Origins of a Form: Acoustical Exploration, Science and Incessancy

Alvin Lucier

JOHN CAGE AND DAVID TUDOR

On 24 September 1960, I attended a concert by John Cage, David Tudor, Merce Cunningham and Carolyn Brown at La Fenice Theater in Venice. I had come to Venice that summer on a Fulbright Scholarship to study at the Benedetto Marcello Conservatory before going on to Rome, where I would spend the next 2 years. The Cage-Tudor event came like a bolt out of the blue—all the protocols of the concert situation were violated. The concert began, as I remember, with David Tudor striding down the aisle of the theater and diving under the piano, hitting the underside to make the first sound of the concert. Cage made an appearance playing a piano that rose up into the pit hydraulically. The four performers had cards upon which were written instructions regarding sounds or actions to be made and where to make them. The entire theater was used—stage, aisles, balconies. The work was *Music Walk with Dancers* (1958). During that concert a man walked down the aisle and struck the piano with an umbrella and announced: "Now I am a composer!" At the height of the pandemonium, Cage was tuning a radio that he used as a sound source, and the Pope came on asking for peace on earth.

That concert forever altered the way I thought about music. Until that time I had followed the conventional pattern of composer-performer-audience relationships. One would compose a work, wait for some soloist, ensemble or orchestra to perform it, then hope that the audience would like it. It was a lonely life; a waiting game. I had studied at Brandeis University with the gifted composer Harold Shapero, who, after having composed the stunning *Symphony for Classical Orchestra* (1947), suffered the bitter humiliation of a long hiatus before another orchestra performed the work and propelled his career along. It was a lesson to me. It was not until a few years later, when I got back to the United States and worked directly with Cage and Tudor, that I fully realized the ramifications of their pioneering work. At that time, Tudor was developing systems of homemade and consumer electronic devices primarily for realizing the live electronic compositions of John Cage. Devoted to live performance, Tudor would scour electronic stores searching for inexpensive components, mixers, phonograph cartridges and contact mics, which he combined in ingenious ways, creating his own portable orchestra capable of an immense range of expression.

THE SONIC ARTS UNION

In 1966 I started working with composers more my own age: Robert Ashley, David Behrman and Gordon Mumma, with whom I formed the Sonic Arts Union. For a few years we called ourselves the Sonic Arts Group, but Ashley suggested we change our name to Sonic Arts Union because we were not really a group that improvised or made collaborative works. We were simply like-minded composers who got together to share equipment and perform concerts; we lived in different parts of the country. When we first started the Sonic Arts Union, Bob Ashley and Gordon Mumma lived in Ann Arbor, Michigan, David Behrman lived in New York and I was teaching at Brandeis University in Waltham, Massachusetts. In the early 1970s, Ashley moved on to Mills College in Oakland, California; Mumma joined the Merce Cunningham Dance Company in New York, and I transferred to Wesleyan University in Middletown, Connecticut.

I was at first surprised by Ashley's and Mumma's attitudes toward music making. Their musical gaze looked neither west to Europe nor east to Asia, but was rooted in the American Midwest. Ashley looked at, and listened carefully to, the Michigan landscape for images and speech patterns, which he used in a series of works with speech, including his many operas for television. For example, in *She Was a Visitor* (1967), for spoken chorus, the last syllable of "visitor" was pronounced "er," not "or," as is customary in the more standard North American vocal pronunciation. In his vocal works he made no attempt to hide the Midwestern twang; instead, he exploited it for its musical qualities. Ashley's works were always theatrical; even his acoustical explorations were staged in imaginative ways. In *Four Ways* (1967), four men in business suits open and close the lids of attache cases, altering the acoustics of sounds hidden inside them. In *The Wolfman* (1964), essentially a work about feedback—a microphone is positioned so close to the performer's mouth that changes in the size of the oral cavity bring about great changes in the feedback sound—the performer projects the image of a nightclub singer or political demagogue. Ashley used to say that music was always "about something." From 1957 to 1964, Ashley and Mumma directed the Cooperative Studio for Electronic Music in Ann Arbor, Michigan.

