Singing cells, art, science and the noise in between

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Synopsis

My investigations focus on the artistic, scientific and cultural context of *The dark side of the cell* project, as well as on the larger context of art-science collaboration in which this project is situated.

The dark side of the cell is an audio-visual event treating what I consider to be one of the most interesting recent discoveries in nano-biotechnology: cellular sounds. *The dark side of the cell* takes this scientific discovery and places it in an artistic context. The act of claiming the tool of the scientist – the Atomic Force Microscope - as a new musical instrument and introducing the sound of cells in the form of a concert is performed as a cultural act. It is another step in extending the repertory of music, and shifting the borders of art. Cells can be observed and their sounds recorded but they can also be manipulated through temperature changes, chemicals and physical force, which results in a change of sound. Much mystery is brought forth by the discovery of cellular sound, and few answers can be given. It is unknown how or why cells oscillate, but it is possible to manipulate this oscillation. *The dark side of the cell* project draws attention to the discrepancy between scientific knowledge and technological power. Its composition reflects the general scientific process from discovery through experimentation to control.

For a long time musicians have been inspired by microscopic life-forms and the fascinating structures of the smallest building blocks of the universe, but not until now have we been able to listen to the sound of living cells. Prof. James Gimzewski and Andrew Pelling at the UCLA Department of Chemistry first made the discovery that yeast cells oscillate at audible frequencies in 2002. In collaboration, Andrew Pelling and Anne Niemetz from the Design|Media Arts department developed the first concert of cell sonics.

Interdisciplinary projects such as *The dark side of the cell* naturally raise the issue of collaboration in the art making process and production. Media artists have broken ground for a growing understanding between art, the humanities and science, but the ongoing controversies triggered by C. P. Snow's thesis of the "two cultures" indicate that, although changing, the separation between science and the humanities remains a problematic aspect in Western culture.[1] The process of reconciliation between the "two cultures" is still in a vulnerable stage, even though 45 years have passed since Snow's lecture. Remaining issues and positive developments are discussed in regards to the role of the media art as field of intersection of the disciplines. Examples of various art-science projects give insight on how transdisciplinary collaborations can be established, and on what basis successful collaborations can flourish. Pioneers of the interdisciplinary alliance are continuing the exploration of emerging fields of research, and in doing so continue to challenge the traditional views of art and science.

[1] *The two cultures*, C.P Snow, Cambridge: Cambridge University Press, Orig. published 1959

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1.0 Introduction

1.1 Background

The dark side of the cell is the project I developed in collaboration with Andrew Pelling, PhD student at the UCLA Chemistry department. The project grew out of the interdisciplinary exhibition project *NANO*, led by our mentors, media artist professor Victoria Vesna and nanoscientist professor Jim Gimzewski. *NANO* involved several UCLA departments, as well as the Los Angeles County Museum of Art (LACMA) and various industrial sponsors.[1] My experience within these collaborations led me to investigate upon the general circumstances of interdisciplinary work and the specific context of art-science collaboration in which *The dark side of the cell* project is situated. Both, *NANO* and *The dark side of the cell* are exemplary for art projects that recontextualize scientific research by introducing it to an artistic audience in a museum. My participation in these projects allowed me to observe the challenges and problematic aspects of bringing together art and science, academic and commercial world. As media artist, I am particularly interested in the role of my discipline within this process.

Media artists use technology as medium and subject matter, observing, mirroring, criticizing, creating dialogue and contributing their view to our society of rapid technological development. One of the tasks media artists commit ourselves to is exploring cutting edge technologies and observing advances in science, in order to be able to anticipate future technological developments and their impact on society. On the one hand, there are media artists who devote themselves to artistic and scientific research to equal degrees, while on the other there are media artists who seek to collaborate with scientists. When scientists and artists team up to tackle an issue, they combine their specific expertise in both fields, to have a broader scope in approach and treatment. Collaborations can be the base of close and intense exchange between the participants, allowing the creation of a whole that is larger than the sum of its parts. But they can also unearth differences and disagreements, challenging the collaborators to bridge the divide. Projects bringing art and science together have become more popular in recent years, but it is still rare to see projects that engage artists and scientists equally in current media art practice.

An example of such a collaboration is the *NANO* exhibition project, shown at LACMA in 2003/2004. It was produced by LACMALab and the UCLA departments of Design|Media Arts, Chemistry and Literature. A group of media artists and nanoscientists, led by Prof. Victoria Vesna and Prof. Jim Gimzewski, developed the installations for the exhibition. As a Design|Media Arts graduate student, I was one of those who participated in the development of the exhibition.[2] *NANO* is a transdisciplinary collaboration, including, among its many elements, text interventions by a group of writers led by professor Katherine Hayles, set in the innovative architectural structure designed by Sharon Johnston and Mark Lee.

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[1] *NANO*: http://nano.arts.ucla.edu; LACMA: http://www.lacma.org;
LACMALab: http://www.lacmalab.org; UCLA: http://www.ucla.edu

[2] Participating Design|Media Arts students: Ashok Sukumaran, Daniel Sauter, Osman Khan, Michael Chu

Nine interrelated installations aim to involve the visitor in the radical shifts of scale and sensory mode that characterize nanoscience. In the central installation, visitors enter a giant cell, where they can interact with virtual “molecules”. A reactive floor that mimics the structure of graphite will change form as visitors move through the architectural space design based on the Dymaxion Map[3]. Quotations from novelists and scientists are placed throughout the exhibition to offer insight into how nanoscience is being imagined by many different creative minds.

The term “nanotechnology” was coined by Norio Taniguchi in 1974.[4] Generally, K. Eric Drexler is credited with introducing the term into public consciousness though his popular book *Engines of Creation*, in which he proclaims the interchangeability of the terms “nanotechnology” and “molecular technology”:

> “One might doubt that artificial nanomachines could even equal the abilities of nanomachines in the cell, if there were reason to think that cells contained some special magic that makes them work.”[5]

“Nano” comes from “nanos” – the Greek word for “dwarf”. The scale of nano is the scale of the molecular level, one nanometer being defined to be a billionth of a meter. The Merriam-Webster Online Dictionary describes nanotechnology as “the art of manipulating materials on an atomic or molecular scale especially to build microscopic devices (as robots)”.[6] Most scientists will agree on the definition of nanotechnology as the “science of the very small”, but there the agreement usually ends.[7] Nanotechnology crosses a wide range of fields including physics, engineering, biology and medicine.

1.2 The collaboration within the collaboration

Since I began my media arts studies in 1995, I have created a number of sound installations, and the exploration of “white noise” as a sound resource has become a main topic in my research. The acoustic aspect plays an important role in all of my work, be it in the field of video, installation, or in my more recent experiments with wearable controllers.[8] When I was invited by Professor Vesna to participate in the *NANO* project, I had no concept of how far I would dive into the “rabbit hole”. Using the rabbit hole as a metaphor for the development process of *NANO* seems especially appropriate considering

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[3] The Dymaxion Map, created by Buckminster Fuller, is the only flat map of the entire surface of the earth that reveals our planet as an island in one ocean without any visible distortion of the relative shapes and sizes of the land areas, and without splitting any continents. See http://www.bfi.org/map.htm

[4] *In Whose Image?: Remaking Humanity Through Cybernetics and Nanotechnology*, C. Christopher Hook: http://www.cbhd.org/resources/biotech/hook_2002-winter.htm

[5] *Engines of creation,* K. Eric Drexler, New York: Anchor Press/Doubleday 1986, p. 17

[6] http://www.m-w.com/cgi-bin/dictionary?book=Dictionary&va=nanotechnology&x=15&y=13

[7] Simson Garfinkel in *Endo und Nano, Ars Electronica 1992*, Linz: PVS Verleger, 1992, p. 70

[8] See i.e. “Noise Ratio”, “Sub_Trakt”, “Stretching L.A.” by Anne Niemetz and collaborators: http://www.adime.de

that Alice entered a world of ever-changing scale through it.[9] I was introduced to Andrew Pelling in order to design the sound for the exhibition and to create the concept and realize the acoustic side of *NANO* over the course of nine months. We both had dealt with audio production in the past, and were able to share our experiences. Both Pelling and I first became interested in music when learning to play an instrument in our early youth, and later on when forming bands. Our interests in "traditionally produced" music as well as electronic music have continued throughout our studies. Pelling also engaged in an art-study before he began his interdisciplinary research in biology, chemistry, and physics, all of this while pursuing music and photography as creative outlets.[10] During his PhD studies at UCLA he began his research in the field of cellular audio.[11]

The collaboration among the different teams, each assigned to various tasks within the development of the *NANO* exhibition, was characterized by frequent meetings and discussions, resulting in a strongly interconnected process. The ideas and concepts, presented to all the groups involved, often underwent criticism and many changes before they entered the final concept. Guests were invited to give lectures on specific topics related to our enterprise, and a series of informal meetings without agenda were held alongside the work meetings to ensure an exchange of ideas and philosophies on a casual level as well.[12] Not all collaborations within the project were successful, and not all goals were reached. Like in any large-scale group project, some participants contributed and benefited more than others. However, working together on the sound design within this larger group was an enriching and inspiring experience for Pelling, Wanchuk and I.

During the production of the *NANO* sound design, Pelling and I realized that we enjoy working together. Our common background in music and our specific backgrounds in chemistry and media art seemed to complement each other ideally. I found a fair and reliable partner in Pelling, who was equally interested in a continuation of our collaborative work. We wished to create our own project that would evolve around the topic of cellular audio, as both of us saw need in exploring this discovery not just on a scientific but on an artistic level as well. The *NANO* experience had provided us with a basis for future collaborations, which led us to propose *The dark side of cell* project.

The *NANO* exhibition space was intended to host various special events related to the theme of the show, so we decided to make good use of this opportunity. While the sound design for *NANO* was developed to serve the purposes of an exhibition lasting eight full months, we were inspired by the challenges of a presentation in the form of a concert. We made it our goal to develop our research further and present it as *The dark side of cell*, an audio-visual experience that can be described as a concert-installation hybrid.

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[9] *Alice in Wonderland*, Lewis Carroll. The literature group involved in the *NANO* development chose specific quotes dealing with scale from this book for display in the exhibition space.
[10] See http://www.andrew-pelling.com
[11] Tenzin Wanchuk, an undergraduate student at the Design|Media Arts department, joined the *NANO* sound team later during the development process, bringing in his expertise as well.
[12] Monthly informal meetings were held at the UCLA retreat in Malibu. Whereas the members from the Design|Media Arts and Chemistry department enjoyed these meetings, most of the members from the Literature department did not participate because of the lack of an agenda.

The dark side of cell deals with one of the most interesting recent discoveries in nano-biotechnology: cellular sounds. Prof. James Gimzewski and Andrew Pelling first made the discovery that yeast cells oscillate at frequencies, audible when amplified, at the UCLA Department of Chemistry. The idea for the cell experiments had arisen from a collaboration of Prof. Gimzewski with Prof. Carlo Ventura of the University of Sassari, Italy, in 2002. At that time Prof. Ventura was researching a type of stem-cell that turns into a beating heart cell. This beating characteristic led Prof. Gimzewski to the idea to "listen" to cells. Prof. Vesna was the first artist to suggest using the cellular audio samples in artistic projects, which has been realized in the *NANO* exhibition. "Sonocytology", the term Prof. Gimzewski suggests for this cutting edge field of cell sound study, represents a new realm of challenge and potential for scientists, artists, and in particular for musicians.

The dark side of the cell is the first concert ever to be composed of cellular sounds. It introduces into the context of art the scientific discovery of cellular audio, drawing attention to the cultural implications of this finding, and demanding recognition of these sounds as an extension of the repertory of music.

1.3 Context

1.3.1 Rainbows: the separation of art and science

"I believe the intellectual life of the whole of western society is increasingly being split into two polar groups"

C. P. Snow[13]

Until the Renaissance, art and science were united in the Western world. Due to various socio-economic factors, the developing split of the comprehensive "natural philosophy" was then manifested by the separation into the discipline of art and the discipline of science in the educational system.

