN.com, ESPN.com, Yahoo.com). Guided by uniform tools, users settle into a uniform, unsurprising experience.

37. When it enters the actual, the digital cedes the perfection of abstraction and opens itself to the possibility of error. A purely digital bit is always exactly 0 or 1 as long as it confines itself to the abstract, but when it is stored on a hard disc or sent over a wire, the 0 or 1 may be corrupted by the vicissitudes of actuality. Made actual, a bit can lose its rigid boundary, cross the threshold that defines it as 0 or 1 to become illegible or mistaken or ambiguous. Which is why computers and digital technologies generally are fallible. Hard drives generate errors due to magnetic interference or electrical spikes; monitors blur pixels when their CRTs no longer aim properly; mouse devices send erroneous data when their optical sensors become dirty or cracked. Such failures can befall only what is concrete, what is more than just a pure abstract form.

38. Heidegger has been criticized for allowing the technology to disappear in its use, for reducing modern technology to mere means. For this not only eliminates all of the remainder, the misuse of technology and the inherent resistance of the real to the ideal toward which it is pointed, but it also leaves little room for consideration of the unforeseen consequences or by-products of technology's use.

39. Intervals narrower than a third tend to sound dissonant, especially when more than two notes are clustered closely. Wider intervals can be very consonant but lose some harmonic integrity as the ear resolves the individual notes. Moreover, the harmonics of widely spaced notes do not align except at very high frequencies, at which the ear is not as sensitive. The theory of psychoacoustics indicates that it is the agreement of lower harmonics that makes a given chord sound pleasant to the ear.

40. Note that the rationality of these equal steps lies in their scientifically determined subdivision of the octave. The steps themselves represent irrational intervals, as discussed in chapter 2.

41. This discussion has focused on the spatial articulations of the instrument in relation to the palette of sounds available. One could also consider the temporal possibilities, simultaneous notes, repetitions, control over attack and decay. There is, moreover, the question of the body's articulations with respect to the instrument, and there has been considerable study of the question of gesture in relation to musical instruments. See Cadoz and Wanderley 2000, for example.

42. The separation of sound from gesture is so severe as to allow the rich possibility of creating some instruments that make no sound (but only send signals) and other instruments that can generate sound but provide no mechanism for triggering it.

43. See Attali 1985, 114. This quotation continues, "A simulacrum of self-management, this form of interpretation is a foreshadowing of a new manipulation by power: since the work lacks meaning, the interpreter has no autonomy whatsoever in his actions; there is no operation of his that does not originate in the composer's manipulation of chance."

44. See Iazzetta 2000, 81.

45. Many synths feature firmware or nonvolatile RAM, which is a digital memory bank that can be altered but that holds its value over time even when the instrument is turned off. Firmware can be used to store updates to the operating system of a synthesizer, adding new powers and new sounds. Expansion is a goldmine for the music industry, which can convert one-time profits on an instrument purchase into a revenue stream by selling additional hardware and software to a captive audience of instrument owners, most of whom are desperate to stay on the cutting edge by keeping their instruments current.

46. Perhaps this closed interior and open exterior characterizes the digital age generally: extension and connection rather than intensity and isolation? The power of the Internet is "to connect."

47. In a lecture at the Humanities Center at Harvard University in November 2000, Arthur Kroker coined the phrase "digital detritus" to refer to the leftover data strewn throughout cyberspace, Web sites forgotten and left for dead. I have since seen this term used without attribution in a number of places, some predating Kroker's lecture.

48. For an overview of this genre of music, see "The Aesthetics of Failure," by electronic musician and theorist Kim Cascone, who affirms this influx of noise in music, and examines the implications of music in "the area beyond the boundary of 'normal' functions and uses of software" (2000, 14).

49. The final chapter of this book examines and critiques this ideal of transparency and universality.

50. The envelope is the dynamic shape of the sound, how quickly it rises to its loudest point, how long it stays at this level, how quickly it dies out.

51. Listen to early rap or techno; the sounds themselves, as well as the production techniques, sound dated, "ol' skool." The hallmark of an era of commercial sound synthesis is the association of a sound or group of sounds with a given style and period of music. For example, the Roland TB-303 associated with acid house music, or the Yamaha DX-7 as the sound of mid-eighties synth pop. These fixed associations arise because the sounds themselves are stamped by the character of their synthesis methods and the synthesis architectures used to implement them. The finite character of electronic instruments leads to much value being placed on finding new and different sounds, which demonstrates the music producer's currency as much as any compositional genius could. There is a constant search to escape from the generic or reproducible character of the standard sound set, to produce the "new" sound. (The history of Western music might perhaps be described as the search for new sonorities, but there is a richness in the sound of a violin or kettledrum that is felt to be lacking in the playback of a sample. It has never been the sound of the violin that is tired, only the uses to which it is put.)

52. For instance, another popular means of enhancing a sample-playback synthesis engine is to allow the user to control a filter the characteristics of which are independent of the sample. So, a musician could set up a sampler to "open" the filter more for notes with high amplitudes such that louder notes would also have more harmonic content. This technique gives the sense of a more complex instrument since there is a greater variation among different notes. It also offers highly musical possibilities, as acoustic instruments tend to operate just this way: notes sounded with greater force are not only louder but also include more harmonic content. Independent filter control on a sampler could also be used to achieve the opposite effect, which would sound less familiar to the ear, but still complex and interesting.

53. These technical complications of sampling pale in comparison to the tangle of legal, economic, and social issues associated with sampling. Those issues demand further discussion, which will not be found here, but the reader is encouraged to consult the many informative books and articles in this area.

54. The filters used in subtractive synthesis are generally implemented in the digital domain by first applying a Fourier transform to the signal in order to represent it as a bunch of frequencies, then reducing or augmenting certain of those frequencies according to the requirements of the filters, then finally performing an inverse Fourier transform to re-create the (now-filtered) signal as a representation of amplitude over time.

55. See Mowitt 1987, 192.

56. Although Fourier analysis is a generalized mathematical technique, it is treated here specifically in terms of acoustic signal analysis, which is to say, in terms of frequency, amplitude, energy, and other physical-acoustic phenomena rather than the more general mathematical language of functions in a dot-product space.

57. A Fourier transform thus produces a frequency response curve, used often to describe the performance of stereo and other audio equipment. To measure the frequency response of a stereo component, one plays white noise (which consists of all frequencies at equal strength) through its inputs, then calculates a Fourier transform of the resulting output. This reveals which frequencies are exaggerated and which attenuated by the component.

58. This discussion obscures a number of important technical aspects of the DFT. First, there is the question of how to choose which sine waves to use in the comparison. This issue is relatively easy to resolve by choosing a low-frequency sine wave, at least as low in frequency as the lowest frequency in the original wave, and then using harmonics of that sine wave, up to the highest frequencies that need to be represented in the Fourier transform. In practice, this is never an issue in the DFT since the frequencies of the sine waves used for comparison are determined by the number of sample points given for analysis. (The number of samples is often "padded" with additional 0s in order to make a number of samples that is a power of two, 2^n. This padding is for convenience, as it makes application of the FFT, described in the next paragraph, much more efficient.)

It should be noted that in practice, the DFT requires a vast number of calculations in the complex domain, especially for a large number of samples, and so is impractical to calculate directly in real time. As such, synthesizers and computer programs tend to employ a streamlined version of the DFT, called the Fast Fourier Transform (FFT), which significantly reduces the amount of calculation but yields only an (adequately close) approximation of the true DFT.

59. The term *broadband* refers to the way in which the energy is spread out over a large section of the frequency domain rather than being focused in a narrow breadth centered on a particular frequency.

60. Given its similarity to Fourier analysis, but also the differences noted here, wavelet analysis can be usefully understood as a kind of fractal Fourier analysis. Its fractal properties accrue because of its method of analyzing the original signal at different scales; what a wavelet analysis reveals is the degree of self-similarity of the wave at each measured scale and in each of its parts. Different wavelet shapes are used depending on the aim of the analysis and the kind of data being analyzed. The most common wavelet shape is the Morlet wavelet, which is a windowed sine wave, a sine wave multiplied by a bell curve. Another intriguing possibility is to use a wavelet that is itself fractal, which results in a measure not only of the self-similarity of the signal but of the self-similarity of the self-similarity. By choosing the appropriate fractal wavelet, the original may be very accurately represented by a relatively small amount of data, making for extremely efficient data compression, and this is another promising area of employ for wavelet analysis.

61. Using an original sampled sound as the basis for the grains is called *granulating* the original sound. Steve Reich wrote a piece in the 1960s, "Slow Motion Sound" in which the instructions were to stretch out a sound to hundreds of times its original length without changing its timbre. Prior to the innovation of granular synthesis, such a composition was not realizable or at best extremely impractical. In any case, Reich never realized the piece himself.