Behrman and Mumma designed their own equipment rather than relying on the banality of the synthesizer or the institutional electronic studio, to which they did not have ac-

---

**ABSTRACT**

John Cage's use of chance operations coupled with David Tudor's configurations of found electronic devices formed a radical departure in twentieth-century music composition and performance. Inspired by this collaboration, author-composer Lucier, along with composers Robert Ashley, David Behrman and Gordon Mumma, formed the Sonic Arts Union, a live electronic music ensemble devoted to the performance of each other's works. The author used scientific experiments, as well as audio test equipment, to compose works that explored the natural characteristics of sound. Along with certain other composers, including Robert Ashley, Tom Johnson, James Tenney and Steve Reich, who created works in which simple procedures yielded complex results, the author helped create a new musical form.

---

Alvin Lucier (composer, author, teacher), Department of Music, Center for the Arts, Wesleyan University, Middletown, CT 06457, U.S.A. E-mail: <alucier@wesleyan.edu>.
Of course. For *Hornpipe* (1967), Mumma designed what he called a “Cybersonic Console,” a small metal box worn on the performer’s belt, which consisted of a microphone and eight variable resonance circuits. As Mumma played sounds into the space on his French horn, the microphones would pick up the room acoustics articulated by the horn sounds, gradually mapping the resonances of the space. Gordon had designed the circuits to change, depending on the sounds and how the space responded to them—he never explained exactly how they did that. It was as if the circuits were alive and had the capacity of memory. Sometimes the system would get out of balance and try to balance itself, hence the prefix “cyber” from cybernetics, the science of self-governing control systems. At a certain moment in the performance, gigantic strands of feedback would sound. That moment was the turning point in the form of the work and took the place of the classical climax in conventional music. For the rest of the piece, Mumma’s task was to complicate the mapping circuits, perhaps by overloading them with information, until they could no longer function—then the performance was over.

In David Behrman’s *Runthrough* (1967–1968), one or two players work dials and switches that control various sound generators and modulators while two other players shine small flashlights onto photoresistors housed in tin cans, distributing sounds to four loudspeakers deployed around the concert space. A photoresistor is simply a semiconductor that, when illuminated, causes a drop in resistance, allowing the signal to flow unimpeded—as if a dam were suddenly removed in a fast-flowing river. Each resistor was routed to an amplifier and loudspeaker, so the performer could send the sounds from David’s equipment to any loudspeaker in any combination, simply by shining lights on the resistors. The photoresistors acted like pan pots or balance controls on stereo amplifiers. Behrman had designed and built his own configuration of homemade components, all of which could be found in commercially available synthesizers at the time, including sine and pulse wave oscillators, voltage control amplifiers and ring modulators.

Sine wave oscillators produce pure tones—that is, sounds without overtones—similar to those heard by blowing across the mouth of a bottle. Pulse waves, however, have rich timbres, somewhat like a clarinet in its lower range. Also called “square waves,” pulse waves consist of all the odd-numbered overtones or harmonics. The nomenclature of these wave forms is derived from the shapes they assume when viewed on an oscilloscope—a device consisting of a cathode ray tube and fluorescent screen, the vertical axis representing the amplitude (loudness) of the signal, and the horizontal, the frequency (pitch). A voltage control amplifier is simply an amplifier that can be controlled by an external signal. A ring modulator produces the sums and differences of two or more frequencies fed into its input, while suppressing the original signals. It was a simple device to make; its name is derived from the ring-like arrangement of its four diodes. Behrman’s system was designed for a specific work, not as a common denominator of what a large consumer public wanted. It sounded better than store-bought synthesizers—it had the mark of a master craftsman.

