# Rencontres internationales du Collegium Musicæ
# Jean-Claude Risset : interdisciplinarités
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**Jean-Claude Risset, le temps des découvertes**

**Abstract -**
Découverte et création d'un nouvel univers sonore
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La remarquable percée de la recherche en informatique musicale de Jean-Claude Risset, à partir de 1964 chez Bell Telephone Laboratories, a élevé les idées abstraites que Max Mathews avait développées à des exemples concrets de sons synthétiques qui ont répondu à des questions d'acoustique et de perception posées de longue date . Son travail a servi de balise pour quelques-uns d'entre nous qui suivaient aussi la piste de Mathews. Avec un doctorat en physique et des années d'études musicales, Risset s'intègra parfaitement dans l'environnement grisant qui était le domaine de Mathews. J'ai aussi commencé en 1964 dans un environnement similaire au laboratoire d'IA de Stanford. J'ai d'abord rencontré Risset en 1967 lorsque nous avons partagé notre travail, le sien dans l'analyse et la synthèse et le mien dans la spatialisation et la synthèse FM que je n'avais découverte que quelques semaines auparavant. Ainsi a commencé notre longue association. Mais c'est dans la composition de Mutations (1969), dans un moment de génie, inspiré et inspirant, qu'il conjoint les timbres inharmoniques avec la mélodie et l'harmonie dans l'espace des hauteurs, brisant le verrou des lois de la nature sur la façon dont leurs partiels peuvent être arrangés et perçus. Chacun selon notre propres sensibilité, nous avons suivi cette voie.

Discovering and creating a new universe of sound

The remarkable breakthrough research in computer music by Jean-Claude Risset, beginning in 1964 at Bell Telephone Laboratories, elevated the abstract ideas that Max Mathews had developed, to concrete examples of synthesized tones that answered longstanding questions of acoustics and perception. His work served as a beacon for a few of us who were also following Mathews' lead. With a PhD in physics and years of music studies, Risset fit perfectly in the exhilarating environment that was Mathews' domain. I also began in 1964 in a similar environment at Stanford's AI Laboratory. I first met Risset in 1967 when we shared our work, his in analysis and synthesis and mine in spatialization and FM synthesis that I had discovered only a few weeks before. Thus began our long association. But it was composing *Mutations* (1969), in a moment of genius, inspired and inspiring, that he conjoined inharmonic timbres with melody and harmony in the pitch space, breaking the lock of nature's laws over how their partials can be arranged and perceived. According to our own sensitivities, we each followed this path.

[*When coordinating text with ppt slides,* ➤ *<space bar> or <right arrow>to advance to the next animation and to the next slide*]

**DISCOVERING AND CREATING A NEW UNIVERSE OF SOUND**

➤ ➤
It is my honor to be present to pay homage to my inspiri C Cng colleague and friend at this celebration of Jean-Claude Risset's musical and scientific contributions.

We both entered on this grand adventure of computers and music in 1964 without knowledge of one another's work until several years later. We were enabled by Max Mathews, Jean-Claude at Bell Telephone Laboratories (known as Bell Labs) and I at the Stanford Artificial Intelligence Laboratory (known as SAIL) at Stanford University. Standing behind Max Mathews at Bell Labs was John Pierce, the director of research, who provided the corporate protection that permitted Mathews to pursue part-time his interest in computer music, which was outside the mission of Bell Labs.

It was Mathews' seminal paper ➤ "The Digital Computer as a Musical Instrument" [Mathews 1963] that captured our attention. The paper describes the basic ideas of creating sound from numbers in contrast to contemporaneous uses of computers in music that had to do with the generation and manipulation of music data to be performed by acoustic instruments. ➤ The paper emphasizes the generality of Mathews' computer program in which he boldly states «any perceivable sound can be produced.» This is the assertion that got our attention.
In addition to Mathews' program, both Pierce and Mathews contributed seminal ideas to this field that defined research and artistic paths that are being pursued to this day. They composed pieces to demonstrate their ideas. While not musically sophisticated — they were sometimes awkward and even cartoon-like in character — these short works are filled with insights into the perception of music and they present sophisticated ideas about composing with computers. They were unique in that they were rooted in perceptual research. [*]
➤We listen to an example from Mathews' Numerology (1960). ➤ As I said, cartoon-like in character, but rich in ideas!