62. "Depending on the time scale the control operates on, [granular synthesis] will allow for musical structuring of sound on the level of the temporal or rhythmical (Xenakis, I.) or on the level of spectral, timbral, or harmonic organisation (Risset, J.-C.) The fact that the same structures used on different time scales do affect different domains of musical perception has always been a rich source of compositional imagination (Stockhausen, K.) In the field of sound synthesis, it is certainly granular synthesis which is best suited to compositionally exploit this fundamental principle of perception" (Eckel 2001).

63. Cellular automata are part of a family of techniques that involve self-determining autonomous cells interacting. The usual definition of cellular automata requires that the rules for progressing from state to state are deterministic and are the same for each cell. That is, any cell in state *c* must produce the same output for a given input. Other techniques, related to cellular automata, relax one or both of these requirements, allowing variable or reprogrammable cells into the network or using chance to influence the output of a cell. These techniques are also very powerful and musically useful, though they must be carefully implemented so as to maintain the desired balance of control and chaos.

64. To be more precise, when the signal under scrutiny is two-dimensional, its wavelet analysis representation is three-dimensional. In graphic representations of a wavelet analysis, the third dimension—which represents how much the signal at a specific time resembles a wavelet of a specific frequency—is often indicated by the color of the point at the intersection of that frequency (*y*-axis) and that time (*x*-axis). For example, dark points might indicate a lot of energy at that frequency at that point in time. A Fourier analysis, on the other hand, produces a two-dimensional representation of a two-dimensional signal. (Technically, this is only a subcategory of Fourier analysis, which can operate in a vector-space of arbitrarily many dimensions. In practice, Fourier transforms are usually performed in four dimensions since the "extra" two dimensions represent a phase factor that is important in signal analysis. Still, the analysis does not add any dimensions but always maps *n* dimensions into *n*.)

65. See Deleuze 1998, 70.

66. Quote from Barthes 1985, 291. One suspects here that Barthes has been reading Deleuze, whom he mentions a few pages (but three years) later as one of very few fellow "Schumannians." In any case, the Nietzschean heritage of this quotation is readily apparent.

67. See Barthes 1985, 282, 290.

68. Ibid., 283.

69. This critique of analysis as an index according to a standardized code of emotions is an echo and elaboration of Barthes's ideas (1985) about the grain. See especially page 373.

70. The recent availability of digital music production tools has spurred the *project studio*, a middle-class musician's collection of gear, generally based around a personal computer, that rivals the sonic potential of major studios. Though the general availability and ease of use of these tools creates an environment in which individual expression outweighs the repetition of convention, there are counterforces that encourage lockstep adherence to the musical standards and styles of the day. By virtue of its analytic nature, the digital promotes reliance on unoriginal sources. In the studio, the digital breaks down songs and sounds into their component pieces, supporting audio montage that borrows its sounds from elsewhere and constructs its form from preexisting templates. Store-bought rhythmic patterns, *grooves*, can be imposed on familiar chord progressions to create new songs that sound like the old ones. Libraries of sampled sounds allow amateur musicians to *drop in* the same snare drum used by the pros. It has never been easier to create popular music, and even those lacking musical intuition can employ cheap algorithmic composition tools to create a song marginally similar to the latest chart toppers. Software like Band-In-A-Box (PG Music) generates on-the-fly passable arrangements of a given chord progression, including solos in a style selectable by genre. Using Steinberg's software, Groove Agent, one chooses a style of drumming ("samba," "disco," "trip-hop") and then dials in the desired *complexity* of the drum pattern.

71. Compare Attali 1985, 106ff.

72. Consider in this regard the U.S. presidential election in 2000 (and 2004). The statistically unlikely split in the popular vote and the electoral college, not only nationally but within many states, was engineered. Of course, both sides have top-notch demographers, the best polling, and could and did focus their efforts in precisely those locations they predicted would have the most "swing" effect. Both sides overtly targeted the center until they were literally fighting over the votes of a few people. But this statistical manipulation of votes would not be possible were the population not already divvied into categories, groups, affiliations, calculable and predictable behaviors, choices from among a few options.

73. The loss of space in music is mitigated to some extent by its subtraction from the production side of the equation. Much music produced today is intended for headphone listening. Moreover, music producers acknowledge the electronic origins of their sounds by placing them within an unreal and abstract space, rather than trying to recreate the sound of a real acoustic space. Even prior to the hegemony of digital technology in music, Barthes summarizes the flattening effects of technology on the music of mass culture. He distinguishes, following Kristeva, pheno-song from geno-song (1985, 270). Pheno-song comprises the articulations, the hinges that define the form of a piece or a phrase. These articulations survive the technologies of recording and playback, even under conditions of poor fidelity. The digital is adept at capturing pheno-song, which was nothing but form to begin with. The geno-song, on the other hand, is intensive and nonlocatable, nothing but content, and so is lost under the manipulations of technology. Few even care to look for it since coded emotion is easier to deal with, more comfortable than the challenge of the unexpectable. Coded emotion is the association of a clear and distinct sign with a clear and distinct response, no confusion, no surprise. A code regulates the relationship between listener and music, so that little of the music need be heard in order to identify its genre (and thus also identify oneself as part of the group of people who listen to this genre).

74. See Mowitt 1987, 193.

75. The record companies are deeply concerned about online music trading, which they condemn in no uncertain terms as morally repugnant and blatantly illegal. But they condone the idea of reduced bitrate music in general. Their response to music *piracy* has not been an attempt to convince listeners that they are missing out on much of the music that they steal. Rather, record companies are expending considerable effort to get in on the action by opening reduced-data music stores to sell files online at prices comparable to full-data CDs (even though the reduced-data versions do not come with jewel cases and cover art).

76. See Mowitt 1987, 195.

77. "'I don't want to express anything with music,' asserts Toshimaru Nakamura. 'I don't like emotional music any more. Who cares how I think or how I feel? I just want to play an instrument which doesn't have any connection to inner emotion'" (England 2000). Stripped of expression, the music becomes an experiment in technology: what can this machine do? A mixing board is generally a "secondary" element for making music and a staple of the recording studio; it generates no sound of its own but is used to mix together the sounds from a number of different sources. Nakamura intensifies the question of technology by removing any external sources of sound, coaxing unorthodox sounds out of the mixing board itself using a feedback loop. The noise generated inside the machine, which is traditionally minimized in favor of the sound sources, is instead amplified to turn the machine into an instrument in its own right.

78. See Cascone 2000, 17.

79. See Deleuze and Guattari 1987, 343.

80. Barthes recalls (but where?) the comment by a cynical pianist, who laments that in the age of recording, not making mistakes has become the paramount criterion of musical excellence. Cascone emphasizes the necessary experimentalism of digital tools when they are misused: "Because the tools used in this style of music [glitch and microsound] embody advanced concepts of digital signal processing, their usage by glitch artists tends to be based on experimentation rather than empirical investigation" (Cascone 2000, 16).

81. See Iazzetta 2000, 71.

4. Making Music

1. *Virtuosity*, *Lawnmower Man*, *The Matrix*, *Existenz*, *A.I.*, *2001: A Space Odyssey*, *The Thirteenth Floor*. In some of these examples, the computer fabulates a reality in the ordinary phenomenal world, while in other examples, humans enter the "internal" world of the computer, only to become trapped in it or absorbed by it. In either case, the danger arises when the computer becomes powerful enough to confuse these two worlds, and the moral of the story always points to the risks of an unholy or unnatural mixture.

2. Of course, Orwell's most direct target was the totalitarian state, but his book is haunted by the nightmare of technology, without which the totalitarian state is itself unthinkable.

3. Apple Computer did not invent either the desktop metaphor or the mouse but introduced them in a personal computer.

4. Friedrich Kittler (1995) in his brilliant analysis, "There Is No Software," aims the computer at the converse phenomenon: instead of reality becoming computerized, the computer becomes a reality; instead of immersing ourselves in a virtual world of representations, we will have computers that genuinely present themselves. This is possible only when computers begin to operate, like "real" entities, through a connectivity of all their parts, every molecule a bit. But real entities are as much noise as signal, and the two cannot be sharply distinguished. Thus, this immediate computer would have to operate by virtue of its noise, not in spite of it, and would be subject to all the errors and accidents that everything else must endure.

5. See Bolter and Grusin 1999, 5–6.

6. New media theory misreads the absence of the desired presence because, as a theory of media, it regards the computer as a medium. In other words, it understands the representation from the outset as placed between two presences, the present (represented) thing, which is, via the mediation of the computer, placed before the present user. Such a view, consistent with other media (and, incidentally, with the logic of signification), overlooks the fundamental importance of the computer as a tool, so that the instrumentality of the computer is subsumed in new media studies under the notion of interactivity. This latter must be tacked on to the medial nature of the computer and hence remains poorly understood. Interactivity is regarded as a special property of new media, which are understood as media (not instruments) in the essence of their aesthetics and utility.