The most exciting possibility that voltage control offered the composer was that virtually every component could be used as a sound source and a control signal. One of the salient characteristics of *Runthrough*—slow crescendos followed by thumps of sound—was generated by ramp waves controlling voltage control amplifiers. A ramp wave, also known as a sawtooth wave, rises from zero in amplitude to a pre-determined level, then falls abruptly to zero again. When in the audible range, its timbre (or tone color) consists of all the overtones above the fundamental, decreasing in amplitude as the wave rises in frequency or pitch. When tuned below audibility—that is, too low to be heard as sounds by the human ear—the sawtooth wave may be used as a control voltage, imparting its shape (envelope) to whatever components it is patched into. *Runthrough* had an all-over form, similar to Jackson Pollock’s action paintings—that is, most of the time the listener heard everything there was to hear. There were, however, abrupt changes in rhythm, texture and loudness that could be achieved only by the electronic medium. The circuit, amplifier and loudspeaker implemented these changes more quickly than could a bowed string or blown column of air. (The only other work that matched, and perhaps exceeded, these quick shifts of level was Gordon Mumma’s *Mesa* [1966], in which sustained planes of softness and loudness alternate instantaneously. It was unprecedented and exhilarating to experience.) While listening to a recording of *Runthrough*, one is struck by how much of the acoustic space one can hear. Conceiving this piece as a quasi-improvised performance work, Behrman allowed ample time for the possibilities offered by his circuitry to unfold. This time-space, as well as the repetitive rhythmic figures that dominate the performance, served to articulate the acoustic characteristics of the space—they became additional components in the work. In *Hornpipe* and *Runthrough*, there were no scores to follow; the scores were inherent in the circuitry—that was a new idea for me.

**Making Music with Found Equipment**

I did not have the inclination to learn electronics to the extent that I could design my own equipment. I had been on the constant lookout for existing equipment I could use for musical purposes. For my composition, *Music for Solo Performer* (1965), for enormously amplified brain waves and percussion, I procured a differential amplifier that had enough gain to pick up and amplify alpha waves through a pair of electrodes applied to the performer’s scalp. A differential amplifier is simply a circuit that amplifies the voltage difference between two input signals. The output voltage is equal to some constant multiple of the difference between the input voltages. For my work *North American Time Capsule* (1967), I used a Sylvania Electronic Systems vocoder designed for making secure voice communications and efficient transmission through narrow bandwidths via telephone or radio channels over long distances. A vocoder (voice coder) analyzes and decodes speech sounds into slowly varying voltages, then synthesizes or encodes the original speech from the analyzer output. As performers spoke, sang and played musical instruments into an unfinished prototype—the vocoder was still under construction, with wires hanging out of it—I de-tuned and physically altered the sounds I was looking for [1].

In 1967, I discovered Listening, Incorporated, a small company in Arlington, Massachusetts, that was engaged in human-to-dolphin communication research. This company was at the time manufacturing devices called “Sondols” (sonar-dolphins)—battery-operated, hand-held pulse wave oscillators that emitted short clicks whose repetition rate could be manually varied and were optimal for creating echoes off reflective
Fig. 1. Crossings (1982), for small orchestra, with slow sweep pure wave oscillator, page 1 of the manuscript score. The diagonal line represents a slowly ascending sine wave sweeping from C at 32.7 cycles per second to F-sharp at 92.5 cycles per second. Whole notes straddling the diagonal denote long tones played by various instruments. Those on the left and right of the diagonal denote the left and right sides of the loudspeaker from which the rising wave flows. Numbers to the left and right of the diagonal are cues in cycles per second for the players to begin and end their sustained tones.
waves—they only have to be on a fraction of their cycle time—in my work Solar Sounder (1979), a sun-powered sound installation that is still up and running in the Citizens Bank in Middletown, Connecticut. Numerous times, I have used sine wave oscillators for creating standing waves and interference patterns (audible beating) between closely tuned waves, in performance pieces as well as in sound installations. Because of their purity, the crests and valleys of their waves can be perceived in the same way as one can see the nodes and antinodes on a vibrating violin string. The nodal point is where the string is barely moving; the antinode is where it is most actively vibrating. For example, in Seesaw (1983), a sound installation, a slowly sweeping oscillator tone crosses a fixed tone, causing the beating patterns to continually slow down and speed up. If one stands midway between the two loudspeakers, one can feel the waves moving across the space as the wave fronts collide [2]. Perhaps the first work to use sine waves in a spatial way was La Monte Young’s Drift Study (1964), in which two or more oscillators, routed through amplifiers to loudspeakers, were allowed to drift in pitch, their waves moving around the room. Test equipment, particularly sine and pulse wave oscillators, has provided me with neutral sound sources with which I have tried to make expressive music.