MULTIDISCIPLINARY LABORATORIES — CONTEXTS FOR DISCOVERY
➤
Both laboratories were multidisciplinary environments that had an enormous impact on the direction and ultimate success of our work. In both the environments the ongoing work was open for everyone to know, with no concern for "idea theft" as one would expect of first class researchers at the top of their fields. Comments by colleagues advanced the pace and the quality of a researcher's work. In my case, I cannot imagine having succeeded outside of SAIL's special environment.

Bell Telephone Laboratories

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[*] Following their retirement from BELL LABS years later, Pierce and Mathews pursued their musical research interests fulltime at the Center for Computer Research in Music and Acoustics (CCRMA) at Stanford University.

In 1964, Bell Labs was certainly the greatest concentration of scientific and engineering brain power on Earth. Pierce himself conceived and directed the development of the first two communication satellites and originated the name “transistor” that was invented in his lab. Mathews was the director of the Behavioral Research and Acoustics Labs, where Roger Shepard developed his theory of pitch, multi-dimensional scaling, and auditory and visual paradoxes — work that Jean-Claude immediately saw could be developed and used in his music. Manfred Schroeder worked in many areas including acoustics and artificial reverberation. There was an anechoic chamber and audio equipment befitting such a major laboratory. There were powerful computer analysis and synthesis tools available that had been developed for speech and hearing research. In the tradition at Bell Labs of open office doors, the coders of these tools were available to provide guidance in their use. ➤And in the background was Claude Shannon’s sampling theorem from his Mathematical Theory of Communication, the first reference in Mathews’ seminal paper.

Invited to work at Bell Labs by Pierce and Mathews on the recommendation of Risset’s advisor Professor Grivet at l’Insitut d’électronique fondamentale, this was the rich context into which Jean-Claude entered Bell Labs in September 1964. With his solid education in physics and his musical training in both performance and composition, he came fully prepared to engage with all that Bell Labs offered him. What Pierce and Mathews could not have known in advance was his remarkable «ear», his ability to hear inside of sounds — and because of his knowledge of the underlying physics, he knew how to manipulate the parameters provided by Mathews’ program, to modify and discover sounds. They could not have known, also, his determination to bring together music, perception, and physical acoustics as the foundation of his research and his oeuvres.

As Mathews’ work became known to the music community, many musicians and composers visited Bell Labs, of whom the most important was Varèse. Jean-Claude had rich discussions with Varese from whom he gained support for the elevation of science and technology in the composition of new music and for the importance of Jean-Claude’s work to its future.

Jean-Claude’s very first project at Bell Labs was the analysis and synthesis of brass tones. Using available analysis programs, he discovered that the «signature» of a brass tone is found in the rapid increase of the harmonic partials from low to high-order during the attack portion of the tone. This had not been known before because until the age of digital computers there had never been a tool that was capable of a period by period analysis. The results from this research were profoundly meaningful to Jean-Claude (and to my work, as we shall see), as his synthesis based upon the analysis was the first instance of a computer generated tone that had the internal complexity of a natural acoustic tone. From this experiment he was able to produce a number of lively, supple timbres that had a naturalness similar to those found in natural tones: flute, high and low brass tones, gongs, and drums.

He extended Roger Shepard’s famous tones to compelling illusions that with others will be described in a following presentation.

STANFORD ARTIFICIAL INTELLIGENCE LABORATORY (SAIL), STANFORD UNIVERSITY

SAIL was founded in 1963 by John McCarthy, after he moved from the Massachusetts Institute of Technology to Stanford with Les Earnest as the executive director SAILwas lavishly funded by the Department of Defence and was populated by graduate students and staff from computer science, mechanical and electrical engineering, linguistics, mathematics, and even philosophy — like a small Bell Labs. Located in the hills above Stanford, many of the staff and students had long hair and wore tie-dyed T-shirts in the spirit of nineteen sixties San Francisco—quite unlike Bell Labs. The projects included robotics, speech recognition, fast machine architectures, cryptography, self-driving vehicles and the development of the SAIL programming language. All the research was performed on a fast time-shared PDP-10 research computer having thirty or more terminals throughout the building. Most of the terminals were in shared spaces, available to any user, which permitted everyone to know something about one another's work. An unused terminal screen displayed, «Take me, I'm yours.»