> "The actual two cultures divide dates back to the 19th century, or more precisely, to the 1830s when the term 'scientist' was coined analogous with 'artist'. A split in educational degrees (Bachelor/Master of Arts vs Bachelor/Master of Science) led to a subsequent split in professional socialization—a division of tasks where ethics, aesthetics, history and culture became the domain of one group of scholars, whereas another group was exclusively concerned with understanding and controlling the laws of nature."[14]

[13] *The two cultures*, C.P Snow, Cambridge: Cambridge University Press, Orig. published 1959, p. 3.
[14] *After the 'two cultures': Towards a '(multi)cultural' practice of science communication*, paper by José van Dijck, University of Amsterdam, The Netherlands, p. 2
http://www.saasta.ac.za/pcst/papers/papers/vandijck.pdf

C. P. Snow described the separation between the sciences and humanities, caused by the industrial and scientific revolutions, in his famous and controversial lecture of 1959 titled *The two cultures*. By depicting the two disciplines as isolated from each other and ignorant of each other, Snow started an ongoing public debate about the polarization of the community of scientists and the community of intellectuals of the literary and artistic world. *The two cultures* caused a flood of discussions about the verity and severity of his dramatic portrayal, leading to a distinguished analysis of the origins of this polarization.

The generally accepted division of the arts and sciences did not necessarily hinder individuals in their interdisciplinary pursuits, as is well exemplified by Johann Wolfgang von Goethe (1749-1832), one of the most versatile artists of the Romantic period. But the concept of specialization influenced the public's perception of the work and research of these individuals. Goethe, who himself dedicated much of his time to optical research, is mainly credited for his literary work. As poet, novelist, playwrite, and natural philosopher, he was interested in a great variety of studies and pursuits throughout his life. He made important discoveries in connection with plant and animal life, and competed in science by evolving a non-Newtonian theory of the character of light, with which he earned the suspicion of the scientific community. It is said that Goethe considered his color studies, summarized in the extensive volumes titled *Zur Farbenlehre*, more important than all of his poetic works.[15]

To demonstrate the animosity present in the relationship between the humanities and science in the 18th century, Arthur Zajonc recounts the story of the "unweaving of the rainbow".[16] The rainbow has always been a significant metaphor in religion and spirituality, and has enchanted the human mind since earliest ages. According to his book *Catching the light: the entwined history of light and mind*, Isaac Newton's experimental observations concerning the refraction of light in the late 17th century finally allowed a scientifically satisfactory explanation of the rainbow phenomena. This caused an uproar among the literati of the time, who hurled many accusations towards the scientific world. Zajonc describes incidents that exemplify the swirling emotions of Romantic hearts "who saw in the triumph of optics over the rainbow the death of poetic sensibilities".
For instance the writers John Keats and Charles Lamb "agreed that he [Newton] had destroyed all the poetry of the rainbow by reducing it to its prismatic colors".

Despite scientific explanation, the rainbow did not lose its ability to enchant and provoke philosophical thoughts. In the introduction of *Our Rainbow World*, Otto E. Roessler and Peter Weibel discuss objective reality and the role of the observer by reflecting on the old saying "a rainbow's ends stand in a pot of gold".[17]

[15]Johann Wolfgang von Goethe's *Zur Farbenlehre* was first published in 1810 and consisted of 3 volumes comprising 1400 pages.
[16] *Catching the light: the entwined history of light and mind*, Arthur Zajonc, New York: Oxford University Press, 1995, p. 164 ff
[17] *Unsere Regenbogenwelt*, by Otto E. Roessler and Peter Weibel in *Endo und Nano*, *Ars Electronica 1992*, Linz: PVS Verleger, 1992, p. 13

Another connection to the rainbow is conceptually linked to *The dark side of the cell* project. In 1973, Pink Floyd published their album *The dark side of the moon*. The album cover, designed by Storm Thorgerson, did not depict a moon, as the title would suggest, but a prism refracting a rainbow of light:

And, as Robert P. Crease correctly points out, the “unweaving of the rainbow” illustrates a dichotomy on another level: “The split between the Romantic poets of the eighteenth and early nineteenth centuries represents a split that is still within us, between those for whom inquiry and investigation destroy beauty, and those for whom they deepen beauty.”[18]

1.3.2 Art and technology

From the time of the invention of art and science degrees in the 1830s until today, educational institutions clearly separate the arts, humanities and sciences. Western society in general makes clear divisions between scientific and artistic activities, often forgetting that these disciplines once were one. Media art, a relatively new field within the arts, continues to claim a space in between. Due to its preoccupation with technology, the step towards science is inevitable. In fact, the establishment of the discipline media art was in itself a process of separation from the traditional arts.

With the increasing use of machines in industry and daily life in the early 20th century, increasingly more artists felt it was time to deal with the evolving technology. The “Constructivist” movement brought forth a synthesis of sculpture, painting and architecture, drawing attention to the aesthetic quality of the “machine age” and presenting the machine as a work of art. In the 1920s, Laszlo Moholy-Nagy and his colleagues introduced Constructivist philosophies into the teachings at the “Bauhaus”, which is credited for the creation of “a new design paradigm in which the artist’s creative

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[18] “*The Prism and the Pendulum: the ten most beautiful experiments in science*”, Robert P. Crease, New York: Random House, 2003, p. 80

output was to intermingle with technological innovation".[19] The Bauhaus slogan "Art and Technology - A new Unity" represented the highly innovative spirit of the institution. Contemporary media art and design schools such as the "Staatliche Hochschule fuer Gestaltung Karlsruhe" in Germany owe much of their philosophical heritage to this legendary undertaking.

Naturally, this development in art towards technology did not only have advocates, but opponents as well. Anti-technology attitudes were maintained both by the Dadaist and the Fluxus movement. The former regarded technology as a means of warfare, a "bait for the bureaucrats to use to recruit young men by appealing to their masculinity by offering them the marvels of technology stressing power and invincibility".[20] Dadaist dealt with the progress of technology critically and ironically, since it enabled totally mechanized war machines. Dada artists, the most popular being Marcel Duchamp, challenged society with a total anti-technological and anti-traditional approach.

Fluxus, however, propagated an intellectual stance towards the making of art, rather than pursuing the exploration of technology. In a populistic manner Ken Friedman presents Fluxus as a counter-reaction to the art and technology movement of the 1960s, which he describes as "spectacular and shallow". In his opinion, the experiments in art and technology were "as important as they were ultimately without purpose", and he goes as far as to judge the art and technology movement as "a failure of philosophy" practiced by artists that were "unconscious about ideas".[21]

Indeed the exploration of technology within art faced many struggles and failures, which called forth such superficial criticism. When Bell Laboratories engineer Billy Kluver collaborated with sculptor Jean Tinguely in 1961 to present *Homage to New York*, a gigantic kinetic sculpture of junkyard parts, equipped with sophisticated electrical triggers, self-destructing in precisely 27 minutes, the result was laughs from the audience.

In the perspective of the media artist, however, the developments in the1960s are regarded as ground breaking, marking the changing notion of art towards technology and science. Influenced by the philosophies of Marshall McLuhan and Buckminster Fuller, a group of artists and engineers created an organization devoted to promoting the interaction between art and technology.[22] E.A.T. (Experiments in Art and Technology)

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[19] *Art and Technology - A new Unity: The Bauhaus 1923 - 1932*, http://www.absolutearts.com/artsnews/2000/08/20/27348.html

[20] *Dada: Paradox of Art, Paradox of Life*, Graham Hunter, http://www.discovery.mala.bc.ca/web/hunterg/Dada.htm

[21] *Forty Years of Fluxus*, Ken Friedman, http://www.artnotart.com/fluxus/kfriedman-fourtyyears.html

[22] See *Buckminster Fuller: Illusive Mutant Artist*, Victoria Vesna 1998, Artbyte, the Magazine of Digital Arts. Vol. 1, No 3, New York 1998. Online version: http://telematic.walkerart.org/timeline/timeline_vesna.html: "Fuller influenced and inspired many artists who went on to revolutionize and redefine the idea of art and his complex relation of links to interests, activities and people could easily be likened to one of his geodesic structures consisting of a seemingly endless number of triangular links. One particular triangle of connections is that of Fuller to the artist and composer John Cage, the media theorist Marshall McLuhan, and the scientist Albert Einstein."
In 1964, Marshall McLuhan published his essay Understanding Media: The Extensions of Man, in which he postulated his famous thesis "The medium is the message".

was founded by the artists Robert Rauschenberg and Robert Whitman, and the engineers Billy Kluver and Fred Waldhauer, who believed that working together would greatly benefit society as a whole. Based in New York, E.A.T. created a matching service for artists and engineers: the "Technical Services Program" with more than 4000 members. These pioneers in interactive media art had the vision to "expand the artist's role in contemporary society and eliminate the separation of the individual from technological change".[23]

Rudolf Frieling summarizes:

> "Their credo can be summed up in the statement that the emergence of new artistic activity is only possible as part of a dialogue between technicians and artists, industry and art. They followed this insight in a whole series of remarkable and historically influential projects and events; these were not by definition directed against the museum as a location for art, but took place in locations that were de facto external to the art context. The most lucid example of this was the industrial arena par excellence, the World's Fair, as can be seen most clearly in the famous Pepsi Pavilion."[24]

In 1967, another interesting project in the history of art and technology was initiated at LACMA, which, as mentioned before, also hosted the *NANO* exhibition: *Art & Technology* (*A & T*) was a large undertaking aiming to bring together the resources of industry with the creativity of artists. "Artist in residency" programs were established at various California companies, enabling several artists to produce works that were presented in the *A & T* exhibition at LACMA in 1971.[25]

Maurice Tuchman, director and main curator of *Art & Technology*, compiled selected documents of the development process in a catalog titled *A Report on the Art and Technology Program of the Los Angeles County Museum of Art 1967-1971*. Tuchman describes in detail all of the problematic issues in establishing and maintaining the *A & T* program. It was difficult not only to find companies that were willing to support the program and supply residency for an artist in their facilities, but also on the part of the artists the interest and capabilities to collaborate were uneven. The *A & T* idea was new to industry as well as to the organizing museum, and the overall outcome was a mixture of successes and failures. The problems of establishing collaborations between companies and artists in order to produce art works were manifold. Some companies were offended by the unconventional appearance, politics and working methods of artists

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[23] *Experiments in Art and Technology (E.A.T.) Histories: The "9 Evenings" Artists & Engineers Collaborations With Archival Footage*, by Robin Oppenheimer, http://seattleweb.intel-research.net/seminars/presentations/Dec 2003/E.A.T. abstract for Intel Lab.doc

[24] *Form Follows Format. Tensions, museums, media technology and media art*, Rudolf Frieling. Translation by Michael Robinson: http://www.medienkunstnetz.de/themes/overview_of_media_art/museum/4/; "Pepsi Pavilion for the Expo 1970", a project of E.A.T, sponsored by Pepsi. Also see: *E.A.T. – The Story of Experiments in Art and Technology*, NTT InterCommunication Center, Tokyo: NTT Publishing Co., 2003

[25] *A Report on the Art and Technology Program of the Los Angeles County Museum of Art 1967-1971*, Maurice Tuchman, Los Angeles County Museum of Art, 1971, p.12ff

(for example IBM declined to work with Jackson MacLow), or rejected project proposals for reasons of excessive expenses (RCA declined Glenn McKay's project). Some invited artists were opposed to *A & T* based on idealistic reasons: they did not want to be in contract with "the temples of Capitalism". Others were not included in the program because of the unrealistic technical requirements of their proposals. From the over fifty artists who initially wished to collaborate, twenty-three actually did, and sixteen actually produced pieces for the exhibition.

In her essay *Thoughts on Art and Technology*, which is a part of the *A & T* catalog, Jane Livingston points out, that the artists with experience in dealing closely with technical personnel most likely had the best basis for participating in the program. But some of the collaboration-inexperienced artists, as well, were able to work effectively:

> "There is little doubt that a number of serious artists will continue to assimilate technical knowledge and will evolve an increasingly sophisticated and refined body of technologically-oriented works of art."

Whether or not a collaboration resulted from the preliminary efforts was largely determined by two factors, according to Tuchman. On the one hand, he identifies the artist's personality and his capability to communicate as a major factor, on the other hand, the company's wish to utilize their own resources for the projects. When the corporation in question anticipated having to sub-contract in order to realize the proposed project, the collaboration often failed. It seems that the personal aspect was most important. In the cases of successful collaboration, not only was the artist capable of communicating with the corporation, but there was also an individual interested on behalf of the company, who took the responsibility of fostering the exchange.

Media art has undergone many changes since the period of ambitious art and technology projects in the 1960s and 70s, and the role of the media artist is developing constantly. With the arrival of new technologies, new art projects are emerging. Media art has not only blurred the borders between art and the commercial world, it has also created a new kind of audience, brought forth new modes of presentation, and questioned the traditional definition and perception of art.