7. The ambiguity of the computer as a medium is not unique. Every medium folds into its content inextricably and thus calls its medial nature into question. The television presents a content that is uniquely televisual and cannot be separated from the context of its presentation (viz., on television). As such, it is no longer clear what television would mediate since it is impossible to designate a presence that is merely represented on the television screen. However, and despite Sam Weber's insightful linguistic analysis of the phrase, "to watch television" (Weber 1996, 118), the viewer does not so much view the television but, rather, the program on television. One does not use television by operating on it, whereas one uses the computer precisely by working on *it*, the computer itself, which cannot be separated even in principle from the data it contains.

8. See Bolter and Grusin 1999, 33.

9. See Shonberg 1986.

10. Compare with Dobson 2002.

11. Quotes from Augé 1999, 30, 28–29.

12. See "Transcendental Aesthetic," §81, in Kant 1929.

13. Many thanks to Timothy Murphy for pointing out the close relationship between my analyses of immersive music and Cardew's brilliant and evocative discussion of improvisation. Quote from Cardew, *Treatise Handbook*, 1971, xx.

14. See Deleuze 1994, 147.

15. See Nyman 1999, 25.

16. See Corbett 1995, 222.

17. See Bailey 1992, 63.

18. Jamie Muir, interviewed in Bailey 1992, 96.

19. See Mertens 1983, 54.

20. For an elegant theoretical treatment of the rhetoric of the mobile phone and its dramatic effects on modern culture, see *Heidegger, Habermas, and the Mobile Phone* by George Myerson. Scanner's work forcibly demonstrates some of the most compelling conclusions of this short book.

21. Quote by Spruance (2002).

22. See Corbett 1995, 227.

23. Ibid., 231; see also Uitti 2000, 67.

24. Quote by Williams (2002).

25. Studio time remains expensive, but small *project studios* are rapidly becoming less expensive and more capable, giving larger professional studios a run for their money. The principal advantage of a professional recording studio is the expertise of the engineer there.

26. See Cage 1961, 13.

27. Consider Timothy Murphy's excellent analysis of Pierre Boulez's strangled concept of freedom in "Composition, Improvisation, Constitution," where he compares Boulez's retention of the composer's status as *auteur* with Ornette Coleman's abdication of that same role.

28. An oft-quoted but uncorroborated quip, attributed to Frederic Rzewski: "In 1968 I ran into Steve Lacy on the street in Rome. I took out my pocket tape recorder and asked him to describe in fifteen seconds the difference between composition and improvisation. He answered: 'In fifteen seconds the difference between composition and improvisation is that in composition you have all the time you want to decide what to say in fifteen seconds, while in improvisation you have fifteen seconds.' His answer lasted exactly fifteen seconds."

29. This view of improvised versus composed music is not hyperbolic; plenty of music lovers disparage improvisation on these or similar grounds. Improvisation as unedited composition.

30. Technically, twenty grams is not a measure of force, but of mass, which has an inertial force.

31. Even the theremin, with which there is no direct contact, draws forces of resistance out of the earth, gravity, proprioception, air pressure, and it establishes a domain of these forces in relation to its own geometry, effectively making felt the electromagnetic field, whose disturbance ultimately generates the sound.

32. Improvising guitarist, Derek Bailey: "To change the instrument, or to use a found instrument attitude is okay, and it can make some nice music sometimes. I found in my efforts in those areas that the instrument actually lost malleability and permutability. You couldn't fuck around with it as much, you couldn't improvise" (quoted in Corbett 1995, 230, who in turn takes the quotation from an interview between Bailey and Gaudynski).

33. Etymologically, *precarious* means obtained by entreaty, and the music is precarious inasmuch as it begs the musician to rescue it, pleads to be perpetuated even while fighting to die.

34. Readers interested in a concrete phenomenological analysis of the interface between instrument and musician are enthusiastically referred to David Sudnow's landmark study of his own experience learning to play jazz piano, *Ways of the Hand* (2001). His study provides a useful comparison to the present analysis at many points.

35. Thus, we can see how the force that sometimes spills over from music into other expressive arts or into politics, such as in the Fluxus movement, is not a radical break or departure from the musical tradition but a continuity. Though the arts are falsely unified under a common genus, the disposition of the artist is seen to be a common characteristic in the sense that each artist has a desire that is turned to expression by particular techniques, but it is a desire that could, in theory, power some other technique instead. It would not then turn out to be the same desire, but desire is only known in terms of its effects, so this is no surprise.

36. In addition to the experiments of Alvin Lucier and others—using brainwaves (read by encephalographs) to trigger musical instruments—there is now a commercially available product (Interactive Brainwave Visual Analyzer, see http://www.ibva.com/) that measures certain kinds of brain activity in real time and allows the user to output these measures as MIDI data, which can be fed to any of the thousands of standard MIDI devices on the market, to control volume, pitch, or pretty much any other aspect of a sound (within the parameters of the sound engine of the MIDI device). The fetishistic fascination with this setup, a mind-controlled instrument, is no doubt largely due to the fact that one can make music, or at least determine certain aspects of sound, without moving a muscle: thought become sound. But it would be a gross confusion to imagine that some sort of effort is saved thereby. As with any instrument, the user must practice a technique for producing the appropriate neuroelectrical conditions, and any subtlety in the end result will be won by the greatest effort to produce and control those states.

37. See Hamman 1999, 99.

38. Documented in de Laubier (1998).

39. One further complication not yet considered here is the issue of longevity of the semiotic. Even a challenging semiotic interface will eventually fail to surprise its users because computers only run so deep. Is it not the case that, eventually, the user will become algorithmically familiar with its structure of variables, will begin to map, both in body and intellect, certain gestures onto certain sounds? Even simple physical instruments seem to hold more mystery in their bodies than the most elaborate computer programs.

40. It should be noted that programming is not a task distinct from other more directed computer use but refers to the more complex end of a continuum of activities. Most anyone can customize to some extent the "desktop" of his personal computer, changing the background picture or the way in which files are presented within windows. Such modifications are primarily aesthetic, but these aesthetics have an impact on productivity, as they affect the way information is presented, and computers do little besides present information to the user. More advanced users can create *macros*, a series of steps that is executed automatically on issuing to the computer a single command. In principle, a macro does not allow the user to do anything new, anything that could not have been done without the macro, but in practice, a well-designed set of macros can make some tasks easy that would otherwise be so labor-intensive as to be nearly impossible. Imagine taking thousands of photographs and scaling them to a smaller size one at a time. A macro can do this in one step instead of thousands. (Technically, such a macro would be called *batch processing*.) The next step in increasing complexity would be a scripting language, where the syntax is the primary constraint that the programmer must learn.

41. The digital becomes fluid at a number of different scales. Viewed microscopically and microtemporally, the static and hard edges of individual bits melt into a flow of electrons through silicon chips, a continuously variable magnetic field strength on the surface of a hard drive, an approximate frequency of signal over a phone line. These continua turn back into hard-edged digital phenomena when viewed at still another scale: the quantum basis of electricity is once more a digital domain.

42. Even the mountains become molten rock in geological time. The progress of a liquid digital is easy enough to see, for it has happened primarily in the last fifty years and has already been somewhat theorized. (Witness, for example, Moore's Law, which dictates that data storage capacity will double approximately every eighteen months.)

43. Quote from Cascone 2000, 17.

44. The exception is a change of paradigm, as when digital synthesizers overtook analog ones in the early to mid-1980s. There is a current vogue that favors the old analog synths, which have a textural richness unparalleled on digital instruments. Even this inequality has been largely overcome as more powerful digital synthesis provides a means of analog-emulation, where a digital instrument is designed to act like an analog one, including the unreliable tuning and warm harmonic distortion.

45. This Chinese doll model of software succession is true in principle but not always in practice. Many generations of development of programs have stranded some older data formats and executables. Generally, the data can be extracted from the old files, and there are tools for reading legacy media. But innovation is not always continuous and sometimes sharper breaks are necessary for the sake of progress.

This page intentionally left blank

Works Cited

Adorno, Theodor. 1967. *Prisms*, trans. Samuel and Shierry Weber. Cambridge, MA: MIT Press.

———. 1998. *Quasi una Fantasia: Essays on Modern Music*, trans. Rodney Livingstone. New York: Verso.

———. 1999. *Sound Figures*, trans. Rodney Livingstone. Stanford, CA: Stanford University Press.