As I noted earlier, it was Max's seminal paper published in 1963 that caught my attention. I was given this article by Joan Mansour, a scientist and fellow percussionist in the Stanford Orchestra ➤who had heard me speak of electroacoustic music. Before coming to Stanford as a graduate student in 1962, I had studied with Nadia Boulanger for three years in Paris where electroacoustic music was often a part of new music concerts — although not hers. I heard for the first time works where the loudspeakers are the intended **source** for music — electroacoustic music and musique concrete — rather than used as a means to reproduce acoustic music. I was struck especially by Stockhausen's *Gesange Der Junglinge* (1956) and the cavernous spatial atmosphere that he created with four loudspeakers surrounding the listeners. I imagined composing music in imagined spaces that were constructed for compositions in which sound could be positioned, animated, and moved through space ➤ as Stockhausen composed to a limited extent in *Kontakte* (1958). When I arrived at Stanford directly from Paris, I was disappointed to learn that there was no interest in electroacoustic music. As I was completely naïve in regard to physical acoustics, tape recorders, electronic or tape music studios, Mathews' paper suggested that I could compose music for loudspeakers if I could gain access to a computer and learn to program. Joan Mansour's thoughtful act determined the course of my life.

With Mathews' paper in hand, I discovered that the undergraduate tuba player in the Stanford Orchestra, ➤David Poole was a computer science major who spent most of his time in John McCarthy's year old Artificial Intelligence Lab. After taking an undergraduate programming course for non-engineering majors that convinced me that I could learn to program a computer, David Poole got permission from McCarthy for me to use his computers at nights and on weekends.

Always at Poole's side, I learned from him and others. Poole rewrote Mathews' synthesis program for the PDP-10 computer, Music 10, and I began learning and programming spatial illusions, ➤ first in stereo and then by 1968, ➤in four channels after a young engineer built for me a four channel digital to analogue converter (DAC). ➤ ➤➤➤➤➤➤➤➤➤➤➤After completing the spatial control and processing programs, I reflected on what I had accomplished and the nurturing environment in which researchers had freely answered my many questions providing my incidental education along the way. Without ever touching a physical patch cord or a soldering iron, I had been able to create complicated Lissijous sound trajectories in a 360° space that only required some ability at programming. There is some irony in the fact that I was able to gain access to a million dollar computer system but not to a four thousand dollar Buchla synthesizer from across the San Francisco Bay.

➤

The discovery of FM Synthesis

Late in 1967 I began searching for sounds that had internal dynamism for my spatial experiments. I experimented with pure tones that had rapid periodic change in pitch, vibrato. Over the course of many hours in the middle of the night I increased the vibrato rate and depth beyond the limits of change of pitch through time. I had created sounds that were rich in partials, both harmonic and inharmonic in the frequency domain. The sounds transposed, the number of partials increased with increase in vibrato depth, the partials were harmonic when the ratio of the carrier frequency and the vibrato frequency were integers. It was clear that there were some laws behind this phenomenon and it was clear too, that this was a breakthrough as these partial-rich sounds were being generated with only two sinusoidal oscillators. ➤ I carefully wrote down the parameters, but not having the habits of a scientist I did not date them. George Zucker, an engineering graduate student, pointed out that vibrato was a special case of frequency modulation. From the SAIL library we looked at a radio engineering text and there, explaining perfectly what I had just produced, were the equations for a sinusoidal modulation with graphs of the resulting spectrum. For this reason, I have never called FM synthesis an invention, rather a discovery of my «ears», a great gift from nature — hence the title of my composition *Turenas* ➤ (1972). [show anagram]

## ➤MY FIRST MEETINGS WITH JEAN-CLAUDE RISSET

In December 1967, during the holiday break from Stanford, I visited Mathews at Bell Labs. I had not known of Jean-Claude Risset before Mathews introduced us at this meeting. It was for me, and perhaps for him, too, and exhilarating moment. We shared with enthusiasm what we had accomplished to that point. He played for me his finely wrought timbres, the spectra of which evolved through time, and his early «Shepard Tones» experiments, all of which would become part of his compositions to come and described in his «Catalog of Computer Synthesized Sounds» [Goebel 1995] that is one of Jean-Claude's great legacies. (Risset 1969) He also explained in great detail his analysis of brass tones three years earlier and his conclusions regarding their «signature».