Meanwhile media art is a well established field of the art and technology intersection. But the interest in an enhanced exchange particularly between art and science is just now starting to become popular on a larger scale, although the development of media art as a common ground has been well underway for at least two decades, according to Itsuo Sakane, president of and professor at the International Academy of Media Arts and Sciences in Gifu. He states: "the collaboration between art, science and technology has been appealing to society as one of the most desirable cultural contributions in history."[26] In his opinion, conflicts among different cultures in the world will not be overcome

[26] "*Toward the Innovative Collaboration Between Art and Science: The Task in the Age of Media Culture through Case Studies in the Contemporary Field of Media Arts*", Itsuo Sakane, Proceedings of the IEEE Virtual Reality 2003, Abstract: http://csdl.computer.org/comp/proceedings/vr/2003/1882/00/18820159abs.htm

without “an active integration between the artistic sensibility and scientific way of thinking in the future.” Sara Diamond, Artistic Director at The Banff Center for the Arts, as well supports the thesis that in today’s era of technological advance, collaborations are necessary in order to invent new forms of knowledge and new inter-disciplines.[27]

1.3.3 Collaborations: breaking down borders

The intersection of disciplines naturally presents the question of collaboration. The old concept of the comprehensively educated and skilled “homo universalis”, who had the world’s knowledge at his disposal, could not be maintained beyond the 17th century.[28] The rapidly growing complexity of knowledge required specialization in order to advance.

Today, in a largely specialized world, collaborations are becoming more and more necessary. Communication between many disciplines is required to put together the puzzle pieces of knowledge. The comprehensive level of “Renaissance knowledge” might be achieved by a team, but not by an individual. Or, as Bill Buxton puts it, they idea of neo-Renaissance men and women is “nonsense”.[29] In my experience, artists dealing with technology learn early in their career to value good team work, since practical circumstances often require a number of people to create a piece of work.

The Tissue Culture & Art Project (TC&A) is an ideal example for an art-science group that creates works building upon the combined knowledge and skills of its individual members. Their work focuses on the intersection of artistic and scientific fields and touches upon matters that are highly relevant in our society of rapid scientific progress. The TC&A members all come from a background that fostered their interest in the arts, biology and biotechnology. Oron Catts was trained in product design and specialized in the future interaction of design and biologically derived technologies. Ionat Zurr studied art history, photography and media studies and specialized in biological and digital imaging. Both met as Research Fellows at the Tissue Engineering and Organ Fabrication Laboratory at Harvard Medical School. Guy Ben-Ary, who joined the group in 1999, was trained in programming, web development and law, and specialized in light microscopy, biological and digital imaging. TC&A continues to produce works in the cutting edge field of biotechnology, raising ethical questions and emphasizing the drastic potential effects of biotechnology on society.[30]

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[27] *CodeZebra Habituation Cages* is one of the projects that Diamond initiated to support her ongoing investigations of collaborative processes. http://deaf.v2.nl/deaf/03/249-244-7-1-172-136-12-82-3-4-189-8-232-225-120-225.py

[28] Leonardo da Vinci is the role model of the “universal man”. The mathematician, physicist and religious philosopher Blaise Pascal (1623-62) is largely considered to be the last person who can be titled “homo universalis”. Of course it can be argued that Johann Wolfgang von Goethe (1749-1832) ranks among the universally educated men that deserved this title.

[29] *Snow’s two cultures revisited*, Bill Buxton, in *Cyberarts*, San Francisco: Miller Freeman Inc. 1992

[30] *The Tissue Culture & Art Project* homepage: http://www.tca.uwa.edu.au/

Numerous media art groups like TC&A benefit from the combined technological knowledge of its members, and several individual artists work together with scientists in laboratories. Exemplary for the latter group are for instance the transgenic artists Joe Davis and Eduardo Kac.[31] Institutions like the Massachusetts Institute of Technology, the Center for Art and Mediatechnology (ZKM) Karlsruhe, the Banff Center for the Arts and others have been supporting the exchange of artistic, technological and scientific knowledge. Festivals such as the Ars Electronica Festival Linz and others are landmarks for the presentation of cutting edge work in the field of art, technology and science.

In recognition of the merging tendencies, and in order to focus more on the areas of convergence between art and technology, and their social and cultural implications, the German media art festival Transmediale has abolished all categories in their competition. Formerly the applicants were asked to situate their work in separate categories such as "interactive", "video" and "artistic software". This positive tendency of abolishing borders is exemplary of a growing consciousness within media art community towards the interdisciplinary practice of all arts, technology and science.

1.3.4 Ongoing controversies

Media art, with its history rooted in the intersection of art and technology, is a promising field for art and science experiments. Although much can be learned from media art history, the combining of art and science requires its own development process. Pioneers such as Itsuo Sakana may have been able to speed up the process of convergence by relying on their experiences since the 1960s, but contemporary projects such as the *science + fiction* exhibition of the Volkswagen Foundation show that recurring as well as new issues must be dealt with when bringing art and science together.[32]

The exhibition *science + fiction* was first presented at the Sprengel Museum in Hanover, Germany, in late 2002, and has continued to travel to artistic venues and research institutes, with plans for further presentations throughout Europe up into the year 2005. The Volkswagen Foundation commissioned artists and scientists to work on questions regarding the impact of nanotechnology and globalization, and to present their collaborative outcome in this exhibition. Among the questions to be discussed were:

> "…where is the borderline between the foreign and the familiar in a globalised world? What consequences do manipulations of matter on the atomic level have? Where does science become fiction - and vice versa?"[31]

[31] Joe Davis: http://www.viewingspace.com/genetics_culture/pages_genetics_culture/gc_w03/davis_j_webarchive/davis_profile_sciam/jd.htm; Eduardo Kac: http://www.ekac.org/

[32] *science + fiction:* http://www.scienceandfiction.de/en/01/01_01_01_content.html

Complementing the exhibition, two publications were released in 2003: the *science + fiction* catalog and the book *science + fiction - Images and Essays*.[33] The editors, Stefan Iglhaut and Thomas Spring, mention general reluctance and preconceptions of scientists, when asked to work with artists, and vice versa. In conversation with Iglhaut and Spring, artists Ralf de Moll and Christiane Delbruegge report their experiences in establishing artist-scientist collaborations for their exhibition piece *WildCards*. One main factor that scientists declined to participate was their fear of being placed into the "non-credible" context of an art exhibition, which might lead to reduced chances for acquiring scientific funding. In one specific case a climate researcher was not willing to engage in the proposed project because of his career, stating that a scientist cannot be an advocate. Delbruegge suggests that this researcher embodied the type of scientist, who, according to Paul Feyerabend, evaluates his career and the opinion of his colleagues as more important than taking social responsibility.[34]

Wilhelm Krull points out another issue in his essay *Science, Communication and Public Interest:* due to the extent of specialization in contemporary research, an exchange of critical thoughts has become more and more problematic even for scientists working in related fields.[35] Krull defines this as the price we pay for the immense progress of knowledge acquired through scientific specialization and institutional division of labor. But he also points out that the public is loosing trust in science, and has become more skeptical towards scientific progress in the past years. The optimistic belief in the omnipotence of science has vanished, so that now the task of communicating with the public is more important than ever. He concludes that an intense discussion between scientists and artists about questions that concern our future is a great possibility to raise public interest, and to create new spaces for interaction between science and the public.

In general, we find the conservative communities of art, the humanities and science, as well as their respective audiences in opposition to the progressive stance of the advocates of the art and science alliance. Progressive projects create controversial opinions, which can be said to be true, for example, of the *NANO* project as well as of works of TC&A. The latter group often experiences hostile encounters when presenting its critical work. The reaction and acceptance of the audience plays a vital role in the advancement of interdisciplinary practice. And, although recognized by some as highly relevant to contemporary art practice, the general audience does not seem prepared for the disturbing effect of artwork utilizing biologically related technologies. Experienced collaborators may interpret controversies as a positive sign, acknowledging that the evoked discussion is part of the goal. Frustration takes hold when controversies are not discussed but simply rejected.

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[33] *science + fiction - Images and Essays* and *science + fiction – exhibition catalog.* Edited by Stefan Iglhaut, Thomas Spring. Berlin: Jovis Verlag 2003

[34] More information on Paul Feyerabend, "philosopher of science" can be found at: http://plato.stanford.edu/entries/feyerabend/

[35] the original German title is *Wissenschaft, Kommunikation und oeffentliches Interesse,* and was translated by the author

Comments about digital media projects, such as "There is no content! It doesn't have any depth", recently uttered by a UCLA Professor of the traditional arts may lead to the presumption that nothing has changed in the past 40 years since C. P. Snow's thesis of the two cultures.[36] One may ask oneself how the conservative mindset was able to ignore the gigantic impact of technology on society and culture.

Other examples, as well, demonstrate the strong belief in the division of disciplines. When the group of scientists from the UCLA chemistry department, including my collaborator Andrew Pelling, first proposed their paper on the discovery of cellular audio to various scientific magazines, they were rejected with arrogant comments, stating that the discovery was non-credible and might be of interest to artists, but not to science. Here we see the tendency to maintain the borders of disciplines, maintain specialization and the incontestable authority of science, ignoring the benefit brought in recent years to the scientific understanding of matter by sound-related approaches. Meanwhile the research of cellular audio receives international recognition of the science community, but it did take more than two years to achieve this.[37]

And indeed, tearing down borders requires extreme measures as well as time. Whereas a media artist and a computer scientist, for example, might find little problems in communicating and collaborating, the divide between the perception of the world by a chemist and a writer could remain unbridgeable for a long time. The establishment of a common ground can be advanced by the fact that both disciplines deal with technological methods, which I found true for the group working on the *NANO* project, but does not necessarily guarantee a common basis, which I realized through my interactions with members of the UCLA computer science department. Some disciplines are said to be closer to each other through common characteristics, for instance mathematics and music, but my personal experience leads me to the conclusion that these relations are mere generalizations that cannot be counted on for collaboration.

Stephen Wilson points out that mathematics takes a special role in the discussion of art-science intersecting, as it has a "dual identity": pure and applied mathematics. Although the high level of abstraction gives pure mathematicians "the opportunity to dream up arbitrary worlds with their own internally consistent rules unfettered by connections with the conventional world", which is akin to artistic practice, I have found that pure mathematicians and logicians maintain a conservative perspective that ends their recognition of art and music with the Renaissance period as often as other scientists.[38]

In *NANO*, the theory of the "two cultures" was again enforced by the fact that the participating media artists and chemists had little problems collaborating, but both had to contend with inflexible members of the literature group. The chemists were disappointed by the humanists' tendency to hold on to "outdated" views of science derived from

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[36] Quote by Prof. Herman, taken from *The Daily Bruin*, UCLA campus newspaper, Feb. 12, 2004, p. 7

[37] *Local Nanomechanical Motion of the Cell Wall of Saccharomyces cerevisiae* by Andrew E. Pelling, Sadaf Sehati, Edith B. Gralla, Joan S. Valentine, James K. Gimzewski, published in *Science*, Vol. 305, Issue 5687, 20 August 2004: http://www.sciencemag.org/cgi/content/abstract/305/5687/1147

[38] *Information Arts*, Stephen Wilson, Cambridge, Massachusetts: The MIT Press, 2002, p. 298

science fiction literature, and in response to this criticism the humanists decided to develop their perspective of the project on their own.

To summarize, the ongoing controversies triggered by C. P. Snow's thesis of the two cultures indicate that, although changing, the separation between science and the humanities remains a problematic aspect in western culture.

1.4 Premise

The dark side of the cell is another step in extending the repertory of music, and shifting the borders of art. Cells can be observed and their sounds recorded but they can also be manipulated, which results in a change of sound. A "singing cell" can be turned into a "screaming cell" by altering its living environment.[39] The discovery of cellular sound, however, brought with it many unanswered questions. It is unknown how or why cells oscillate, but it is possible to manipulate this oscillation. By emphasizing this discrepancy between scientific knowledge and technological power, the symphony of cells draws attention to the ethical implications of the scientific process of discovery.

In dissecting the basis upon which my collaborator and I were able to work together, I wish to contribute to the discussion about the importance of communication between artists and scientists, treating the problematic as well as the beneficial aspects. Media art has broken ground for a growing understanding between art and science, but equal and serious communication between the disciplines remains to be established. As shown in the preceding chapter, the process of reconciliation between the two cultures is still in a vulnerable stage, even though 45 years have passed since Snow's lecture. Interdisciplinary projects that truly balance both sides are rare. How can transdisciplinary collaborations be established, and on what grounds can a successful collaboration flourish?