In the mid-1980s, performers began asking me for works. In order to maintain the poetry I had tried to achieve in my earlier electronic compositions, I decided to explore the acoustic phenomenon of audible beating. If two or more closely tuned tones are sounded, audible beats—bumps of sound that occur when the waves coincide—are produced. In several works I used musical instruments combined with sine waves, whose purity of sound provided optimal beating with the richer instrumental timbres. For example, in Crossings (1982), for small orchestra, a slowly rising sine wave sweeps up through the range of the orchestra, from a low C (32.7 cycles per second) in the double basses to the high C (4,186 cycles) in the violins. As the wave rises, the instruments play long tones across the rising wave, creating audible beating patterns that start at the speed of the difference between the pitch of the long tone and that of the rising wave at that moment, slowing down to zero and no beating when unison is reached and speeding up again as the wave rises above the sustained tone. The speed of this gesture doubles with each higher octave. The orchestration is determined by the ranges of the instruments—that is, as soon as the rising wave comes into range of a particular instrument, that instrument enters; as the wave rises out of range, that instrument exits (Fig. 1). I also created purely acoustical works in which the beating is produced by the combination of two or more musical instruments. In my work Fideliotrio (1987), for viola, cello and piano, the strings slowly sweep up and down, a semitone above and below a central tone, A at 220 cycles per second, while the piano repeats that tone at time intervals proportional to the distances between the pitch of the piano tones and those of the sweeping strings. The closer the tone of the strings is to the tone of the piano, the farther apart are the repetitions of A on the piano, and vice versa. At unison, the piano’s time intervals are 12 and 13 seconds (the distance in cycles between the adjacent semitones, A flat and B-flat, respectively). At the apex of the sweeps, the pianist repeats the A once per second. The piano part could be considered a code for the strings’ tunings. The beats in this work are less vivid; but at the beginning and ending of the work, when the strings and the piano are close in pitch, the results sound like an out-of-tune piano. The viola and cello act as a fourth and fifth string sounding on the piano’s A below Middle C, in which there are already three strings sounding on the piano when the soft pedal is not depressed.

SCIENTIFIC EXPERIMENTS

Scientific experiments have often given me ideas for pieces; sometimes I do little more than frame them in an artistic context. For example, in my work The Queen of the South (1972), Chladni figures are formed in real time during the performance. By bowing or striking solid objects that have been sprinkled with iron filings or other fine materials, E.F.P. Chladni (1756–1827) showed how sound waves propagate in solid materials. During the duration of the vibra-
tion, the solid material would resonate sympathetically and the grains would migrate along the nodal lines of the object, forming geometric figures. In The Queen of the South, sand, tea, coffee, salt, rice, etc., are strewn on metal, wood, glass or other flat surfaces. As sound from any source causes the surfaces to resonate, the fine materials form patterns determined by the frequency and loudness of the sounds and the physical dimensions of the surfaces. Because the surfaces are not exactly symmetrical, the figures that are created are imperfect and asymmetrical, resembling sand dunes, moon craters and other natural geological formations (Fig. 2). Spectacular photographs of these figures can be found in Hans Jenny's book, Cymatics [3]. Most recently The Queen of the South was performed by the Barton Workshop, a Dutch ensemble consisting of violin, cello, double bass, clarinet and trombone. The surfaces used were two stretched canvases, one white, one black. (Dutch art students were commissioned to make them; they came up with Mondrian-like results.) Ground coffee was strewn on the white surface, sugar on the black. Each player's instrument was miked and its sounds routed at the speed of the beating. One video camera hung above the canvases, an- other at a low grazing angle, picking up the visual activity for viewing by spectators. In the summer of 1996, Queen of the South was performed in Indonesia with vases. The clarinet played the G an octave above. The violin had to be excluded because its range was too high, or it did not have enough power to enable even its low G to cause the canvas to resonate. The players were free to sustain long tones on and around the G, slightly raising and lowering the pitch, causing the grains to move in greater and lesser ways. Closely tuned tones between instruments created audible beatings, which caused the grains to pulsate at the speed of the beating. One video camera hung above the canvases, another at a low grazing angle, picking up the visual activity for viewing by spectators. In the summer of 1996, Queen of the South was performed in Indonesia with four gongs. The struck gong sounds, consisting of initial attacks followed by fairly long decays as the sounds faded to silence, caused the strewn material to move abruptly rather than continuously as it did when vibrated by sustained wind and string tones.