Aicher, Otl. 1994. *Analogous and Digital*, trans. Michael Robinson. Berlin: Ernst & Sohn Verlag für Architektur und Technische.

Attali, Jacques. 1985. *Noise: The Political Economy of Music*, trans. Brian Massumi. Minneapolis: University of Minnesota Press.

Augé, Marc. 1999. *The War of Dreams: Exercises in Ethno-fiction*, trans. Liz Heron. London: Pluto Press.

Backus, John. 1964. *Composer* 14: 16–20. London 1964. Originally published as “Die Reihe: A Scientific Evaluation.” *Perspectives of New Music* 1, no. 1: 160.

Bailey, Derek. 1992. *Improvisation: Its Nature and Practice in Music*. New York: Da Capo Press.

Barthes, Roland. 1985. *The Responsibility of Forms: Critical Essays on Music, Art, and Representation*, trans. Richard Howard. New York: Hill and Wang.

Baudrillard, Jean. 1983. *Simulations*, trans. Paul Foss, Paul Patton, and Philip Beitchman. New York: Semiotext(e).

Beckett, Chris. 2001. “The Marriage of Sea and Sky.” In *Year’s Best SF 6*, ed. David G. Hartwell, 190–209. New York: HarperCollins.

Benjamin, Walter. 1968. “The Work of Art in the Age of Mechanical Reproduction.” In *Illuminations*, trans. Harry Zohn, 217–51. New York: Schocken Books.

Bennett, H. Stith. 1983. “Notation and Identity in Contemporary Popular Music.” *Popular Music* 3: 215–34.

Blackmer, David E. 2002. “The World beyond 20kHz.” http://www.drtmastering.com/blackmer.htm (accessed November 2004).

Bolter, Jay David, and Richard Grusin. 1999. *Remediations*. Cambridge, MA: MIT Press.

Boulez, Pierre. 1986. *Orientations: Collected Writings*, ed. Jean-Jaques Nattiez, trans. Martin Cooper. Cambridge, MA: Harvard University Press.

Buchanan, Ian. 1997. “Deleuze and Pop Music.” *Australian Humanities Review*. http://www.lib.latrobe.edu.au/AHR/archive/Issue-August-1997/buchanan.html 2004.

Cadoz, Claude, and Marcelo Wanderley. 2000. “Gesture–Music.” *Trends in Gestural Control of Music*, [CD-ROM]. Paris: IRCAM.

Cadwallader, Allen, and David Gagné. 1998. *Analysis of Tonal Music: A Schenkerian Approach*. New York: Oxford University Press.

Cage, John. 1961. *Silence.* Hanover, NH: Wesleyan University Press.

Cardew, Cornelius. 1971. *Treatise Handbook.* London: Edition Peters.

Cascone, Kim. 2000. "The Aesthetics of Failure: 'Post-digital' Tendencies in Contemporary Computer Music." *Computer Music Journal* 24, no. 4: 12–18.

Cavell, Stanley. 1971. *The World Viewed: Reflections on the Ontology of Film.* New York: Viking.

Chun, René. 1995. "Fleeing Cold Perfection for Lovable Lo-Fi Sound." *New York Times* 144, Jan. 8, 1995: sec. 1: 33, 36.

Corbett, John. 1995. "Ephemera Underscored: Writing Around Free Improvisation." In *Jazz among the Discourses*, ed. Krin Gabbard, 217–42. Durham, NC: Duke University Press.

De Laubier, Serge. 1998. "The Meta-Instrument." *Computer Music Journal* 22, no. 1 (Spring): 25–29.

Deleuze, Gilles. 1998. "Boulez, Proust, and Time: 'Occupying without Counting.'" *Angelaki: Journal of the Theoretical Humanities* 3, no. 2, trans. Timothy S. Murphy.

———. 1994. *Difference and Repetition*, trans. Paul Patton. New York: Columbia University Press.

Deleuze, Gilles, and Félix Guattari. 1987 [1980]. *A Thousand Plateaus*, trans. Brian Massumi. Minneapolis: University of Minnesota Press.

———. 1994. *What Is Philosophy?* Trans. Hugh Tomlinson and Graham Burchell. New York: Columbia University Press.

Denby, David. 1996. "My Problem with Perfection." *The New Yorker*, Aug. 26 and Sept. 2: 64–83.

Dineen, Murray. 1993. "Adorno and Schoenberg's Unanswered Question." *The Musical Quarterly* 77, no. 3: 415–28. Dobson, Andrew. 2002. "About Hypnosis: An Explaination. *[sic]*" *Hypnotic MP3.com.* http://www.hypnoticmp3.com/ 2002.

Eckel, Gerhard, Manuel Rocha Iturbide, and Barbara Becker. 2001. "The Development of GiST, a Granular Synthesis Toolkit Based on an Extension of the FOF Generator." http://viswiz.gmd.de/~eckel/publications/eckel95c/eckel95c.html 2001.

England, Phil. 2000. "Hot Desking: Toshimaru Nakamura." http://dusan.satori.sk/i/txt/nakamura01.php (accessed November 2004).

Eno, Brian. 1981. "Generating and Organizing Variety in the Arts." *Breaking the Sound Barrier: A Critical Anthology of the New Music*, ed. Gregory Battock, 129–41. New York: E. P. Dutton.

Fischetti, Mark. 1993. "The Sound of Data: Virtual Acoustics." *Technology Review* 96, no. 5 (July): 17–19.

François, Jean-Charles. 1992. "Writing without Representation, and Unreadable Notation." *Perspectives of New Music* 30, no. 1: 6–20. Freud, Sigmund. 1985. *The Complete Letters of Sigmund Freud to Wilhelm Fliess 1887–1904*, trans. and ed. Jeffrey Moussaieff Masson. Cambridge, MA: Belknap.

Gabor, Dennis. 1946. "Theory of Communication." *Journal of the IEEE* 94: 369.

———. 1947. "Acoustical Quanta and the Theory of Hearing." *Nature* 159, no. 4044: 591.

Goodman, Nelson. 1976. *Languages of Art: An Approach to a Theory of Symbols.* Indianapolis, IN: Hackett.

Graham, Gordon. 1999. *The Internet: A Philosophical Inquiry.* New York: Routledge.

Hamman, Michael. 1999. "From Symbol to Semiotic: Representation, Signification, and the Composition of Music Interaction." *Journal of New Music Research* 28, no. 2: 90–104.

Harris, Ed. 2000. *Pollock*, [film]. Zeke Productions.

Hegel, G. F. W. 1977. *The Phenomenology of Spirit*, trans. A. V. Miller. Oxford: Oxford University Press, 1977.

Heidegger, Martin. 1996. *Being and Time*, trans. Joan Stambaugh. Albany, NY: State University of New York Press.

———. 1977 [1954]. "The Question Concerning Technology." *The Question Concerning Technology and Other Essays*, trans. William Lovitt. New York: Harper & Row.

Hindemith, Paul. 1952. *A Composer's World: Horizons and Limitations.* Cambridge, MA: Harvard University Press.

Iazzetta, Fernando. 2000. "Meaning in Musical Gesture." *Trends in Gestural Control of Music*, [CD-ROM]. Paris: IRCAM.

Kant, Immanuel. 1929. *Critique of Pure Reason*, trans. Norman Kemp Smith. New York: St. Martin's Press.

Kierkegaard, Søren. 1980. *The Sickness Unto Death*, trans. Howard Hong and Edna Hong. Princeton, NJ: Princeton University Press.

Kittler, Friedrich. 1995. "There Is No Software." *Ctheory*, eds. Arthur and Marilouise Kroker. http://www.ctheory.net/text_file.asp?pick=74.

Koenigsberg, Christopher K. 1998. "Stockhausen's New Morphology of Musical Time." http://www.music.princeton.edu/~ckk/smmt/index.html 1998, and always available through http://www.ckk.com/.

London, Justin M. 1993. "Loud Rests and Other Strange Metric Phenomena (or, Meter as Heard)." *Music Theory Online* 0, no. 2. http://www.societymusictheory.org/mto/index.html. Society for Music Theory.

Lucier, Alvin. *I Am Sitting in a Room*, [compact disc]. Lovely Music, CD1013 1990.

Manovich, Lev. 2001. *The Language of New Media*. Cambridge, MA: MIT Press.

———. 1999. "What Is Digital Cinema?" In *The Digital Dialectic: New Essays on New Media*, ed. Peter Lunenfeld, 172–92. Cambridge, MA: MIT Press.

Massumi, Brian, ed. 2002. *A Shock to Thought: Expression after Deleuze and Guattari*. New York: Routledge.

———, ed. 1997. *Canadian Review of Comparative Literature: Special Issue: Deleuze, Guattari, and the Philosophy of Expression* 24, no. 3. Toronto: University of Toronto Press, September 1997.