[39] The term "screaming cell" was coined by Margaret Wertheim in her article *Bucky Balls and Screaming Cells*, LA Weekly, April 3, 2003: http://www.laweekly.com/ink/03/20/features-wertheim.php

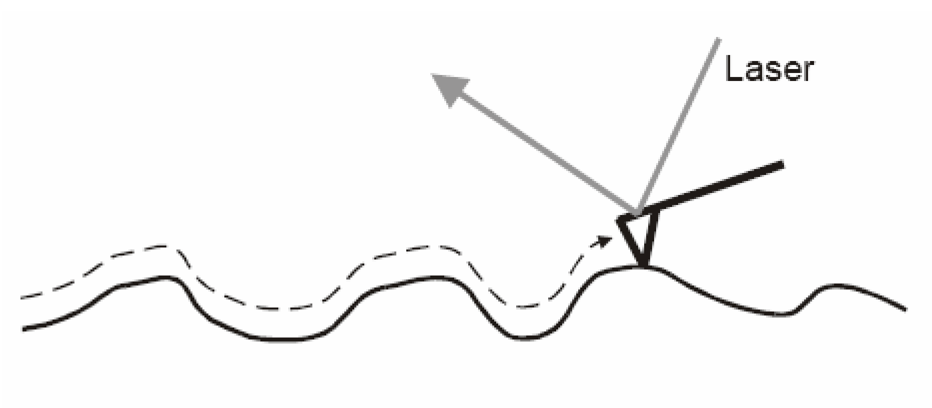
2.0 The dark side of the cell

2.1 Cell Sonics and the Invisible

In 2002, Prof. James Gimzewski and Andrew Pelling of the UCLA Department of Chemistry made the discovery that yeast cells oscillate on a nanoscale. Since sound derives from vibration, Prof. Gimzewski amplified the oscillation and found that the cell sound lies within the audible range of humans. Inspired by this discovery, Prof. Gimzewski and Pelling set forth to explore this phenomena, and decided to name this cutting edge field of research "Sonocytology".

When Christa Sommerer and Laurent Mignonneau developed their piece, *NanoScape*, a table on which an "invisible" sculpture can be experienced through a magnetic force-feedback interface attached to the hand, they emphasized one of the most important characteristics of nanoscience: it cannot be experienced through sight.[1] At first, this statement might seem obvious and unnecessary, as we know that matter on a nanoscale is too small to be observed by the human eye alone. But the importance and depth of this realization becomes clear when one considers the tools of the nanoscientist.

Currently, the atomic force microscope (AFM) is the most powerful tool for observing the nanoscale realm.[2] Unlike microscopes that use optical imaging, the AFM "touches" the sample surface with its small tip, comparable to a record needle "feeling" the bumps in a groove on a record. Light waves are "too long" to be utilized at this scale. The tiny silicon tip glides over the surface, and transmits the differences in height" felt" by the needle as an electric signal. This data can then be translated into a visual image.



[3]

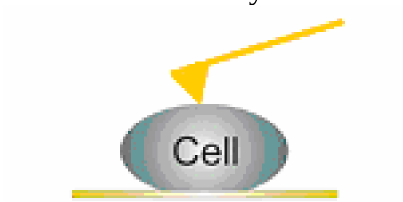
[1] *NanoScape*, Christa Sommerer & Laurent Mignonneau 2002, http://www.iamas.ac.jp/~christa/WORKS/FRAMES/TOPFRAMES/NanoScapeTop.html
[2] G. Binning, C. F. Quate, C. Gerber, Phys. Rev. Lett. 56, 930, 1986
[3] Image taken from *Single Molecule Force Spectroscopy of DNA Duplexes By Atomic Force Microscopy. Insights Into The Mechanical Stability of DNA* by Andrew Pelling, Department of Chemistry Honors Thesis, University of Toronto, 2001.

Prof. Victoria Vesna's suggestion to refer to the AFM as a “tactoscope” rather than a microscope makes the concept of the AFM's unique imaging techniques substantially more accessible to the layman. It is the sense of touch, the notion of feeling, which allows us to “see” the nano-realm. Focusing on tactile sensing was also a main goal in the development of the *NANO* exhibition at LACMA. For example, in the entrance areas of the exhibition, the sound team attached silent “bass shakers” to the handrails, so that the audience could feel the vibrating sound.

2.2 A new musical instrument

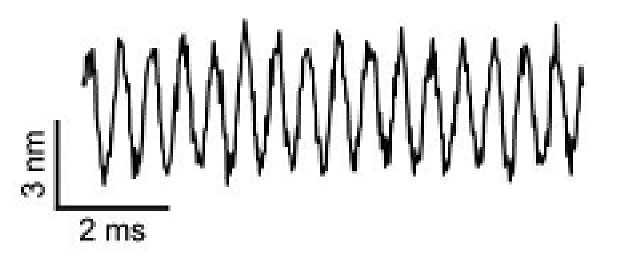
From basic physics we know that the source of sound is vibration. Sound is a disturbance, or wave, which moves through air, liquid and metals. If the frequency of the oscillation lies within the range of 20 – 20000 cycles per second and the amplitude is strong enough, the human ear can perceive it.

It is possible to drag the tip of the AFM across a sample surface, or to observe an oscillating object by holding the tip stationary on top of its surface. Resting the AFM tip without moving it on the cell membrane allows the detection of motion, as the tip will bend and follow any movement beneath it.



[4]

This, precisely, is how “singing cells” were discovered. A healthy baker’s yeast cell (Saccharomyces cerevisiae) displays a “beating rate” of about 1000 cycles a second. The range of this vibration is 3 nanometers.[4]



[4]

[4] Illustrations taken from the paper that provides more detailed information about cell motion and sound: *Local Nanomechanical Motion of the Cell Wall of Saccharomyces cerevisiae* by Andrew E. Pelling, Sadaf Sehati, Edith B. Gralla, Joan S. Valentine, James K. Gimzewski, published in *Science*, Vol. 305, Issue 5687, 20 August 2004: http://www.sciencemag.org/cgi/content/abstract/305/5687/1147

Although a yeast cell vibrates with a frequency of about 1000 Hz, the amplitude of the oscillation is too small to create a sound wave that can be heard by the human ear. The electrical signals of the AFM tip can be amplified. The vibrations of the cell can then be distributed through audio speakers. This process is not much different from reading data on an audio CD and amplifying the signals with a stereo system. The amplifying procedure intensifies the weak volume of the yeast cell sound but does not change the pitch or character of the sound itself. The sound of the first vibrating cell to be discovered can be described as a clear, high-pitched tone.

In that sense, the AFM can be regarded as a new type of musical instrument. To prove that cellular motion is in fact a metabolically driven feature of the living cell, Prof. Gimzewski and Pelling created a number of experiments. The results show that manipulating the cell with chemicals causes a change of oscillation and, therefore, a change in sound. Isopropanol (rubbing alcohol) for example, will slow the frequency down. A chemical such as sodium azide will kill the cell, causing the emitted frequency to die away, leaving only noise.

2.3 Small sounds, small instruments and the music of the universe

Knock on the sky and listen to the sound.
Zen Saying

For a long time musicians have been inspired by microscopic life-forms and the fascinating structures of the smallest building blocks of the universe. Sound artists have played a special role as pioneers in the relationship of art, science and technology, since they were amongst the earliest to integrate technology, utilize personal computers and enter the scientific discourse about sound and hearing. The fact that vision is generally regarded dominant over hearing in western culture, and sound exploration is relatively underrepresented in both art and science, places the musician in a particularly challenging, but very potential position within the art-science discussion. Accustomed to this traditional dominance of vision, the sound-artist might be able to draw attention to the misrepresentation of all other senses in general. And since the study of sound includes the abstract, physical and psychological levels, it naturally brings an understanding of the entanglement of these realms.

The deconstruction of sound into its smallest parts and the mimicking of biological structures to create sound lies within a long history of artistic exploration of the natural. The media artists Kurt Hentschläger and Ulf Langheinrich, known under the name of Granular Synthesis, split audio and video sequences into the smallest possible particles, creating tiny sound grains.[5] In their installations, they re-arrange, loop and mix these synthesized fragments of audio and video and then restructure them freely outside the time continuum of the original material. Thomas Feuerstein writes in his article about the Granular Synthesis installation *Modell3*:

[5] *Granular Synthesis* Homepage: http://www.granularsynthesis.info/

> "With all sense of time and position lost, natural perception is undermined and confronted with an artificial sequence of images that is actually no longer a sequence. Each image seems to be newly generated in potential simultaneity, i.e. timelessness."[6]

This "molecularization" of sound is exemplary for Deleuze's and Guattari's vision of the sound machine which atomizes sound matter in order to harness cosmic energy, as Timothy Druckrey points out in his essay *Chaos Pilots/Event-Horizons*.[7] Whereas the sound particles of Granular Synthesis installations do not under-run the technical limit of the frame, which is 1/25th of a second in the PAL format, and 1/30th in the NTSC format, the smallest physically possible acoustic signal is of course disproportionately smaller. Quantum physics indicates that there is in fact a limit to how small a sound can be, or as Curtis Roads writes in his book *Microsound*: "no signal fluctuation can be faster than the quantum changes of states in subatomic particles, which occur at close to the Planck scale." In between the length of a video frame and the speed of a quantum change lie the limits of human sound perception, which depends on the pitch and volume of the acoustic signal. Roads mentions listeners who are able to perceive acoustic "microevents" of less than 2 thousands of a second in duration.[8]

On the one hand we have the search for the smallest entity of sound, on the other the search for the smallest sounding element of the universe. In 2004, physicists at the National Institute of Standards and Technology in Maryland discovered noisy atoms.[9] The researchers found that atoms forced from one location to another with the aid of electric currents emit a noisy sound that can be monitored. In Interview, the NIST physicist Robert Celotta said about the atoms: "That jumping back and forth, between its preferred place and where we are really forcing it to be, turns out to make this noise." So far, the noisy atoms are the smallest sounding elements known to science.

Built specifically to demonstrate the capability to construct micro-electromechanical devices, the world's smallest man-made instrument is the *Nano-guitar*, presented by Cornell University researchers in 1997.[10] The 10-micrometer long guitar was built of crystalline silicon and is about the size of a human blood cell. Theoretically, the instrument could be played with the aid of an AFM, but there are no records of any attempts to play this extraordinary instrument. The six guitar strings are each about 50 nanometers wide, and would resonate, but at frequencies inaudible to the human ear.

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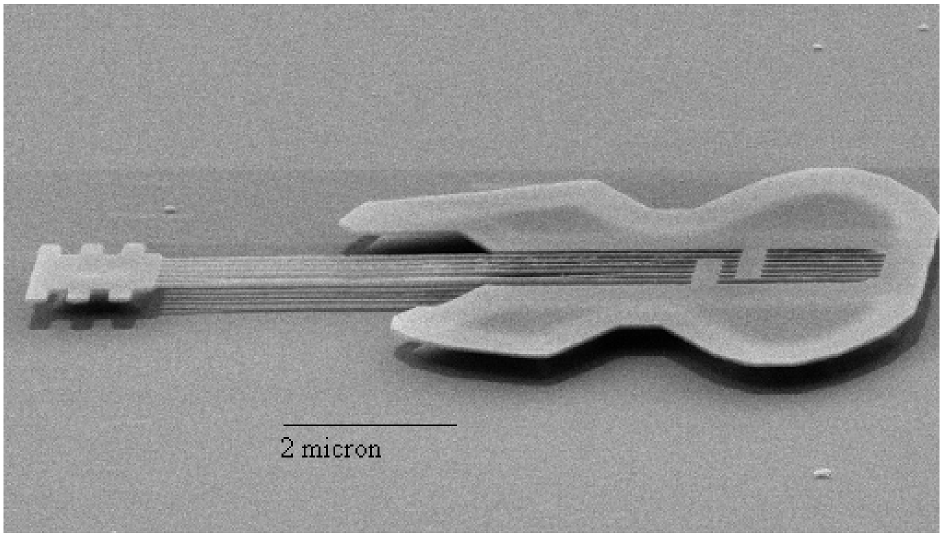
[6] *MODEL 3.1*, Thomas Feuerstein, Catalogue text for *TRANSIT 92*, http://www.granularsynthesis.info/start/content/

[7] *Chaos Pilots/Event-Horizons*, Timothy Druckrey, http://www.granularsynthesis.info/start/content/reset/