The writings of natural philosopher John Tyndall (1820–1893) have given me ideas for pieces [4]. His experiments with sound-sensitive flames inspired my piece Tyndall Orchestations (1976), a work in which a gas flame reacts to recorded birdcalls, a female voice, violin, jangling keys or other high-pitched sounds, causing the flame to assume temporary shapes. I think of the Bunsen burner as a nineteenth-century oscilloscope—instead of a varying electrical signal being manifested by curves on a fluorescent screen, a picture of the sound is outlined as the sound waves disturb the flame. One can almost imagine seeing the shape of the bird whose call is causing the flame to jump. In another version of this work, glass tubes are placed over the gas flames, producing pure tones whose pitches may be slightly altered by regulating the flow of gas and raising and lowering one end of the tube over the flame. Two or more closely tuned tubes produce vivid beating.

Music for Pure Waves, Bass Drums and Acoustic Pendulums (1980) is simply an orchestration of an experiment I discovered in a British college textbook on the physics of sound [5]: a pith ball was hung by a silk cord against a bell that was sounded with a violin bow. The ball was driven away from the bell by the action of the sonic vibrations in the bell. The experiment was meant to demonstrate the presence of sound in a solid object when the waves are too faint to be seen or felt by touch. In Music for Pure Waves, Bass Drums and Acoustic Pendulums, I suspended Ping-Pong balls in front of and touching four upright bass drums, which are driven by a rising sine wave flowing from loudspeakers positioned behind the drums. As the wave rises, it briefly passes through the resonant regions of the drums, the drumheads vibrate and the Ping-Pong balls are sent flying away from the heads (Fig. 3). Although the waves are constant and the drums are all of the same size, the resonant regions are never the same from drum to drum. It often happens that one or two drums are inactive, almost unresponsive, until well into the wave. All of a sudden, a quiescent drum will become active for no apparent reason. As the waves flow through the drumheads, the balls are sent on excursions of various lengths, depending upon the force of the resonant regions.
nances. It often happens that a ball will fall back to a drumhead just as that head is vibrating outwardly; the ball may be propelled away from the head in extremely long excursions, up to 4 or 5 feet in length. If a ball is caught when the drumhead is in an inward mode, it may be stopped dead.

In 1994, I dedicated a whimsical work, Spira Mirabilis, to biologist Spencer Berry, who teaches a popular course on animal architecture at Wesleyan University, Middletown, Connecticut. In D'Arcy Thompson’s textbook on this subject [6], I came across a drawing of the spiral path of an insect as it moves toward light. Since the insect has compound eyes, it cannot look straight ahead and has to crawl toward the light at a certain angle. As it adjusts its path, it draws an equiangular spiral—that is, one in which all of the angles are equal (Fig. 4). Spira Mirabilis is for any bass-sustaining instrument and electric light (an ordinary floor lamp) illuminating an array of photoelectric cells which, when lit, acts as a microphone, picking up the 120 cycles per second tone (roughly a B, second line bass clef). The tone is caused by a 60-cycle hum, the sound of alternating current in the United States (it is 50 cycles in Europe). During the brief performance, the player walks toward the light in an equiangular pattern—in ten constant angles—imitating an insect. For each angle, the performer sounds a long tone whose duration and pitch follows a descending Fibonacci series (each succeeding number is the sum of the two previous ones). Starting on F (55 cycles above the B), the player sustains that tone for 55 seconds, followed by a D-sharp for 34 seconds, a D for 21 seconds and so on, until eventually reaching unison with the 60-cycle hum, the tone of the sounding light (B-natural at 120 cycles per second). Because the light tone is more or less pure, audible beating can be heard between it and the instrument, typically a trombone. Spira Mirabilis is not in the category of my other works that are actually in some sense experiments, the outcome not exactly known. It is rather a piece about something scientific, similar to program music. In any event, I was happy to create a work for a friend, for a specific occasion.

**TOWARD A NEW FORM**

Several other composers have made works in which a constant unidirectional action yields unexpected and complex results. In James Tenney’s work Having Never Written a Note for Percussion (1971), a percussionist rolls continuously on a gong or other percussion instrument, making one slow, gradual crescendo and diminuendo. The gong’s response, however, is not continuous; it steps into different modes of vibration.