Mertens, Wim. 1983. *American Minimal Music: La Monte Young, Terry Riley, Steve Reich, Philip Glass*. London: Kahn & Averill.

Meyer, Leonard. 1973. *Explaining Music: Essays and Explorations*. Chicago: University of Chicago Press.

Mowitt, John. 1987. "Music in the Era of Electronic Reproducibility." In *Music and Society: The Politics of Composition, Performance, and Reception*, ed. Richard Leppert and Susan McClary, 173–97. Cambridge: Cambridge University Press.

Murphy, Timothy S. 1998. "Composition, Improvisation, Constitution: Forms of Life in the Music of Pierre Boulez and Ornette Coleman." *Angelaki: Journal of the Theoretical Humanities* 3, no. 2.

Myerson, George. 2001. *Heidegger, Habermas, and the Mobile Phone (Postmodern Encounters)*. London: Icon/Totem Books.

Nietzsche, Friedrich. 1969. *Thus Spoke Zarathustra*, trans. R. J. Hollingdale. London: Penguin.

Nyman, Michael. 1999. *Experimental Music: Cage and Beyond*, 2d ed. Cambridge: Cambridge University Press.

Oohashi, Tsutomu, et al. 2000. "Inaudible High-Frequency Sounds Affect Brain Activity: Hypersonic Effect." *Journal of Neurophysiology* 83, no. 6: 3548–58. Full text available at http://jn.physiology.org/.

Ostertag, Bob. *Say No More CDs 1&2*, [two compact disc set]. Seeland 2000, 521CD.

Oswald, John. 1996. *Grayfolded*, [compact disc]. Swell/Artifact. Canada.

Palmer, Robert. 1981. "A Father Figure for the Avant-Garde." *Atlantic* 247, no. 5 (May): 48, 56.

Pankhurst, Thomas A. 2001. *Schenkerguide.com: A Guide to Schenkerian Analysis*. http://www.schenkerguide.com/ 2001.

Pearson, Harry. 1996. "HP's Place." *The Absolute Sound Online* Web site. http://www.absolutesound.com/hpsplace.html 1996. This Web site is now defunct, but the opinions quoted are strewn throughout the print edition of the magazine, *The Absolute Sound*, ed. Harry Pearson.

Plomp, Reinier. 1993. "Music and the Ear." *Internationaler Musikwissenschaftlicher Kongreß zum Mozartjahr 1991*. Tutzing: Hans Schneider, 1993.

Reich, Steve. 1974. *Writings About Music*. New York: New York University Press.

Rickert, Thomas, and Byron Hawk. 1999. "Introduction, 'Avowing the Unavowable': On the Music of Composition." *Enculturation* 2, no. 2 (Spring), ed. Thomas Rickert. http://enculturation.gmu.edu/2_2/index.html (accessed November 2004).

Schoenberg, Arnold. 1984. *Style and Idea*, trans. Leo Black, ed. Leonard Stein. Berkeley: University of California Press.

Shonberg, Harold C. 1986. On Arthur Rubinstein. http://www.arims.org.il/artist.htm. Web site text taken from article "Arthur Rubinstein," which appears in the brochure of the *Fifth Arthur Rubinstein International Piano Master Competition*, April 1986.

Sloboda, John. 1994. *The Musical Mind: The Cognitive Psychology of Music*. Oxford: Clarendon Press.

Spruance, Trey. 2002. "Trey Spruance on John Zorn." *The Trey Spruance Gallery*. http://www.geocities.com/spruancegallery/interviews/spruance/goblinzorn.html 2002.

Stockhausen, Karlheinz. 1987. "Comme le temps passé [extraits de l'article, «...wie die Zeit vergeht.»]" *Analyse Musicale*, Nov. 1987, no. 1. Paris: L'A.D.A.M.

———. 1989. *Stockhausen on Music*. Compiled by Robin Maconie. New York: Marion Boyars.

Sudnow, David. 2001. *Ways of the Hand: A Rewritten Account*. Cambridge, MA: MIT Press.

Truax, Barry. 2001. *Acoustic Communication*. Westport, CT: Ablex Publishing, 2001.

———. 1994. "Discovering Inner Complexity: Time Shifting and Transposition with a Real-time Granulation Technique." *Computer Music Journal* 18, no. 2 (Summer): 38–48.

Uitti, Frances-Marie. 2000. "An Adventure." *Arcana: Musicians on Music*, ed. John Zorn, 67–77. New York: Granary Books/Hips Road.

Weber, Samuel. 1996. *Mass Mediaurus: Form Technics Media*. Stanford, CA: Stanford University Press.

Williams, Davey. 2002. http://www.the-improvisor.com/transmuseq/davey/dwritings.htm. May 2002. Requoted from *Improvisor XI*, "In Praise of Clams."

Wolfram Research, Inc. 2002. *Mathematica*, version 4.2 for Macintosh OS X [computer software].

Young, La Monte. 1987. Program Booklet, 2d ed., for *The Well-Tuned Piano*, *81 x 25*, *6:17:50 – 11:18:59 pm*, *NYC*, [five-compact-disc box set]. New York: Gramavision.

Young, Neil. 1992. “Digital Is a Huge Rip-Off.” *The Absolute Sound* 17, no. 81 (July/Aug.): 12. Originally in *Guitar Player*.

Zuckerkandl, Victor. 1956. *Sound and Symbol*, trans. Willard R. Trask. New York: Pantheon Books.

Index

Absolute Sound, The, 7, 176n8
abstraction, 169, 173; in Deleuze, 176n15; of the digital, 71, 185n37; in digital instruments, 87; discouraging creativity, 167
accident, 90, 96; affirmation of, 156
accidental, 156
acoustic instrument, subtlety of, 89
acoustics, 30
actuality, 74; exceeding its form, 66; as fallible, 185n37; as ontologically fuzzy, 71; relation to virtual, 183n18
additive synthesis, 92–93, 96
Adorno, Theodor, 56–57, 122, 160, 178n21, 179n30, 182n63; on repetition, 181n51; versus Schoenberg, 178n14, 181n61
affect, 11, 16, 20, 21, 22, 24, 58. *See also* percept and affect
affirmation, of accident, 156
African percussion, 38
Aicher, Otl, 182n10
air pressure, 1–2
Alberti bass, 59
algorithmic composition, 38
aliasing, 80
alienation, of musical subject, 56
AMM, 151
amplitude, 2–5, 99; and perceived loudness, 175n2. *See also* wave
analog, explanation of, 11–12
analog-to-digital conversion, 12
analysis, and musical genre, 117
anticipation, 19, 141
Apple Computer, 69, 127, 128, 188n3
architecture, of computers, 171
art: as challenge for technology, 81; as test of the digital, 82; cosmic forces in, 181n46; digital editing of, 82; digital, 77
Artaud, Antonin, 144
articulation, 17; of body, 185n41; of instrument, 84; as too clear, 117
artwork, 158
ASCII (American Standard Code for Information Interchange), 182n7
asymmetry: and double-articulation, 182n9; of hands, 182n10; of sound, 42
attack, of real-world sounds, 103
Attali, Jacques *(Noise)*, 34, 54, 56–57, 88, 117–19, 176n10
audiophile, 7–10; and aura, 176n9; as arbiter of fidelity, 8; in automobile, 176n13; and measurement, 176n14
Augé, Marc, 135–36
aura, 176n9, 183n21
authenticity, 141; of *Dasein*, 139
auto-generated music, 119
automata, cellular, 112

Bach, Johann Sebastian, 59
background, drawn into foreground, 48, 181n46
Backus, John, 178n15
Bailey, Derek, 150, 177n3, 189n18, 190n32
Band-In-A-Box (PG Music), 187n70

Barthes, Roland, 30, 116–17, 177n6, 187n68–69, 188n80; as Deleuzian 187n66; on technology and culture, 188n73
Baudrillard, Jean, 76, 184n31
Beckett, Chris, 131
Beethoven, Ludwig van, 19, 24, 32, 35, 57
Being and Time, 139
being-toward-death, 141
Benjamin, Walter, 176n9, 182n8
Bennett, H. Stith, 178n20
Berg, Alban, 55–56
Big Brother, 127
binary code, 65, 182n5
binary digit. *See* bit
bit: as abstraction, 65, 185n37; and articulation, 68; in quantum computers, 183n19; as representing data, 65; as statistical measure of demographics, 119
blackbird, 27, 29
Blackmer, David, 177n20
body: articulations of, 185n41; as part of improvisatory process, 151; of performer, 125; as perfunctory, habitual, 143; role in spirit possession, 135
Bolter, Jay David, 129, 189n5
Boston Sound Collective, 154
Boulez, Pierre, 43–44, 156, 179n32, 180n38, 189n27
bowed cymbal, 5
broadband, 186n59
Brown, Earle, 150
Buchanan, Ian, 179n30