[8] *Microsound*, Curtis Roads, Cambridge: MIT Press 2001, p. 35 and p. 24

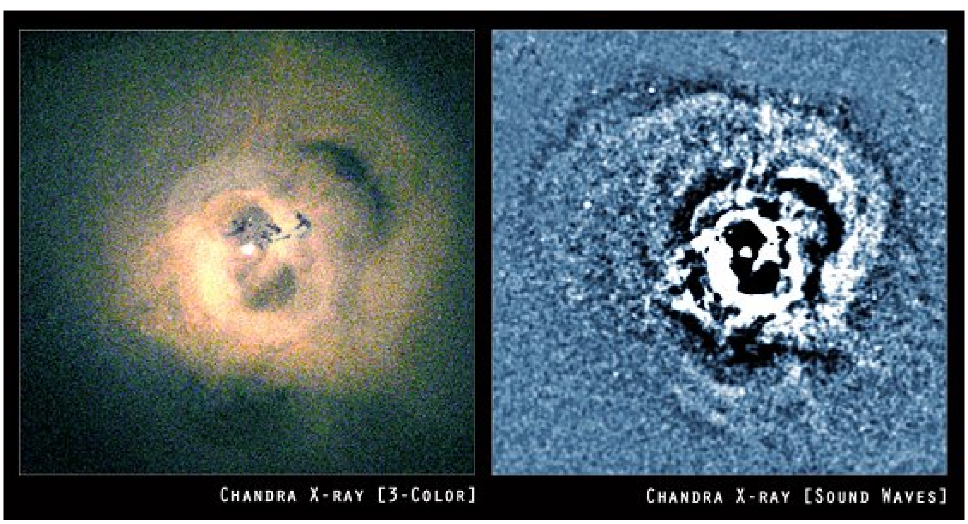
[9] *Will nanotech save the world or is it mostly hype?* Marsha Walton, CNN Science & Space, April 21, 2004: http://www.cnn.com/2004/TECH/science/04/15/nanotech.ideas/index.html

[10] Cornell Science News: http://www.news.cornell.edu/science/July97/guitar.ltb.html



Electron microscope image of the world's smallest guitar

Analogous to the *Nano-guitar*, our limited capability to perceive frequencies also inhibits us from hearing the universes' largest sounding phenomena: In 2003, astronomers discovered that black holes produce sound waves.[11] Utilizing NASA's Chandra X-ray Observatory, a black hole residing in the Perseus cluster was observed. Ripples in the gas that fills the cluster were detected, and these ripples are evidence of sound waves that have traveled hundreds of thousands of light years away from the cluster's central black hole. The emitted frequency of the black hole is, in fact, "the deepest ever detected from any object in our Universe". According to the researchers, the generated sound has a pitch of the note B flat, and is located 57 octaves lower than middle-C.



The Perseus Cluster (left), sound waves rippling through the gas (right)

[11] *Black Hole Sound Waves*, Science@NASA: http://science.nasa.gov/headlines/y2003/09sep_blackholesounds.htm

The black hole sound waves have given researchers insight into the growth of galaxy clusters. The scientific findings of noisy atoms and sounding cells may be keys for a better scientific understanding of nature as well.

The comprehensive exploration of the musical sounds in all species and the expansion of the definition of music is the priority of the BioMusic program.[12] The foundation describes itself as a trans-disciplinary "think-tank" of scientists and musicians exploring the musical sounds in all species. Their research aims to investigate nonverbal processes of communication, and to emphasize the role of sound and music as an approach to understanding nature. According to BioMusic, new meanings and modes of experiencing and appreciating our environment may be revealed through a shared understanding between science and music.

The approaches to understanding matter through sound are manifold: Composing music according to the structures of nature and constructing systems that are inspired by natural processes present an alternative to the direct listening to natural phenomena. In this field we find a series of artists who utilize DNA and protein sequences to create music. Their approach is primarily focused on the coding patterns of DNA, RNA and other small chemical building blocks. By translating the structures of genetic sequences to MIDI, the architecture of these structures can be sonified, for instance, with the aid of a synthesizer. In this procedure, any sound can be assigned a value, and therefore the composer's interpretation is of major importance. John Dunn is one of the musicians, who in collaboration with the biologist Mary Anne Clark, has created a method of musical interpretation of genetic sequences. Their goal was "to make the musical rendering of DNA both artistically interesting and scientifically valuable".[13] Dunn describes his exploration of "nature's score" as so versatile and beautiful, that "it may well become the fountainhead for future sonic artists, just as She has been for visual artists throughout human history."[14] Artists and scientists working in the field claim that DNA sequence music helps to expose the meaning of specific sequences and makes remembering and recognizing specific DNA patterns easier.[15]

Related to the sonification of genetic sequences, the music composed by *cellular automatons* represent the structure of algorithms. Besides creating an extraordinary aesthetic quality, the translation of mathematical models known as *cellular automata* into music also aids pattern analysis and structure recognition. "Cellular automata have been used to model a wide range of scientific phenomena. Although very simple, they can provide models for a wide variety of complex phenomena in a range of disciplines including physics (e.g., dynamic and chaotic systems), genetics and chemistry (e.g., chemical reactions and crystal growth)."[16]

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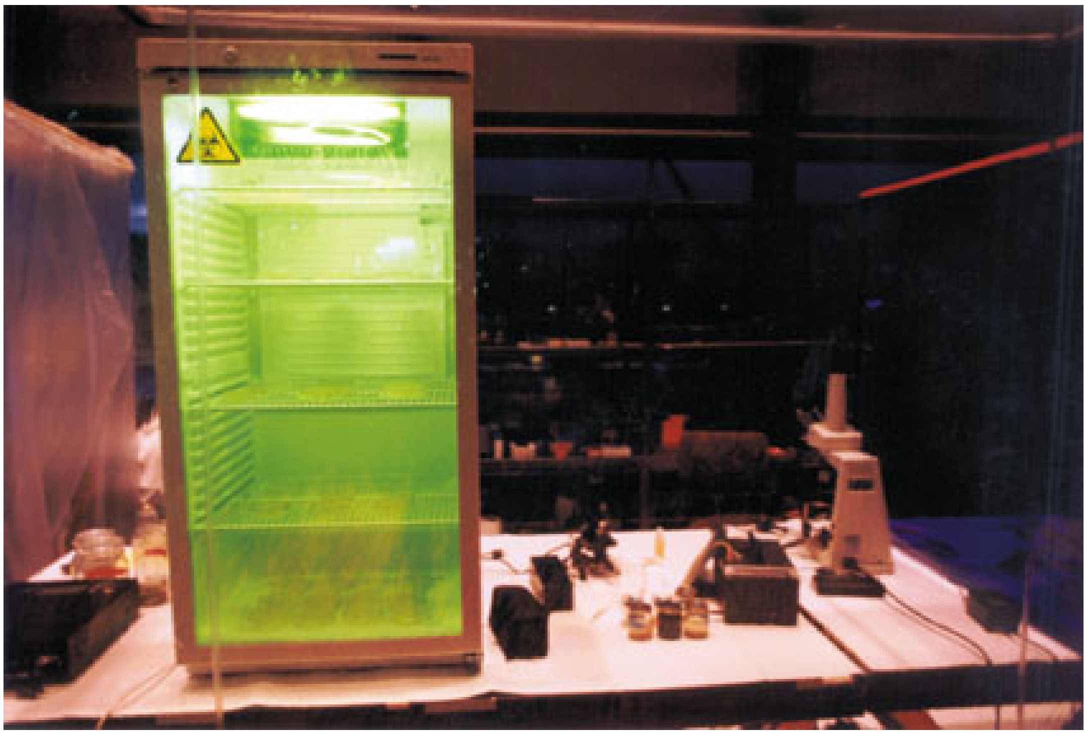
[12] *BioMusic:* http://www.biomusic.org/
[13] *Information Arts*, Stephen Wilson, The MIT Press, Cambridge, Massachusetts, 2002, p. 102
[14] *Life Music: The Sonification of Proteins*, John Dunn and Mary Anne Clark, LEONARDO ON-LINE: http://mitpress2.mit.edu/e-journals/Leonardo/isast/articles/lifemusic.html
[15] *Genetic Music: An Annotated Source List*, M. A. Clark: http://whozoo.org/mac/Music/Sources.htm
[16] *Evolutionary Music Research*, Eduardo Reck Miranda, http://website.lineone.net/~edandalex/celautom.htm

Both the creation of musical structures, as well as the control of a sound synthesizer can be achieved with cellular automata-based software such as, for example, *Chaosynth* and *CAMUS*, which were developed by Eduardo Reck Miranda from the Sony Computer Science Laboratory, Paris, and collaborators.[17]

Indeed, the discovery of cellular audio stands in a large musical and scientific context, in which the scientific exploration of nature's sound goes hand in hand with aesthetic experimentation and artistic reflection. Therefore, a comprehensive summary of all cultural influences and connections lies beyond the scope of this paper. But two projects deserve particular attention, as they stand in closest relation to *The dark side of the cell*:



Audio Microscope installation at Ars Electronica

Artist Joe Davis and biologist Katie Egan presented the installation *Audio Microscope* at the Ars Electronica festival in 2000.

> "Audio Microscope allows the user to image particular living cells while simultaneously listening to their greatly amplified - and species-specific - microacoustic signatures."[18]

This project was inspired by an encounter of Egan with a "medicine man" in the Ecuadorian rain forest, where she was conducting research at the time. The South American Native told her that plants sing songs. Being aware of the fact that many parts

[17] *Evolving Cellular Automata Music: From Sound Synthesis to Composition*, Eduardo Reck Miranda, http://galileo.cincom.unical.it/esg/Music/workshop/articoli/miranda.pdf
[18] Image and quote taken from the *Audio Microscope* page at Ars Electronica: http://www.viewingspace.com/genetics_culture/pages_genetics_culture/gc_w03/davis_audio_scope.htm

of the cell display mechanical motion, and that this motion might lie within the audible frequency range, Davis researched possibilities to amplify these sounds. Unfortunately, no microphone has the sensitivity necessary to amplify the weak signal of sounds generated by vibrating microorganisms or individual cells. So Davis turned to a method of optical frequency translation invented by Alexander Graham Bell in 1880.[19] Utilizing optical detectors to observe the light reflection off the surface of the cell probes, Davis was able to translate these optical signals into electrical signals. The next step is the amplification of the electrical signals so that the signals are perceivable as sound. The result is the installation *Audio Microscope*, which makes it possible for the observer to "hear" bacteria by translating the light information into sound. Since the acoustic signature differs from species to species, a change in acoustic signature indicates a difference in the observed microorganism.

At the time they discovered cell motion using the AFM, and proceeded to listen to the sound of this motion, Prof. Gimzewski and his collaborators were not familiar with this project. It wasn't until later in the development that their attention was drawn to *Audio Microscope*, remarkable in theory, but lacking the technical means to penetrate the cellular level. Considering the physical setup of the installation *Audio Microscope*, it can well be presumed that the accuracy of measurement is approximate, and the results are influenced by a number of external factors such as vibration of the table on which the microscope stands. Nevertheless, according to Davis, this method of listening to microorganisms has been of use in his biological studies.

Adam Zaretsky, student of Joe Davis, also conducted cell sound experiments in 2000 and 2001, whereas his research must be taken with a grain of salt. Zaretsky is an artist known for his tongue-in-cheek projects dealing with bio-technology. He started experimenting with the effects of music on the behavior of E. Coli bacteria as Research Affiliate in the Department of Biology at the Massachusetts Institute of Technology. With the aid of "acoustic vibro-transducers" Zaretsky exposed bacteria to a variety of music such as the Red Hot Chili Peppers, Igor Stravinsky's The Rites of Spring and Engelbert Humperdinck's Greatest Hits, and filmed the results.[20] According to Steve Nadis, Zaretsky played Humperdinck to the cells for two days straight in one experiment, evoking a response of the bacteria, which Zaretsky jokingly calls "the Humperdinck effect".[21] Naturally, exposing bacteria to vibrations resulting from sound creates a quite intense, and often fatal effect on the test subjects. Nevertheless the shaking of E. Coli bacteria brings some insight into the characteristics of different types of music, and also creates humorous movies.