In an age when the compute time to real-time ratio of hundreds or even thousands to one, Jean-Claude's synthesized tones served as a beacon that beckoned me forward, and perhaps others, with the prospect of faster computers making our time-consuming efforts at the time worthwhile.

I showed him my spatialization program and played for him the FM synthesis examples that I had produced only a few weeks before, including many where the deviation changed through the course of the tone producing spectra that evolved through time, although not yet refined as were his that I had heard a few minutes before. ➤ He carefully copied the data from my notebook while his colleague Pierre Ruiz copied the processing diagram. Years later, when asked the year of my discovery, I could not say for sure. But I remembered the importance of this visit to Bell Labs and Jean-Claude found his notes dated 12/18/67, with the heading ➤ «John Chowning's negative increment tones». ➤ The index could move backward as well as forward through the sine table

When Jean-Claude first visited SAIL in April 1969, he heard my spatial illusions in four channels, the advances I had made in FM timbres since the discovery two years earlier and he played for me *Little Boy* (1968) and explained his detailed composition of these elegant sounds. ➤We discussed how Mathews' abstract conception, as in Music IV, V, and Stanford's Music 10,

would lead electroacoustic music into the digital age where a composer's musical ideas could be realized directly as sound objects and then transformed and manipulated in musical contexts within the same programming environment, as in his tiling of a sound's partials in *Little Boy* — syntactical aspects of music are linked to the internal structure of sound through "composing the sound itself."
When he returned to Bell Labs he composed *Mutations* (1969) from June to August.]

*Mutations* (1969) and Structured Spectra-➤

Until *Mutations,* the frequencies and amplitudes of partials in an inharmonic timbre as in gongs and other idiophones, was determined by the physical laws of the vibrating mass. ➤In a moment of great insight, Risset unlocked the inner structure of the sound of a gong from a physical source, creating a complex sound spectrum that cannot exist in the natural world — a natural sounding inharmonic spectrum where the partials are precisely organized: ➤that cohere because of the perceptual law of «common fate», ➤that are imprinted with pitch material, providing a structural link to the music of which it is a part.
In *Little Boy* he had created gong sounds of partial frequencies derived from chords, but in discussing with Jean-Claude the importance of this insight in 2006 — as it was the formative idea of my composition *Phoné* (1981) — he wrote➤ «The beginning of *Mutations* is indeed like a manifest: : melody, harmony and timbre share the same ratios.» [Risset 2006] Here is the opening. ➤ ➤ Here, ➤the same pitches begin exactly together and fuse because of the gestalt principle of "common fate." They are heard not as pitches but as timbre … a single inharmonic spectrum "*imprinted"* with the pitches. ➤ ➤

In every presentation that I give about my own work I include these slides. ➤ Structured Spectra: first elaborated by Jean-Claude Risset in his *Mutations* (1969) – an idea of great theoretic importance, perhaps dreamed of by Varèse. ➤ In his work *Mutations,* Risset defined a relationship of timbre to pitch where sets of pitches also become the spectral components of a sound, yielding a magical, never before heard, functional relationship in the pitch/timbre space.

Even Pierre Schaeffer's imaginative step in detaching and transforming a sound object from its physical causal source, a sound's partials cannot be individually manipulated. In *Mutations* sound spectra became structured, joining line, harmony, and time to manipulate as a parameter of compositional process. The partials were composed as the sound of a gong, then later in the composition they were freed from this temporal lock to fly through the frequency space through his technique of tiling. This can only be achieved through the process of synthesis. He overcame what Pierre Boulez in a presentation at the Théâtre d'Orsay in 1980 [Boulez 1980], would point out is the difficulty in joining percussion instruments in a structured way with "neutral elements," meaning pitched acoustic instruments and their common practice tuning system,➤ «These [percussion] instruments, which were actually gathered from all the civilizations of the world, did not fit into the hierarchy that had been established for the other instruments. And that is indeed the difficulty: being able to integrate them into the universe of composition without them appearing to be intruders or without them appearing as simple additions of color, more or less exotic, more or less external.