Cadoz, Claude, 185n41
Cage, John, 33, 48, 49, 88, 155–56; and noise, 177n4
capitalism, 78, 173, 184n31
Cardew, Cornelius, 142, 189n13
Cascone, Kim, 186n48, 188n78, 188n80, 190n43
Cave, Nick, 24
Cavell, Stanley, 42–43
CD (compact disc): acoustic properties of, 13; criticisms of, 13; expressive potential of, 22; versus LP, 11; and noise, 23; noise floor of, 13; resolution of, 13; sampling frequency of, 176n18; supersession of, 177n19
cell phone: critique of, 189n20; in music, 152
cellular automata, 112–14, 115; definition of, 187n63; as fractal, 116; in music synthesis, 114
chalice, as example of premodern technology, 63
chaos, 114, 187n63
Chun, René, 177n30
classical music, 7, 8; form of, 43; role of memory in, 50; role of score in, 181n56; Schenkerian analysis of, 179n28
clock, 31
"Cobra" (Zorn) 152–53
Cocker, Joe, 59
code, 79; as software, 169
cogitandum, 145
Coleman, Ornette, 189n27
color: digital representation of, 70, 183n16; in wavelet analysis, 187n64
Coltrane, John, 134
common sense, 144
completion, in improvised music, 149–50
complexity: as component of creativity, 166; as programmable, 187n70
composition: ideal, 53; versus improvisation, 159, 189n28
compression: of air pressure, 1; as heterogeneous, 40
computer: as compositional tool, 165; and creativity, 170; as extension of user, 164; in film, 188n1; history of, 171; as instrument, 131, 163, 170; as medium, 163, 189n6, 189n7; as performer, 22;
conductor, 35; as focal point of orchestra, 37, 178n13
Conrad, Tony, 45, 50
consonants, and meaning, 30
contraction, 1, 5, 16–17, 20; agent of, 18; as equicentral, 177n22; of habit in editing, 158; of history of sound, 18; of noise, 15; in perception, 4
convention, as *Dasein*'s domain of possibility, 141
Corbett, John, 149–50, 154, 178n18, 189n23, 190n32
corporeality, in cyberspace, 164
counterpoint, species, 59
counting, 75
creativity, 19, 168; on computers, 165; as experiment, 156
criticism, of the digital, 77
Csound, 92
cymbal, 5

danger, of the digital, 66, 183n21
Dasein: and temporality of the will, 139–42
data reduction, 120; indifference to, 121; and piracy, 188n73; using wavelet analysis, 186n60
death: as threat to music's coherence, 141–42, 190n33; of music, 162
deictic, 73–74, 184n26
de Laubier, Serge, 190n38
Deleuze, Gilles, 40, 123, 144–46, 177n29, 179n25, 187n65, 187n66; *Difference and Repetition*, 176n15, 181n49, 183n18; "Do not explicate oneself (too much)," 21; *A Thousand Plateaus*, 179n33, 182n9; *What Is Philosophy?*, 176n15, 181n46
Denby, David, 176n13
desire, 162; and computers, 164; in the arts, 190n35
detritus, digital, 90, 185n47
DFT (Discrete Fourier Transform), 97, 99, 186n58
diagonal, between harmony and melody, 84
dialectic: as method of analysis, 56; of interface and data, 80
difference, 1; in evolutionary theory, 179n27; implicated, 21; as productive, 71; rendered external in the digital, 76, 184n30; and sensation, 176n15
digital, xiii–xiv; versus analog, 11; characteristics of, 65; continuity of, 172; danger of, 66, 183n21; deficiencies of, 11, 184n32; and double-articulation, 68; etymology of, 73; experience of, 182n8; fluidity of, 171, 190n41, 190n42; homogeneity of, 187n70; as paradigm of

technology, 182n4; scrambled by methods of synthesis, 115; as technology's tool, 64; timing errors in (*see* jitter)
digital copy: perfection of, 66
digital instrument, 88; abstraction of, 87; as mere means, 83; transgressive uses of, 90
digital music: as focused on quality of sound, 124; self-consciousness of, 123
digital recordings, discouraging mistakes in, 155
digital signature, 76, 77, 184n33
digital-to-analog conversion, 12
digitization, 68; difficulty of, 70
digits, in animals, 184n28
Dineen, Murray, 181n61
Dirichelet condition, 175n3
Discrete Fourier Transform. *See* DFT
discreteness, of the digital, 70
distortion, digital, 91; as musical material, 122
DNS (Domain Name Server), 183n13
doctrine of the faculties, 144–45
dog, pointing, 184n28
double-articulation, 71; in Deleuze and Guattari, 182n9; of fingers, 67; to represent numbers, 183n14
downbeat, 37; as organizer of ensemble, 38
Dream House (Young), 45, 179n36, 180n39
drugs, as means to summon spirits, 135
drums, structure of, 86–87
duplication, 66, 184n33
duration, long, 44
DVD-Audio, 177n19
Dylan, Bob, 59

Eckel, Gerhard, 187n62
ecology, of sound, 97
editing, 158–59, 170; contribution to creativity, 157; in digital broadcasting, 183n25
election, U.S. presidential, 188n72
electronic instrument. *See* digital instrument
Enframing, 182n2
England, Phil, 188n77
Eno, Brian, 178n13
entraining, 39, 178n23
Entwurf, 139
envelope: of grain, 106–7; of sound, 186n50
error, on computers, 167
eternal return, 136
ethics of implication, 21, 176n15
ethics of intensity, 21
ethnomusicology, x
European art music. *See* classical music
Evans, Bill, 177n23
evolution, 179n27
exception, in computer software, 167
expectation, 19–20
experiment, 155–60; and digital technologies, 125, 188n80
experimentation, on a computer, 170
explication: as cancellation of difference, 21; as excessive, 22
expression, 11, 14, 19, 24, 143; as balance, 22–23; as ethics of implication, 21; loss of, 23; and performance, 14; of technology, 188n77

faculties, doctrine of, 144–45
faculty, determination of, 147
faculty of computing, 170
faculty of music, 142, 144–48, 157, 166
failure, as essential to experiment, 156–57
Fast Fourier Transform (FFT), 186n58
feedback, 150; of instrument and performer, 83; in no-input mixing board, 188n77
FFT (Fast Fourier Transform), 186n58
fidelity, 7–10, 24, 42; and emotion, 188n73; indifference to, 120
filter, 186n52
fingers: distinction between, 183n15; as between form and actuality, 74; as primordial digits, 67; as tokens, 75
firmware, 185n45
Fischetti, Mark, 178n11
floating, 18, 177n21
Fluxus, 190n35
FM synthesis, 95–96
forgetting, 42. *See also* memory
form, 36, 178n16; as conceptual, 37; as danger of the digital, 77; dimensions of, 187n64; divided from content in synthesis, 111; duplication of, 66; of fingers, 67; as temporality of sound, 31–32; as unifying principle of the digital, 66
formant, 30
Fourier analysis, 3, 102, 104, 175n6, 186n56; dichotomy between time and frequency, 103; explanation of, 97–101; and noise reduction, 106; and overshoot, 177n8; range of application of, 175n3
Fourier theorem, 3, 13, 92, 96, 178n24; range of application of, 175n3
Fourier transform, 3, 4, 43, 98; to test stereo equipment, 186n57
Fourier, Jean Baptiste Joseph, 3
fractals, 115; in Fourier analysis, 175n3; in wavelet analysis, 186n60
François, Jean-Charles, 176n10, 178n20
free improvisation, 148
frequency, 2–7; and sampling, 12, 176n18. *See also* wave
frequency-modulation, 95
Freud, Sigmund, 179n29
fundamental (frequency), 3, 97; absent but heard, 47