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[19] Alexander Graham Bell's Photophone: http://inventors.about.com/library/inventors/bltelephone3.htm
[20] The Humperdinck Effect, Wendy Wolfson, May 7, 2001**:** http://www.informationweek.com/836/uwww.htm. A movie of the "very shaken" bacteria can be retrieved from this site as well.
Note from the author: "Acoustic vibro-transducers" are basically loudspeakers.
[21] *Science for art's sake*, Steve Nadis, Nature Publishing Group, *Nature* 407, 668 – 670, 12 October 2000: http://www.nature.com/cgi-taf/DynaPage.taf?file=/nature/journal/v407/n6805/full/407668a0_r.html&filetype=&dynoptions=

2.4 The dark side of Sonocytology

The fairest thing we can experience is the mysterious. It is the fundamental emotion which stands at the cradle of true art and true science.

Albert Einstein[22]

Much inspiration and many theories have arisen from the discovery of cellular audio. From esoteric to art historic, *The dark side of the cell* set off a wave of speculations. Whereas some interpret the oscillation of the cell as another proof of the "vibrating universe" theory, others conclude that cell sound must be a part of a biological communication system. Science is discovering more and more evidence of a sounding universe, from noisy atoms to black hole sound waves.[23] Whereas these findings may sometimes reveal insights into the functioning of matter, they mostly uncover more mystery. Cellular research, in particular, leads the attentive observer to more questions than answers. Why do some cells sound? We don't know. Can we influence their behavior? Yes.

In a society of rapid technological advances, the disproportion of human knowledge to technological power becomes disturbingly obvious. Nanotechnological tools have opened up a highly complex world yet to be discovered and understood, and, as has correctly been pointed out, the method of "trial and error" may not be an appropriate approach in this field. For instance, Pelling refers to the lack of scientific understanding by making the observation that medication would not have the harmful side effects it often does if chemists actually understood the functioning of chemical processes in the body. Raising ethical questions and emphasizing the drastic potential effects of bio- and nanotechnology on society is rightly a topic in contemporary art practice, as well exemplified by the works of TC&A.

The beauty of the mysterious contrasts with the manipulative power of the scientist. The sounds of the cells are indeed of astounding aesthetic and fascinating intensity, but the process of extracting these sounds is clinical and unemotional. In order to explore the behavior of cell motion and to produce different sounds, cells were exposed to disruptive liquids and life-impairing environments. Penetrating and ripping cells apart with the AFM tip is a less sophisticated but also effective way to create sound. Observing the slow death of a cell may well provoke thoughts of a philosophical nature, since it is life, admittedly a small and primitive life, but nevertheless life that we are manipulating. Where do we draw the line? Unlike TC&A, who face opposition from animal rights organizations, *The dark side of the cell* has revealed a significant difference between scientific knowledge in western culture and mythological knowledge, since "singing cells" have long been part of the belief of non-western cultures, such as the indigenous of the Ecuadorian rainforest. The ambivalence between scientific process and aesthetic result, and the problematic relationship of scientific knowledge to technological power is therefore the thematic focus of the dramaturgical progression of *The dark side of the cell*.

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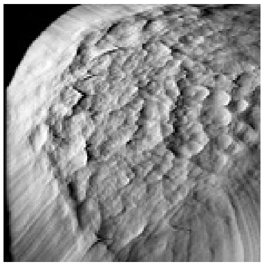
[22] *The quotable Einstein*, edited by Alice Calaprice, New Jersey: Princeton University Press 1996, p. 210

[23] See chapter 2.3

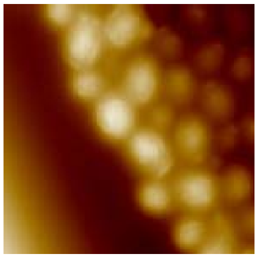
2.5 Dramaturgy – from observation to manipulation

The body of *The dark side of the cell* is comprised of five separate movements. The composition of the piece reflects the general scientific process: from discovery through experimentation to control. To learn, one must first observe, and then begin to conceive in a contextualized manner. Further, one explores reactions through efforts to bend the cell's inherent nature into one's own synthetic order. To better reflect the range of reactions that these cells emote, it was necessary to subject them to a variety of circumstances. The resulting songs must be appreciated as the undiluted result of the cells, unmodified by sound effects.

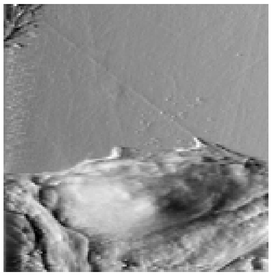
Part I
OBSERVATION
Audio: clear pitched sounds from observing the motion of unperturbed Saccharomyces cerevisiae (baker's yeast).
Audio samples session: Sep. 09, 2002 | Jan. 20, 2004
Video: AFM images of Saccharomyces cerevisiae cells.



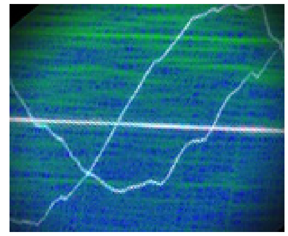
Part II
TAMING
Audio: sounds from observing mutated Saccharomyces cerevisiae, and fluctuating sounds derived from manipulating these cells with the AFM tip.
Audio samples session: April 28, 2003 | Oct. 28, 2003
Video: AFM images of yeast cells. The amber coloring is analogues to the natural tint of these cells.



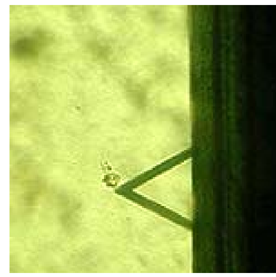
Part III
SUBJUGATION
Audio: sounds from U2OS Osteocarcoma cells (human bone cancer), and sounds from manipulating yeast cells with the AFM tip.
Audio samples session: Dec. 13, 2003 | April 26, 2004
Video: AFM images of Osteocarcoma layered with flickers of blue and green cell sound sonograms. Video footage of experiments with NIH3T3 Fibroblast cells. These cells were exposed to an anti-cytoskeletal drug (Jasplakinolide).



Part IV
CALMING
Audio: sounds derived from observing the motion of bud scars of Saccharomyces cerevisiae cells with the AFM tip.
Audio samples session: Sept. 11, 2003
Video: video footage of the current sonic waveforms mixed with still images of cell sound sonograms.



Part V
MANIPULATION
Audio: sounds derived from manipulating yeast cells through temperature changes, exposure to chemicals (Isopropanol, Sodium Azide) and force changes of the AFM tip.
Audio samples session: Oct. 10, 28, Nov. 19, 2002 | June 21, Sept. 11, 15, 2003 | Jan. 20, April 26, 2004
Video: images of yeast cells and video footage recorded from an optical microscope observing the AFM tip destroying Fibroblast cells.

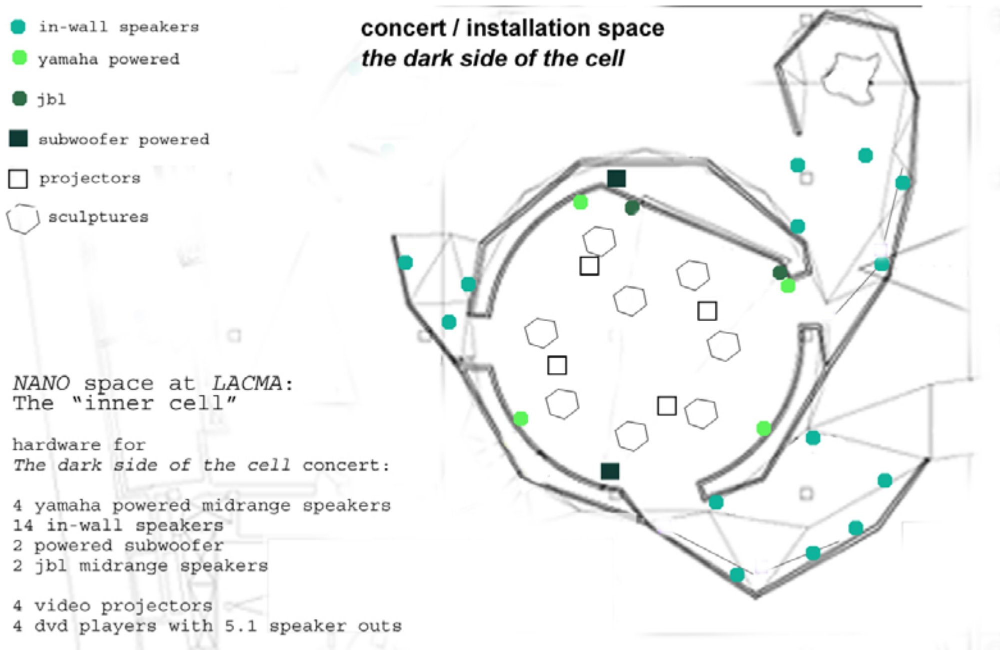

[24]

The composition progresses from sounds that were obtained by observing cells with the least influence possible, to the intentional manipulation of the cells in order to extract sound. In part III, human cell sounds are introduced and mixed with sounds from failed experiments intended to force cells to produce melodies. Part V includes the successful results of cellular manipulation, sounds that were created at the highest level of artificiality: by force of the human will.

2.6 Installation

The dark side of the cell is one of the special events outside regular exhibition hours in the *NANO* space. The exhibition architecture designed by Johnston Marklee & Associates creates a large circular central space named the "inner cell" with three entrance tunnels named the "sense spaces". The structure of the architecture is based on the triangular shapes of the Dymaxion Map by architect and visionary R. Buckminster Fuller. The carbon 60 molecule (buckminsterfullerene) was named after him for its geodesic shape. The buckminsterfullerene molecule plays a major role in nanotechnological engineering, and inspired installations within *NANO*. By shutting off the visual *NANO* installations to create an evenly dark interior and re-appropriating the existing audio system *The dark side of the cell* event transforms the *NANO* space into a stage for "musical cells".

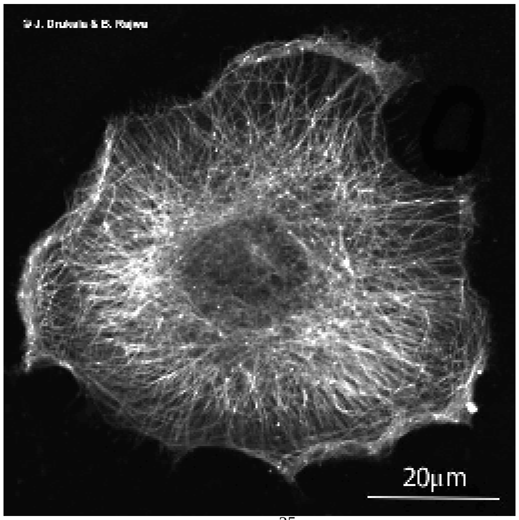
[24] Composition images, as well as sound excerpts can be found at *The dark side of the cell* project page: http://www.darksideofcell.info/



The technical setup

The dark side of the cell installation. Photo: Andrew Pelling

Eight sculptural elements are placed in the inner cell space. Four ceiling-installed video projectors project still footage and video of singing cells and their sonograms onto the sculptural elements from above. The construction of the objects consists of a scaffolding inspired by the inner architecture of cells, over which a semi-translucent skin is stretched. The skin is translucent enough to reveal the scaffolding structures, but at the same time allows the surface to show projected images.



The cytoskeleton of a cell[25]

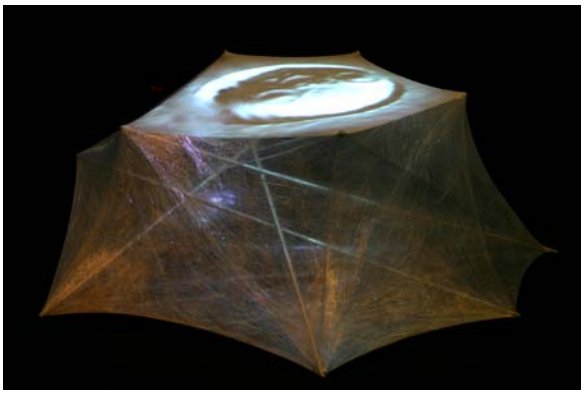
The cytoskeletons of cells are robust structures relying on the principle of tensegrity. Again, Buckminster Fuller was the first to describe the tensegrity building principle in 1961, and applied this system of tensional integrity in his geodesic domes. Fuller also distinguished two types of tensegrity, the geodesic and the prestressed principle. The artist Kenneth Snelson pursued the prestressed version of the tensegrity principle in his sculptures:


The Needle Tower, Kenneth Snelson, 1969[26]

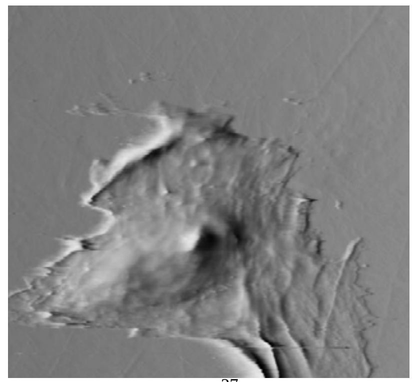
[25] Image source: http://helios.mol.uj.edu.pl/conf_c/chapters/chap_6.htm
[26] *Curious Skeletons*, NASA Life on Earth article: http://www.nasa.gov/vision/earth/livingthings/19jun_cytoskeletons.html

Tensegrity stands for “tensional integrity” and relies on the interplay of tension and compression. Tensegrity systems stabilize their shape through continuous tension.