Robert Ashley’s work String Quartet Describing the Motions of Large Real Bodies (1972) takes its metaphor from the pseudo-scientific writings of Immanuel Velikovsky [7]. In several of Velikovsky’s books, including Worlds in Collision, he states that twice in the distant past the then-comet Venus came perilously close to Earth, sweeping its fiery tail across the land, causing catastrophes of Biblical proportions. If it came speeding toward Earth, we would not perceive it in constant motion; we would only notice it at discrete intervals. The same is true for objects in slow motion. In Ashley’s Quartet, the players bow slack strings extremely slowly and continuously—about 10 minutes per bow length; instead of a continuous tone, discrete pulses of sound are produced. In contrast to the extreme slowness of the bowing, Ashley routes the string pulses through one to seven delay matrices timed from 5 to 250 milliseconds. The structure of Tom Johnson’s work Dragons in A (1979) is taken from a mathematical game he found in an old issue of Scientific American [8]. The game uses a simple binary formula best explained for non-mathematicians by folding a piece of paper in half several times, always in the same direction, revealing, when partially opened up again and viewed from the side, an asymmetric form resembling the shape of an imaginary dragon (Fig. 5). Figure 6 depicts a geometric realization of the same idea. Another way of demonstrat-
ing this phenomenon is to assign 1s and 0s to inward and outward folds, re-
spectively. Five folds of a piece of paper would thus yield the following pattern: 
1, 110, 1101100, 11011001110011100100, 110110011100111001110110001100100. 
By assigning upward steps to 1s, and downward steps to 0s in the preceding 
pattern, Johnson derived a graceful and satisfying melody [9].

The works mentioned above are as different from each other as are the 
composers who created them. In retrospect, it is surprising that so often, these 
composers used scientific, mathematical or acoustical testing procedures as struc-
tural methods. Perhaps the reason was a response to John Cage’s use of the 
Magic Square, the hexagrams derived from the I Ching, the Chinese Book of 
Oracles, and chance operations, which he employed to achieve a non-subjective 
music. A similar result was attained by using neutral procedures devoid of per-
sonal choices or predilections, including exploratory tasks (Gordon Mumma’s 
Hornpipe), continuous actions of the per-
former (Robert Ashley’s String Quartet 
and James Tenney’s piece Having Never 
Written a Note for Percussion), or auto-
matic systems (Tom Johnson’s Dragons in 
A). It is ironic that most of these pieces 
were intensely personal, particularly as 
far as the performances were con-
cerned. The neutrality of these struc-
tures seemed only to place the per-
former, and therefore the listener, more 
firmly in the human situation in which 
most people found themselves in that 
 burgeoning technological world. Most 
of the works share a common composi-
tional principle: an action or process, 
set into motion and sustained through-
out the course of the work, produces un-
expected and complex results. These 
and other similar works, including Steve 
Reich’s Come Out (1966) and my own 
work I Am Sitting in a Room (1970), both of 
which employ repetition to turn ev-
eday speech into music, are perhaps 
closer in spirit to alchemy, whose pur-
pose was to transform base metals into 
pure gold.

References and Notes
5. Edmund Catchpool and John Satterly, Textbook of Sound, 7th Ed., revised by H.N.V. Temperley (Lon-
6. D’Arcy Wentworth Thompson, On Growth and Form (abridged), John Tyler Bonner, ed. (Cam-

Discography of Works by the Author
Bird and Person Dying (1975), Cramps Records, Italy. Performer with microphones and electronic birdcall.
Chambers (1968), RAS, Revista de Arte Sonoro, Number 2. Performers with resonant objects.
Clocker (1978), Lovely Music LCD 1019. Performer with galvanic skin response sensor, digital delay sys-
tem and amplified clock.
Crossings (1984), Lovely Music LCD 1018. Small or-
chestra with slow sweep pure wave oscillator (New World Consort).
I Am Sitting in a Room (1970), Source Record #3. Alvin Lucier, voice.
Thomas Ridenour, for clarinet in A with slow sweep 
pure wave oscillator.
In Memorium Jon Higgins (1985), Timescrapper 
Indian Summer (1993), What Next? Recordings, AC-
Music on a Long Thin Wire (1977), Lovely Music LCD 1011.
“Music for Alpha Waves, Assorted Percussion and 
Automated Coded Relays (1980),” Imaginary Land-

Lucier, Origins of a Form 11