Gabor, Dennis, 110, 177n7
Gadamer, Hans-Georg, 177n1
gamelan orchestra, 86
games, as improvising method, 152–54
genius, 131–34; in Hindemith, 177n27; of the ordinary, 134
genre, 35, 117–18, 188n73
Gestell (Enframing), 182n2

gesture, 125, 185n41; adapting to digital instruments, 172; as separate from sound, 185n42; complexity of, 110; digital representation of, 88
Gibb's phenomenon, 177n8
Glass, Philip, 50
glitch, 122, 188n80
God, 138
Gödel, Kurt, 183n14
Goodman, Nelson, 178n20
Gould, Glenn, 59, 132
Graham, Gordon, 185n35
grain, of music, 116
granular synthesis, 106–12, 115; composition using, 187n62; as fractal, 116; as musical, 110; with sampled sounds, 187n61; using cellular automata in, 114
Grateful Dead, "Dark Star," 178n10
Groove Agent (Steinberg), 187n70
Grusin, Richard, 129, 189n5
Guattari, Félix, 40, 123; *A Thousand Plateaus*, 179n33, 182n9; *What Is Philosophy?*, 176n15, 181n46
guiro, 36
guitar: history of, 84; structure of, 84–85

habit, 157, 170; in music training, 146
haecceity, 70, 74, 184n27; lost in counting, 75
Hamman, Michael 165–67, 168, 190n37
harmonics, 47, 180n43, 180n44; and dissonance, 185n39; of an instrument, 180n45
Harris, Ed, 133
headphones, 121; and acoustical space, 119, 188n73; noise-canceling, 175n7
hearing, 1, 4, 10; as active, 39; limits of, 13, 175n1; neurology of, 181n50; and rational tunings, 47; and the visual, 178n11
Hegel, G.W.F., 73–74, 137, 184n27
Heidegger, Martin, 63–64, 69, 73, 79, 81–82, 139, 140, 142; *Enframing* in, 182n2; idealism in, 185n38; and truth, 182n1
Heisenberg, Werner, 30
Hendrix, Jimi, 131–32, 160
hermeneutic circle, 177n1
Hindemith, Paul, 19, 28, 31, 177n27, 177n2
history: of computing, 171; end of, 137; heard in music, 34
hypnosis, 134

"I Am Sitting in a Room" (Lucier), 53
Iazzetta, Fernando, 90, 188n81
IBM, 128
I Ching, 49
identity, of performers, 37
Illustrator (Adobe), 182n12
immediacy, 162; as the disappearance of the interface, 128; in an instrument, 131; as user's presence in computer, 130
immersion, 133, 135, 138, 140, 143; as attainable by ordinary folks, 148; as mark of genius, 134; in music making, 132; preferable to immediacy, 162; as relationship to music, 147
implication, 16–20, 140; as bodily, 177n24; in Deleuze, 176n15; versus expectation, 177n25; as giving sense to sound, 15; as heard, 19; of noise, 15; too much, 22
improvisation, 148, 168; on computers, 169; with computers, 167–68; versus composition, 159, 189n28; as experiment, 156; free, 148; methods for 150–55; risks in, 149
inauthenticity, of *Dasein*, 139
indeterminacy, 29; of the actual, 69; of computers, 167, 171; of instrument, 161
inertia, and the fragility of music, 142
inflection, 27–30, 55
information, 66
"inherent mutability," of digital, 72, 184n23
innuendo, 27–30, 55
insanity, in improvised music, 149–50
instrument: altered as a method of improvisation, 154, 190n32; computer as, 164; as expressive, 129; indeterminacy of, 161; limitations of, 95; as means to an end, 82; relation to musician, 131–63; resistance of, 160; simulation of, 94
intellectual intuition, 136–38
Interactive Brainwave Visual Analyzer (IBVA), 190n36
interface, 80, 130; humanizing of, 81; as mediating experience, 129; resistance of, 168
Internet: celebration of, 184n34; as heterogeneous, 81; and homogeneity, 185n36; utopian possibilities of, 78, 185n35
Internet protocol address (IP address), 183n13
intonation, just, 46
intuition, 28; intellectual, 137
IP (Internet protocol) address, 183n13
irony, as aesthetic approach to digital music, 122
irrational tuning, 45, 179n36
iteration, of cellular automaton, 112

Jarrett, Keith, 59, 132
jitter, 13, 23, 80
Jordan, Michael, 132
just intonation, 46

Kant, Immanuel, 137–38, 144
Kelley, Greg, 154
Kierkegaard, Søren, 136–37
Kittler, Friedrich, 188n4
Klein bottle, 18
Koenigsberg, Christopher, 178n15
"Kontakte" (Stockhausen), 34
Krasner, Lee, 133
Kroker, Arthur, 185n47
Kronos Quartet, 156

Lacy, Steve, 189n28
latency, 124

limit, xii–xiii, xiv
listening, as active, 147
live music, versus recorded, 9, 10
lo-fi, 10, 177n30
London, Justin, 178n22, 178n23
loquendum, 145
loudness. *See* amplitude
LP (long-play record), 23–24; versus CD, 11
Lucier, Alvin, 53–54, 190n36; space in the compositions of, 181n57

madness, of genius, 133
Manovich, Lev, 184n23, 184n25
mass culture, 118, 120
measurement, as amplifier of technology, 64
mediation, 129; of computer, 168; by sensation, 138; to summon spirit, 135
memory, 43; of the body, 41; of immersive music-making, 136; as molecular, 46; paradox of, 42; as perceptive and affective, 58; as a point, 45; of a room, 54; and serialism, 44
Mertens, Wim, 43, 179n34, 180n37, 180n39, 180n42, 189n19
Messiaen, Olivier, 51
Meta-Instrument project, 166
Metasynth (U&I Software), 184n24
Meyer, Leonard, 20, 177n24, 177n25
Microsoft, 185n36
microsound, 122
MIDI, 88, 124; limitations of, 89
minimalism, 38, 51
mistake: as criterion of excellence, 188n80; as a method of improvisation, 154–55
modulation, of grains, 108
molecularization, of sound, 58
Molino, John, 180n45
"Momente" (Stockhausen), 33
Moore's Law, 190n42
motif, 20, 43, 50; as musical character, 179n33
Mowitt, John, 91, 96, 122, 188n73, 188n76
Mozart, Wolfgang Amadeus, 59
MP3, 120–21, 177n19
MTV, 118–19
Muir, Jamie, 189n18
multisampling, 94
multitracking, 155
Murphy, Timothy, 189n13, 189n27
musical instrument. *See* instrument
musicandum, 146, 148
"Music for Eighteen Musicians" (Reich), 52
"Music of Changes" (Cage), 49
music of the spheres, 47
musicology, ix
music video, 118
musique informelle, 117, 160
mutability, of digital, 72, 184n23, 184n25
Myerson, George, 189n20

Nakamura, Toshimaru, 123, 188n77
Niblock, Phill, 50
Nietzsche, Friedrich, 136–37, 173
1984, 127–28
Nirvana, 19
noise, xii, 29; absolute, 16; and agency, 17; as cosmic vibration, 14; as digital, 23; as endpoints of sound, 30; imperceptible, 16; as implicated reserve of sense, 15, 96, 142; as indeterminacy, 162; interfering with music, 8; as music, 177n30, 186n48; necessity for expression, 22; as the real, 188n4; of recording equipment, 105; recouped as signal, 91; relative, 16; versus signal, 15, 17, 23, 52, 96; as willed in immersion, 140
noise-canceling headphones, 175n7
noise reduction, 105–6, 175n7
nonlinearity, 112, 166; in granular synthesis, 110
Nyman, Michael, 189n15

object-oriented programming, 172
obsolescence, 81
Oohashi, Tsutomu, 177n20
opinion, coordination of, 118
orchestra, organization of, 34–35, 37; in Eno, 178n13
order, of technology, 64
Orwell, George, 127–28, 188n2
Ostertag, Bob, 153–54
Oswald, John, 178n10
overshoot, 177n8

painting, 133
Palestine, Charlemagne, 55
Palmer, Robert (journalist), 179n36, 180n40, 181n53
Pankhurst, Thomas, 179n28
Pearson, Harry, 10, 176n8, 176n11, 176n16
"Pendulum Music" (Reich), 150
percept and affect, 11, 16, 20, 21, 22, 24, 56, 58; in Deleuze and Guattari, 176n15
perception, 4, 11; as active, 41; as dependent on noise, 15; as indexed to temporalities, 36; as power of the body, 39
perceptual coding, 121
percussion instruments, frequency of, 5
perfection, of the digital, 71
performance: as balance between implication and explication, 22; and innuendo, 29
performer: body of, 83; and expression, 21; as player of noise, 21; as sculptor of noise, 17; as straits of contraction, 18
Perlman, Itzhak, 59, 132
personal stereo, 120
phase, 6, 100, 175n5; of grains, 107
phase shift, 50, 98–99
phenomenology, x
Phenomenology of Spirit, The (Hegel), 73
photograph, 43
Photoshop (Adobe), 182n12
piano, 131; prepared, 88; structure of, 85–86

piracy, 188n75
pitch, 4–5, 178n9, 178n16
Plomp, Reinier, 180n43, 181n50
poeisis, 63, 73
Pollock, Jackson, 133
polysemy, xii
popular music, 8, 10; as prefabricated, 117, 187n70
populism, 78
possession, spirit, 134
possibility, as implicated, 140
precision, of digital, 69
prepared piano, 88
presence: of the source of a sound, 43; as unmediated, 129
prismatic composition, 33
problem: as essential for creativity, 165; as site of resistance, 162; as the site of sound, 58; as source of composition, 59
process: as compositional method, 53; as improvising method, 150–51
programming: as creative computing, 169; as everyday activity, 190n40; object-oriented, 172
projection *(Entwurf)*, 139–40
project studio, 187n70, 189n25
prolongation, 42
prophesy, in music, 57
prosthetics, of the digital, 79
psychoacoustics, x, 4, 13, 47, 121, 176n15; of dissonance, 185n39; need for, 178n16
Pythagoras, 46