➤… While a neutral element starts a new life, takes a new aspect depending on the configuration of which it is a part, on the contrary elements that are too rich [percussion] and are no longer neutral tend to escape completely from the configuration imposed upon them. They become independent, they escape the configuration and so if they escape it, they destroy it.»[1] Boulez, eleven years later, seemed unaware of Risset's insight into this altogether new way of thinking about percussion sounds and musical timbre?

➤In a certain sense, Jean-Claude Risset had reattached the sound object to its physical and perceived source, but now mutable, to be composed itself, within the rich tradition of contemporary "common practice" acoustic music system or in altogether new systems that some of us have explored.

➤The YAMAHA DX7 — The Democratization of Computer Music-

The story of the FM patent licensed to YAMAHA is well-known, so I will only make the following points in regard to ~~the license and~~ its most famous product, the DX7 synthesizer of 1983: ➤

- I am not the "father" of the digital synthesizer and I am not the inventor of the DX7. It is the product of about one hundred very skilled YAMAHA engineers' working over a ten year period based upon my 1967 "discovery" and about 10 consulting trips to Japan to give advice in its development, ➤
- paired with a small personal computer and Dave Smith's MIDI, the DX7 became an affordable and reasonably useful computer music work station. As our dear David Wessel told me, «John, computer music has hit the streets!» ➤
- in 1969, I implemented in FM synthesis, a brass tone based upon Jean-Claude's careful explanation of his analysis and data reduction model, which became one the FM timbres that convinced YAMAHA in 1973 to commit to its ten years of research and development. The other was the FM singing voice that I will explain below. ➤
- Ring-tones

➤In producing simulacra of percussive timbres, I had correlated «strike force» with spectral bandwidth and centroid, such that the greater the amplitude the greater the index of modulation and duration. ➤Remembering Jean-Claude's explanation of the brass «signature», I simply let the index follow the amplitude envelope, thus correlating instantaneous amplitude with spectral bandwidth. ➤ This was a major breakthrough!

➤With JCR at IRCAM 1978 -79 Mutations to Phoné

Invited by Jean-Claude, then director of the Département d'Ordinateur at Ircam, to spend a year at IRCAM in 1968, I quickly settled in, ➤ as IRCAM had the same PDP-10 computer, system software, and music software that we had at the Center for Computer Research in Music and Acoustics (CCRMA). ➤ The computer music project at SAIL became an independent center in 1974 with its own time-shared computer and high-performance synthesis hardware. ➤In addition Jean-Claude installed Mathews' MUSIC V program. ➤

This photo is taken at IRCAM in 1977. ➤

As an initial project, I began developing an FM model of the singing voice, based on an insight from Michael McNabb's composition Dreamsong (1978), in which he was able to produce a convincing soprano tone by capturing the fundamental frequency through time of a recorded soprano tone and applying it to a stored wave complex wave. At the same time, Gerald Bennet, Director of the Départment Diagonal, had launched a project, Chant, developing the synthesis of the singing voice by a quite different process developed by Xavier Rodet, Forme d'Onde Formantique , known as FOF. It seems that this was a time for the «singing voice» as Jean-Claude had finished *Inharmonique* (1977), the year before.

As support for his project, Gerald had invited Johann Sundberg, from the Royal Institute of Technology, the preeminent researcher in the acoustics and performance of the singing voice. ➤ Sundberg became an occasional, but essential resource, providing me with formant trajectories as a function of pitch frequency for the five primary sung vowels. These trajectories are not obvious -- and that they are asynchronous in their rise or fall depending upon phonation frequency was one of Sundberg's great discoveries. The importance to Gerald Bennet's project and to our project was enormous.

➤I generated a chorus of voices with carefully tuned control over performance details, exactly of the kind that Jean-Claude had applied to the tones in his sounds. For each formant there is a carrier oscillator whose frequency is set to the harmonic closest to the formant frequency. The formant frequency trajectories are stored in a table. In this example of FM voices, The modulating frequency is always the pitch frequency, which produces true harmonics for each of the carrier oscillators. You will hear that the various sung vowels do not lose their soprano quality with pitch height and varying musical dynamics. ➤ Extending these ideas to male vocal tones I created a basso profundo by frequency modulating the modulating frequency. ➤ Sundberg, was surprised and pleased that his hard-won theory of vowel trajectories was confirmed by three very different techniques, Bennet and Rodet's FOF, our FM simulation, as well as his own subtractive synthesis. ➤