Unlike Snelson’s work, *The dark side of the cell* sculptures are constructed according to an unsymmetrical version of the tensegrity principle, which is closest to the irregular biological structure of a cell. The aesthetic outcome may be interpreted as a simplified version of cancerous cells:



The dark side of the cell sculpture



Bone cancer cell [27]

The surrounding setup of the audio system is of major importance. All 20 speakers installed in the inner cell and in the three sense spaces are utilized during the concert. The spatial distribution of sound through the “flocks” of small speakers, as well as the midrange speakers and subwoofers allow the creation of an immersive acoustic experience. The sound environment is different at each point within the installation.

Unlike a traditional concert there is no stage, performer or other particular center point of attraction. But there is a linear progression of sound, which makes it a concert in the sense of an acoustic narrative with a beginning and an ending. *The dark side of the cell* is a concert, taking place in an installation, perceived by the audience as “lounge-like” experience. The even placement of the sculptures is intended to motivate the audience to move through the space during the concert and to experience the spatial variances in sound. During the premiere, most of the audience chose to alternate between moving through the space while watching the imagery, and sitting or lying in one place to immerse themselves completely in the acoustic experience.

This hybrid form of concert and installation enables to vary the presentation form depending on the exhibition environment. The circular flow of the composition allows a presentation in the “loop mode”, without misappropriating the concept. In its second showing at the UCLA Design|Media Arts department, *The dark side of the cell* was set up as an ongoing installation.

[27] AFM image: Andrew Pelling, Michael A. Teitell and James K. Gimzewski, UCLA 2004


The dark side of the cell premiere. Photo: Jiacong Yan

3. Conclusion

3.1 Singing cells, art, science and the noise in between

As mentioned in chapter 1.3.4, the scientific community did not immediately accept the discovery of cellular audio.[1] Seeing no scientific value in listening to cells, Sonocytology was marked non-credible and referred into the artistic realm. In a similar fashion, my proposition of an artistic project that treated the discovery of cellular sound was first rejected by some members of the Design|Media Arts faculty, stating that the project may well be science, but not art.[2]

These reactions show that some most relevant issues remain to be dealt with: the rigid definition of disciplines even in the generally progressive academic environment, and the elitist and conservative stance of the science and art community. These experiences caused me to question: Does working in a science laboratory prohibit the researcher from creating art? Can an art form such as media art focus on the cultural denotations of technology without dealing with science? What are the perspectives of the disciplines towards each other? And how may we overcome these issues?

The *NANO* project as well as *The dark side of the cell* intend to draw attention to the cultural impact of science by inviting science to enter the museum as art. These acts of recontextualization propel the enactors into a space in between the disciplines, a ground that is only partially occupied by media art. Although lacking a name and a concrete definition, this niche between art and science is not and was never a void, but always has been populated by creative minds that have made this intersection their main focus. It might be the ease with which representatives of the inter-space discipline move within it, the naturalness of collaboration that makes a definition seem unnecessary to its members.

Stephen Wilson describes the situation of the artists working with emerging technologies as a “dilemma” since they stand with their feet in both worlds and can therefore assume different stances. On the one hand Wilson depicts the side of science and technology that invites the media artists “to help create new technologies and elaborate new cultural possibilities”. On the other hand Wilson identifies the realm of cultural and critical theory that requires the artists “to stand back and use their knowledge of technology to critically comments on its underrepresented implications”.[3]

In my mind, media art must then be a multi-legged creature, since it does not have its feet just in science and critical theory, but also in popular culture, the commercial world, architecture, communication design and theory and the social sciences, such as psychology. These disciplines overlap at some points, creating a blurred space of intersection, where we find, amongst others, disciplines such as biotechnological and ecological art.

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[1] The paper on cell sound was for instance rejected by the Biophysical Journal in August 2003, with anonymous reviewer comments such as “catchy for Science News, but in my opinion it is not serious science”.

[2] Graduate reviews/thesis presentations, Design|Media Arts department, March 5, 2004

[3] *Information Arts*, Stephen Wilson, Cambridge, Massachusetts: The MIT Press, 2002, p. 23

While working with Pelling, I decided to investigate the contributions we made to the project from the personal viewpoint of our respective disciplines. I asked of us each to write down our thoughts on our collaboration, in order to compare notes on our experiences. I found that Pelling also recognizes one inter-discipline that seems to be in need of a definition. He refers to it as the “unnamed discipline”, and suggests that it exists besides art and science rather than in between the two. In his opinion this discipline should not be confined by a definition, to allow the enactors to continue blurring the borders between all disciplines. As criteria for someone who wants to work in this unnamed discipline Pelling humorously suggests the “complete confusion of your peers”.

Snow predicted the emergence of a “third culture”, a discipline that would bridge the gap between literary intellectuals and scientists. Optimistic observers believe Snow’s prediction is coming true and is well underway, particularly in media art:

> ‘The kind of artist who is both artist and scientist is now returning. The slogan-like warning against a split into "two cultures," preached by Charles P. Snow forty years ago, is rapidly dissolving away and the well-worn separation of art and technology is dispossessed once again.”[4]

I find this true only for a minority within the arts and sciences. My personal experience does not make me see the split “rapidly dissolving away”. In my opinion much basic work remains to be done before equal collaborations become the rule, not the exception. Many projects are initiated in support of the merging of art, science and literature, but only few actually succeed in doing so. In fact, collaborative projects can aggravate the split, painfully reminding the participants of the limits of their disciplinary backgrounds.

In her essay *Towards a Third Culture: Being In Between* Prof. Vesna draws attention to the vulnerable relationship of the “two cultures” by recounting the “Sokal hoax”, which ridiculed the “pseudo-scientific” writings of prominent intellectuals. This example warns of naïve and all too bold approaches to the merging of the humanities and science, since “some of the work coming out of science philosophy and some theoreticians commenting on the scientific process have infuriated some scientists and actually deepened the gap between the Two Cultures.”[5]

Open-mindedness and respectful dialog seem to be the only base on which a successful collaboration can flourish. As one possible criteria for teamwork, I suggest Nathan Thompson’s definition:

> “A good collaboration is when you can’t figure out who came up with which idea in what order.”

---

[4] *Art @ Science* Review in DIE ZEIT, September 12, 1998, http://www.amazon.com/exec/obidos/ASIN/3211829539/002-2571179-2366458

[5] such as Lyotard, Derrida, Irigaray and Lacan. *Towards a Third Culture: Being In Between*, Victoria Vesna, LEONARDO magazine, Vol. 34, 2001, p. 123

Applying this criteria to a finished piece of work can help the observer recognize the development process. If it is clearly visible which member of the group contributed which part, the outcome better be described a “collage”, and the creative process was more likely one of parallel work rather than of intense exchange. Into this category fall scientific presentations that are merely illustrated by the artist, as well as art projects that engage the scientist only as technical engineer. Many experienced collaborators believe that a respectful dialog would indeed lead to a homogenous result, since the dialog would change the perception not only of the partners’ discipline, but also of one’s own discipline. My personal encounters with scientists from fields such as chemistry, mathematics and computer science often allowed for discussions on the nature of art, bringing insight into alternative perspectives and creative views. This type of inquisitive and open exchange is highly valuable to the advance of progressive disciplines like media art. A homogenous collaboration piece should not allow the observer to distinguish authorship of the ideas integrated in the work, which can be hard for a conservative audience to accept, and may raise copyright questions when analyzed on a legal basis. Again, confusion becomes an indicator of achievement.

My collaborator and I believe that we both contributed equally to *The dark side of the cell* project using our individual strengths. The generation of data was mostly Pelling’s task, but I contributed by suggesting new experiments and alternative ways of treating the cells. The design and video work was mostly my task, but, of course, everything was developed in close discussion with Pelling. As far as the acoustic composition we truly met in the middle, using our combined experience and our musical background. It goes without saying that both of us learned a fair amount about each other’s research and work in the progress.
We do not believe that we have achieved the highest level of collaboration, which abolishes all borders, and thus we can still distinguish our individual contributions to the project from the respective view of our disciplines. But by creating *The dark side of the cell* we manifested our intention to become advocates of the discipline in between, or rather beside, art and science.

Until the “unnamed discipline” becomes more independent and generally accepted in society, we will continue to analyze the contributions of art towards scientific practice, and vice versa. How can artists and scientists aid each other? Both the realm of art and science are naturally rich sources of inspiration. Based on the traditional viewpoint of the disciplines, science teaches analysis and art provides exploration. Among the most often mentioned contributions from the artists’ side are the qualities of critical inquiry, open-mindedness and vision. The artist can aid the scientist not only in finding new approaches in his research, but also in interpreting and contextualizing his investigations. The artist can help to recognize the significance of research results, which might be disregarded within a goal-oriented scientific process. In regards to the scientists, we most often recognize their ability to enlighten the art world with “scientific truth”, grounding the artist in facts, not assumptions, when dealing with technological and scientific matters. And the analytical methodology of science may indeed be of aid particularly to the artist dealing with technology. In general, the different approaches to problem solving in both disciplines may balance each other. Above all, when presenting a collaboration project, cultural recognition of an artistic project can lead to scientific recognition, and conversely, scientific acknowledgment may induce cultural appreciation.

These simple observations on how art and science can aid each otherstand in opposition to a number of general problems that artists and scientists need to be aware of when collaborating. Most important is of course a respectful and interested approach of the participants to each other in order to avoid misunderstandings. The multiple levels on which topics can be interpreted often confuse scientists; and artists may often find scientists too result-oriented. Therefore, sufficient communication must be assured at all times. All my investigations show that communication is the crucial criteria for working together. Institutions like the Volkwagen Foundation or LACMA, for example, have only been able to establish productive projects involving artists and scientists when they found individuals with genuine interest in working together. I will not go so far as to give a list of detailed instructions to artists who desire to work in science, as Wilson does in his chapter "Preparing Artists for Research".[6] It is obvious that curiosity and the will to learn are the basis of a successful collaboration. Productive teamwork cannot be forced, it must evolve naturally. Furthermore, initiators of collaborative projects must recognize that without communication there is no way to overcome traditional perceptions of disciplines. After all, academia is still educating within disciplines. If a scientist is educated in art as well, it was usually the active choice of this individual to seek education in a discipline other than his own. The same is true for the artist and the media artist. Although media art is a wide field, usually taught in a very broad sense at universities, and close to scientific practice in its related methodology of research, media artists do not necessarily have basic knowledge in scientific matters or experience in collaborating with scientists. Working in the space in between brings responsibilities with it, at least for the members that would like to see science and art grow closer. Trust between artists and scientists is usually not a given, but needs to be cautiously established first.

The amount of caution required is well exemplified by Joe Davis' very practical experience while working with amino acids. Davis describes how the scientists in the laboratory he was working in did not trust him at first, and he considers this "a good thing". When he presented an idea for a genetic project to his scientific mentor, his advisor pointed out that he could have inadvertently created a supervirus.[7]
Again, this is an example for the small chance an individual has to reach professional knowledge in both disciplines, art and science. Joe Davis comes from a sculptural background and has worked in the field of genetic engineering for over 15 years; still, the specialized knowledge of his mentor prevented him from creating a disaster, which would certainly have harmed the progress of the art-science relationship.