"Question Concerning Technology," 81
quantum computing, 183n19

radio, shortwave, in improvisation, 151
randomness, as improvising method, 151–52
rap (music), 186n51
rational tuning, 46, 179n36, 180n44
real virtuality, as opposed to virtual reality, 130
reason, spontaneity of, 145
recognition, as the banality of thought, 144
recorded music, as opposed to live, 9
recording and singularity, 46
reduction, data, 121
Reich, Steve, 38, 50–53, 150–51, 178n17, 181n56; "Slow Motion Sound," 187n61; using machines in the music of, 181n55
remote control, 169
repetition, 20; in serialism, 181n51; as sonorous principle, 51
representation, 129, 189n6
resemblance, calculation of in Fourier analysis, 100–101
resistance, 160–73; of the computer, 168; decreased in computer fantasy, 164; as essential for creativity, 154; essential to music, 163; of the real, 185n38
resolution: of digital, 70, 183n17; and Fourier analysis, 175n3
resulting patterns (Reich), 51–52
reverb, 54
revolution, 22
rhythm, 31, 36, 178n16; as articulations of the body, 37; as felt, 39; as heard history, 38; as identifying a language, 178n19; as temporality of sound, 32
Riley, Terry, 50
Rimbaud, Robin, 152
Roland TB-303, 186n51
room, as instrument, 55
Rousseau, Jean-Jacques, 137
Rowe, Keith, 151–52
Rubinstein, Arthur, 131
Rzewski, Frederic, 189n28

Sachiko M, 123
Salter, Lionel, 177n3
sample. *See* sampling
sample-table synthesis. *See* wave-table synthesis
sampling, 68, 186n53; explanation of, 12; frequency of, 12, 176n18; and granular synthesis, 109; libraries, 187n70; resolution of, 12, 183n17
saving power, of the digital, 79
"Say No More" (Ostertag), 153–54
scale, distinction in granular synthesis, 109
Scanner, 152, 189n20
Schenker, Heinrich, 39
Schenkerian analysis, 39, 41–42; critique of, 179n28; explanation of, 179n28
Schoenberg, Arnold, 35, 57, 178n12; versus Adorno, 178n14, 181n61, 182n64; and serialism, 181n51
score, ix; as idealization of piece, 181n56; as template, 176n10
Scott, Ridley, 128
semiotic domain: limitations of, 190n39; of software, 165–68
semiotics, 28
sense, in music, 15–24
sensible intuition, 137
sentiendum, 145
serialism, 38, 44–45, 51
series, 44
Shonberg, Harold, 189n9
signal-to-noise ratio, 14
signature, digital, 76, 77, 184n33
silence, 48
simple harmonic motion, 3
sine wave. *See* wave
singularity: of the actual, 70; lacking in the digital, 76
sinusoid. *See* wave
Sloboda, John, 177n21, 177n26, 179n31
soloist, 34
sonata form, 20, 39
sound design, 91
sound pollution, 97
sound wave. *See* wave
Spears, Britney, 156
species counterpoint, 59

spectrum, 48
spirit possession, 134–36, 138
spontaneity, 157; of the faculties, 145; of faculty of music, 146
Spruance, Trey, 152
squarewave, 99
stagnation, in improvised music, 149
standard: danger of, 183n21; digital as, 71–72; need for openness of, 81
Starship Enterprise, 163
stereo components (and accurate reproduction), 10; measurement of, 186n57
Stevens, Wallace, 27
Stockhausen, Karlheinz, 29–36, 49, 50, 127, 177n4; Backus on, 178n15; and granular synthesis, 187n62
studio, fixing mistakes in, 155
stutter, 55
subject: in immersive music-making, 138; who makes music, 143
subtractive synthesis, 93, 96; and Fourier transform, 186n54
Sudnow, David, 190n34
Super-Audio CD, 177n19
Super Bowl, 127
symbolic domain, of software, 165
synthesis: additive, 92–93, 96; of broadband sounds, 103; FM, 95–96; using Fourier method, 103; granular (*see* granular synthesis); possibilities of, 91; sample-table (*see* synthesis, wave-table); subtractive, 93, 96, 186n54; using wavelets, 104; wave-table, 93–94, 96, 186n52
synthesis engine, 88, 92; limitations of, 96, 186n51
synthesizer, 92, 171–72; analog, 22, 191n44; compromises in, 89; digital, 22; expansion of, 185n45; and freedom, 88; parameters of, 89; stretched beyond its limits, 123; succession of, 172, 191n44

tampering, with digital data, 72
technique, 84, 190n36; relation to resistance, 161
techno, 186n51
technology, fetishized, 122
telephone signals, 12
television, 189n7
temperament, 179n36, 180n37
temporalities: of sound, 31, 34; as unified (*see* unified time structuring)
temporality: as distinguishing experiment from editing, 158; in Heidegger, 139–42; illogic of, 138; structure of, 140
Terry, Clark, 42
theremin, 189n31
this (the deictic), 74; in Hegel, 73, 184n27
threshold, xiii; of digital precision, 70, 185n37
timbre, 1–7, 47, 175n6, 178n16; and compression, 39; constructed from tape layers, 34; in granular synthesis, 108; in score, 176n10; as sound's signature, 37; as the sum of all vibrations in a room, 6; varying with other aspects of a musical sound, 94
time: contraction of, 4; as material of sound, 31; transformed into space in recording, 12, 54
time compression. *See* unified time structuring
time-domain representation, versus frequency-domain representation, 101
token, 75, 184n29
tortoise, 45
totalitarianism, 188n2
total serialism. *See* serialism
triggering: of coded emotional responses to music, 120; of sounds in digital music tools, 124
Truax, Barry, 97
truth: digital as site of, 69; in Heidegger, 182n1; of music, 57, 179n36, 181n61; poeisis as, 64
tuning, 180n37; nontempered, 46, 179n36; stretch, 180n45; tempered, 45, 179n36, 180n44
turntablism, 34

Uitti, Frances-Marie, 154, 189n23
Unabomber, 77
uncertainty principle of acoustics, 30–31, 101
unified time structuring, 33–42, 178n9–11; and material continuity, 35
uniqueness, of acoustic instrument, 87
untimely, 173
URL (Universal Resource Locator), 183n13

VCR, interface of, 80
Velvet Underground, The, 19
Victrola, 9
violin, structure of, 86
virtual: in broadcasting, 184n35; in Deleuze, 183n18; fantasy of, 183n22; as performer's desire, 162
Virtual Reality. *See* VR
virtuoso, 34
voltage: in the determination of the value of a bit, 182n6
vowel, 30, 177n5
VR (Virtual Reality), 128–29, 173; fantasy of, 163

waltz, 36
Wanderley, Marcelo, 185n41
wave, 1–7, 31, 36, 175n3; accurate reproduction of, 10; as form of recording, 12; in psychoacoustics, 178n16; sine, as basis for Fourier analysis, 3
wavelength, 2
wavelet analysis, 104–6, 115, 186n60; extra dimension of, 187n64; and granular synthesis, 109
wave-table synthesis, 93–94, 96, 186n52
Weber, Samuel, 189n7
"Well-Tuned Piano" (Young), 46
white noise, 102
will: annihilation of, 135; as affirmation, 142; becoming equal to the music, 136; as equal to the willed, 138, 140; in immersive music-making, 139; to music, 139; paradox of, 134, 136, 155; to summon spirits, 135
Williams, Davey, 189n24
work, of art, 8–9, 158

world: as responsible for music, 143
World Trade Center, 76, 184n31

Xenakis, Iannis, 187n62

Yamaha DX-7, 37, 95, 186n51
Young, La Monte, 44–51, 176n17, 179n36, 180n45, 181n53; control over recordings of, 180n41; harmonics in the music of, 180n44; on neurology, 181n50; revealing cosmic forces, 181n46. *See also* Dream House
Young, Neil, 11

Zazeela, Marian, 180n39
Zen, 49
zigzag, additional dimension added by, 115–16
Zorn, John, 152–53
Zuckerkandl, Victor, 178n22

Aden Evens is an interdisciplinary scholar, a professional musician, and a computer programmer. He holds the position of assistant professor of technical communication at Massachusetts Institute of Technology.