In the course of my development of sung vocal tones, I made a discovery that Jean-Claude describes: ➤ «John Chowning has demonstrated that the ear uses common fate … to distinguish between different sounds with frequency components that coincide : the ear attaches together all the components that have synchronous microvariations.» [Risset 2003] This is the well-known example. ➤ With the addition of micro-modulation (vibrato), synchronous through all harmonics, the listener perceives the tone as that of a singer rather than an electronic tone. The vibrato causes the harmonics to fuse allowing the listener to identify the source as a voice. Fusion, or the tendency for disparate spectral components to cohere is dependent, in this case, upon micro-modulation - common fate.

Jean Claude continues, ➤ «In Phone (1981), by controlling such modulation, he makes voice-like tones to emerge from an indistinct magma of sound. This effect takes advantage of the fine control afforded by the computer, but also of the idiosyncrasies of perception.» [Risset 2003] Although these words were written twenty-five years after we created these structures in his lab, at the time he always let me know his thoughts about perception and of his strong support of my work — ➤**Jean-Claude, a master of the disciplines, music and science, let ME, having no scientific training, feel comfortable in this universe of sound synthesis that we shared.**

➤But what he did not mention in his writing regarding *Phoné,* is that its fundamental idea sprouted directly from *Mutations* as its base. Because this composition was so much influenced by Jean-Claude and because we will have the opportunity to listen to both works later, I want to note another forward force of Mutations and explain exactly the relationship between the two works.

After concluding the singing voice simjulations, I thought of Mutations and how I could modify my fusion example and make it conform to Jean-Claude's pitched gong. Here is how it worked. ➤First, the fusion example. Then by changing the envelope of the micro variation/ fusion example, I produced a struck metal bar that evolves into a soprano voice and returns at the end to the decay of a metal bar ➤ ➤I let the addition of voice harmonics and micro-modulation be represented by the shaded fundamental.

Now, with this image of the metamorphosis bell to voice to bell ➤ I replace one of the components of the *Mutations*' structured gong. ➤ and so with the other components from the frequency space to the pitch space. ➤ At the beginning of this example the simultaneously occurring sinusoids cohere because there are similar amplitude envelopes that all begin together (common fate). We hear therefore a small bell tone. But as the voices appear, the micro-modulation is synchronous within each voice -common fate-- but asynchronous between the voices enabling us to separate out the individual voices.

This is the example in which the bell to voice metamorphoses are nested within the idea of structured spectra from Mutations ➤

And now the beginning of Phoné ➤ ➤

➤I have limited this talk to our shared experience in synthesis because; ➤

- At the beginning synthesis of sound was the only means of sound generation by computers because memory was so expensive. Except for short samples, sampling did not become possible until the 1980s. ➤
- It was in the terrain of synthesis that we uncovered important attributes of sound and gifts of nature that had, until this work, remained unknown. ➤
- Through many hours of thought as we waited for the computers to compute the sounds, sample by sample, this was where our discoveries were made, all of which have been used and developed through generations of composers and musicians. ➤

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THANK YOU

**References**

Boulez, P. 1980. Pierre Boulez présente: Stria (1976); extraits / John Chowning. Kontakte (1960); extraits / Karlheinz Stockhausen. Arcus (1978); extraits / York Höller. Audio cassette, IRCAM-Radio France Serié II /

Cassette 3 (Matériau et invention musicale, Vol. 3.).
(Audio recording of concerts presented at IRCAM and
the Ensemble InterContemporain, 22–28 April 1980,
recorded at the Théâtre d'Orsay, Paris).

Goebel, J. 1995. (producer). *The Historical CD of Digital Sound Synthesis.*
Computer Music Currents 13, Schott Wergo.

Mathews, M. V. 1963 :"The Digital Computer as a Musical Instrument," *Science*, Vol. 142 (1963) No. 3592, 553-557.

Risset, J.-C. 2003 : "The Perception of Musical Sound," https://liberalarts.utexas.edu/france-ut/_files/pdf/resources/risset.pdf

Risset, J.-C. 2006. Personal email communication, 02/28/06 at 1:45 PM. John Chowning Papers, Stanford University Archives.