In this light, the importance of close collaboration becomes obvious. If we are to understand the deep complexity of nature we will need to consider all perspectives. The

[6] *Information Arts*, Stephen Wilson, Cambridge, Massachusetts: The MIT Press, 2002, p. 39
[7] *Art as a Form of Life*, W. Wayt Gibbs article in the "Scientific American": http://www.viewingspace.com/genetics_culture/pages_genetics_culture/gc_w03/davis_j_webarchive/davis_profile_sciam/jd.htm

holistic approach of pre-Renaissance times, in which the observer was scientist, artist, literate and philosopher in one person, is a high goal to pursue. The continued merging of the disciplines will help to achieve this goal, but there should be no misunderstanding about the complexity of specialized knowledge. Successful art-science collaborations such as the work of John Dunn and Mary Anne Clark, Joe Davis and Katie Egan, The Tissue Culture & Art Project, Victoria Vesna and James Gimzewski, and many others point towards a future that will be mastered together. Teamwork and dialogue between the disciplines are the tasks we need to assign ourselves to in order to deal with the cultural, economical and technological challenges our future will bring.

***The dark side of the cell* project credits:**

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Bibliography

Books and Catalogs

- Binning, G., Quate, C. F., Gerber, C., Phys. Rev. Lett. 56, 930, 1986

- Carroll, Lewis: *Alice in Wonderland*. New York: North-South Books 1999. Orig. published by Macmillan and Co. in 1866

- Crease, Robert P.: *The Prism and the Pendulum: the ten most beautiful experiments in science.* New York: Random House 2003

- *Cyberarts*. Edited by Linda Jacobson. San Francisco: Miller Freeman Inc. 1992

- Drexler, K. Eric: *Engines of creation.* New York: Anchor Press/Doubleday 1986

- *E.A.T. – The Story of Experiments in Art and Technology*, NTT InterCommunication Center, Tokyo: NTT Publishing Co. 2003

- *Endo und Nano. Ars Electronica 1992*. Edited by Karl Gerbel, Peter Weibel, Katharina Gsöllpointner. Linz: PVS Verleger, 1992

- Goethe, Johann Wolfgang von: *Zur Farbenlehre.* Tübingen : J.G. Cotta'schen Buchhandlung 1810

- LEONARDO, Vol. 34, 2001. Towards a Third Culture: Being In Between, essay by Victoria Vesna

- McLuhan, Marshall: *Understanding Media: The Extensions of Man*. New York: McGraw-Hill 1964

- Roads, Curtis: *Microsound*. Massachusetts: The MIT Press, 2001

- *science + fiction - Images and Essays* and *science + fiction – exhibition catalog.* Edited by Stefan Iglhaut, Thomas Spring. Berlin: Jovis Verlag 2003

- Snow, Charles Percy: *The two cultures*. Cambridge: Cambridge University Press, orig. published 1959

- *The Daily Bruin*, UCLA campus newspaper, Los Angeles: ASUCLA Communications Board Feb. 12, 2004

- *The quotable Einstein*, edited by Alice Calaprice, New Jersey: Princeton University Press 1996

- Tuchman, Maurice: *A Report on the Art and Technology Program of the Los Angeles County Museum of Art 1967-1971*, Los Angeles County Museum of Art 1971

- Wilson, Stephen: *Information Arts*. Cambridge, Massachusetts: The MIT Press 2002

- Zajonc, Arthur: *Catching the light: the entwined history of light and mind*. New York: Oxford University Press, 1995

Online sources

Exhibitions, institutions, individuals and project sites

- *Audio Microscope*, Joe Davis and Katie Egan, Ars Electronica 2000: http://www.viewingspace.com/genetics_culture/pages_genetics_culture/gc_w03/davis_audio_scope.htm

- *BioMusic* Organisation: http://www.biomusic.org/

- *CodeZebra Habituation Cages* project by Sara Diamond at the Dutch Electronic Arts Festival: http://deaf.v2.nl/deaf/03/249-244-7-1-172-136-12-82-3-4-189-8-232-225-120-225.py

- Dymaxion Map, Buckminster Fuller. Buckminster Fuller Institute: http://www.bfi.org/map.htm

- Feyerabend, Paul: http://plato.stanford.edu/entries/feyerabend/

- Granular Synthesis, Kurt Hentschläger and Ulf Langheinrich: http://www.granularsynthesis.info/

- Kac, Eduardo: http://www.ekac.org/

- LACMALab: http://www.lacmalab.org/

- Los Angeles County Museum of Art: http://www.lacma.org/

- *NANO*. Produced by LACMALab and a UCLA team of nanoscience, media arts, and humanities. Dec 14, 2003 - Sept 6, 2004 at the Los Angeles County Museum of Art: http://nano.arts.ucla.edu/

- Niemetz, Anne and collaborators: *Noise Ratio, Sub_Trakt, Stretching L.A*: http://www.adime.de/

- Pelling, Andrew: http://www.andrew-pelling.com/

- *science + fiction. Between nano-world and global culture.* Exhibition by the Volkswagen Foundation in cooperation with the Hygiene-Museum Dresden. http://www.scienceandfiction.de/en/index.html

- Sommerer, Christa and Mignonneau, Laurent: *NanoScape*. Installation 2002: http://www.iamas.ac.jp/~christa/WORKS/FRAMES/TOPFRAMES/NanoScapeTop.html

- *The dark side of the cell*, Anne Niemetz and Andrew Pelling: http://www.darksideofcell.info/

- *The Tissue Culture & Art Project* homepage: http://www.tca.uwa.edu.au/

- University of California Los Angeles: http://www.ucla.edu

Papers, essays, articles

- *Art @ Science* Review in DIE ZEIT, September 12, 1998: http://www.amazon.com/exec/obidos/ASIN/3211829539/002-2571179-2366458

- Alexander Graham Bell's Photophone: http://inventors.about.com/library/inventors/bltelephone3.htm

- *Art and Technology - A new Unity: The Bauhaus 1923 – 1932.* “Indepth Arts News” by absolutearts.com: http://www.absolutearts.com/artsnews/2000/08/20/27348.html

- *Black Hole Sound Waves.* Science@NASA: http://science.nasa.gov/headlines/y2003/09sep_blackholesounds.htm

- Clark, Mary Anne: *Genetic Music: An Annotated Source List*: http://whozoo.org/mac/Music/Sources.htm

- *Curious Skeletons*, NASA “Life on Earth” article June 19, 2002: http://www.nasa.gov/vision/earth/livingthings/19jun_cytoskeletons.html

- Druckrey, Timothy: *Chaos Pilots/Event-Horizon:*. http://www.granularsynthesis.info/start/content/reset/

- Feuerstein, Thomas: *MODEL 3.1.* Catalogue text about the Granular Synthesis project *MODEL 3.1* for *TRANSIT 92*: http://www.granularsynthesis.info/start/content/

- Friedman, Ken: *Forty Years of Fluxus:* http://www.artnotart.com/fluxus/kfriedman-fourtyyears.html

- Frieling, Rudolf: *Form Follows Format. Tensions, museums, media technology and media art*. Translation by Michael Robinson: http://www.medienkunstnetz.de/themes/overview_of_media_art/museum/4/. Essay published in *Media Art Net 1*. Edited by Rudolf Frieling, Dieter Daniels. Springer-Verlag Wien 2004.

- Gibbs, W. Wayt: *Art as a Form of Life*, article about Joe Davis in the "Scientific American": http://www.viewingspace.com/genetics_culture/pages_genetics_culture/gc_w03/davis_j_webarchive/davis_profile_sciam/jd.htm

- Hook, C. Christopher: *In Whose Image?: Remaking Humanity Through Cybernetics and Nanotechnology*: http://www.cbhd.org/resources/biotech/hook_2002-winter.htm

- Hunter, Graham: *Dada: Paradox of Art, Paradox of Life:* http://www.discovery.mala.bc.ca/web/hunterg/Dada.htm

- *Life Music: The Sonification of Proteins*, John Dunn and Mary Anne Clark, LEONARDO ON-LINE: http://mitpress2.mit.edu/e-journals/Leonardo/isast/articles/lifemusic.html

- *Local Nanomechanical Motion of the Cell Wall of Saccharomyces cerevisiae* by Andrew E. Pelling, Sadaf Sehati, Edith B. Gralla, Joan S. Valentine, James K. Gimzewski, *Science*, Vol. 305, Issue 5687, 20 August 2004: http://www.sciencemag.org/cgi/content/abstract/305/5687/1147

- Miranda, Eduardo Reck: *Evolutionary Music Research*: http://website.lineone.net/~edandalex/celautom.htm and *Evolving Cellular Automata Music: From Sound Synthesis to Composition:* http://galileo.cincom.unical.it/esg/Music/workshop/articoli/miranda.pdf

- Nadis, Steve: *Science for art's sake*, Nature Publishing Group, *Nature* 407, 668 – 670, 12 October 2000: http://www.nature.com/cgi-taf/DynaPage.taf?file=/nature/journal/v407/n6805/full/407668a0_r.html&filetype=&dynoptions=

- Oppenheimer, Robin: *Experiments in Art and Technology (E.A.T.) Histories: The "9 Evenings" Artists & Engineers*: http://seattleweb.intel-research.net/seminars/presentations/Dec%202003/E.A.T.%20abstract%20for%20Intel%20Lab.doc

- Sakane, Itsuo: *Toward the Innovative Collaboration Between Art and Science: The Task in the Age of Media Culture through Case Studies in the Contemporary Field of Media Arts.* Proceedings of the IEEE Virtual Reality 2003, Abstract: http://csdl.computer.org/comp/proceedings/vr/2003/1882/00/18820159abs.htm

- van Dijck, José: *After the 'two cultures': Towards a '(multi)cultural' practice of science communication.* University of Amsterdam, The Netherlands, 2002: http://www.saasta.ac.za/pcst/papers/papers/vandijck.pdf

- Vesna, Victoria: *Buckminster Fuller: Illusive Mutant Artist.* Artbyte, the Magazine of Digital Arts. Vol. 1, No 3, New York 1998. Online version: http://telematic.walkerart.org/timeline/timeline_vesna.html; *Towards a Third Culture: Being In Between*, LEONARDO magazine, Vol. 34, 2001

- *Will nanotech save the world or is it mostly hype?* Marsha Walton, CNN Science & Space, April 21, 2004: http://www.cnn.com/2004/TECH/science/04/15/nanotech.ideas/index.html

- Wertheim, Margaret: *Bucky Balls and Screaming Cells*, LA Weekly, April 3, 2003: http://www.laweekly.com/ink/03/20/features-wertheim.php

- Wolfson, Wendy: *The Humperdinck Effect*, Informationweek, May 7, 2001**:** http://www.informationweek.com/836/uwww.htm

- *World's smallest silicon mechanical devices are made at Cornell*. Cornell Science News: http://www.news.cornell.edu/science/July97/guitar.ltb.html

Dictionaries

- Hyperdictionary: http://www.hyperdictionary.com/

- Merriam-Webster Online: http://www.m-w.com/

Image Sources

- *Audio Microscope, Joe Davis and Katie Egan*, image taken from: http://www.viewingspace.com/genetics_culture/pages_genetics_culture/gc_w03/davis_audio_scope.htm

- *Black Hole Sound Waves.* Science@NASA: http://science.nasa.gov/headlines/y2003/09sep_blackholesounds.htm

- *Bone cancer cell,* AFM image: Andrew Pelling, Michael A. Teitell and James K. Gimzewski, UCLA 2004

- Cell sound and AFM illustrations taken from *Local Nanomechanical Motion of the Cell Wall of Saccharomyces cerevisiae* by Andrew E. Pelling, Sadaf Sehati, Edith B. Gralla, Joan S. Valentine, James K. Gimzewski: http://www.sciencemag.org/cgi/content/abstract/305/5687/1147 and *Single Molecule Force Spectroscopy of DNA Duplexes By Atomic Force Microscopy. Insights Into The Mechanical Stability of DNA* by Andrew Pelling, Department of Chemistry Honors Thesis, University of Toronto, 2001

- *The cytoskeleton of a cell*: http://helios.mol.uj.edu.pl/conf_c/chapters/chap_6.htm

- *The Needle Tower*, Kenneth Snelson: http://www.nasa.gov/vision/earth/livingthings/19jun_cytoskeletons.html

- *Nanoguitar*. Electron microscope image from Cornell Science News: http://www.news.cornell.edu/science/July97/guitar.ltb.html

- *NanoScape* documentation image. Sommerer, Christa and Mignonneau, Laurent: http://www.iamas.ac.jp/~christa/WORKS/FRAMES/TOPFRAMES/NanoScapeTop.html

- *The dark side of the cell* composition images, technical setup and documentation photos by Anne Niemetz, Andrew Pelling and Jiacong Yan: http://www.darksideofcell.info/

- *The Dark side of the moon*. Cover illustration for Pink Floyd's album by Storm Thorgerson.