Audionano—Vibrating Matter

Dr Paul Thomas

Curtin University of Technology
Biennale of Electronic Arts Perth

When, with our eyes shut we run our hands along a surface, the rubbing of our fingers against the surface, and especially the varied play of our joints, provide a series of sensations, which differ only by their qualities and which exhibit a certain order in time. In this paper, I will explore the sonic relationship of sound to the development of new imaging technologies through Atomic Force Microscopes (AFM). In 2003, UCLA scientist, James Gimzewski, positioned a sensitive instrument called an atomic force microscope over a cell to try to detect its motion and the microscope picked up regular vibrations. These vibrations can be translated to sound files so one can listen to variations on various material structures at an atomic level. Anne Niemetz, a sound artist who worked on the 2004 *Nano* exhibition, suggests that, "the AFM can be regarded as a new type of musical instrument." The issues of the relationship of nanotechnology to sound will be clarified through a discussion of my current research on the molecular particles that exist at the point of transition between the skin and gold. The data gathered at an atomic level is investigated to present sonically what is transferred at the point where the materials of skin and gold make contact. The idea of contact is related to the way that the AFM scan the surface of objects not by optics but by touch. The small stylus, ten nanometres at its tip, is analogous to the old record player stylus as it touches the grooves. Working at a molecular level, nano technologies offer new ways of exploring the infinitely small sonically by defying ocular-centrism and constructing sonic maps of new post-perspectival spatialities.

Visualising Sound Through Vibration

In this paper I will explore the sonic relationship of vibration in context with the development of the Atomic Force Microscope's new imaging capabilities. In 2003, UCLA scientist, James Gimzewski, positioned the sensitive atomic force microscope over a yeast cell to try to detect its motion and the microscope picked up regular vibrations of the atoms. These vibrations were translated to sound files so one can listen to variations on various material structures at an atomic level. Anne Niemetz a sound artist who worked on the 2004 *Nano* exhibition, suggests that, "the AFM can be regarded as a new type of musical instrument."[1]

To create a historical context from the introduction, I want to initially develop a connection between scientist Étienne-Jules Marey (1830-1904) and the philosopher Henri Bergson (1859-1941) to demonstrate the concept of vibration and the objectification of sound. Bergson and Marey would have been aware of each other's work as they were colleagues for a short while in the same institution (the Collège de France in Paris), until Marey's death in 1904. I want to then look at a comparison between the early work of Marey and how that work relates to the function of the AFM.

Marey was a scientist working initially in the area of medical devices and later in the realm of image science. The medical device I want to focus on is Marey's sphygmograph which was his first graphing instrument used to chart pressure changes (see Figure 1). Marta Braun states the device recorded:

those changes that occur in the heart as it undergoes its double sequence of contraction and expansion. This was his sphygmograph, or pulse writer, which he presented to the Academie des Sciences in 1860 ... Marey's instrument was very simple. It comprised of a lever, with one end resting on the pulse point of the wrist and the other connected to a stylus, and a clockwork mechanism that moved a strip of smoke-blackened paper under the stylus at uniform speed, converting the pulsations into a fluid inscription.[2]

The sphygmograph worked in the same way as a needle on a gramophone might operate. As the blood is passed through the vein the arterial wall moves and the needle responds. This response is then translated via an armature to create a graph of the pulse over time.

Duration

This graph was a visual representation of the tempo that Bergson discusses as a concept of duration by using an analogy of hearing the sounds of footsteps:

I retain each of these successive sensations in order to combine it with the others and form a group which reminds me of an air or rhythm which I know: in that case I do not count the sounds, I limit myself to gathering, so to speak, the qualitative impression produced by the whole series.[3]

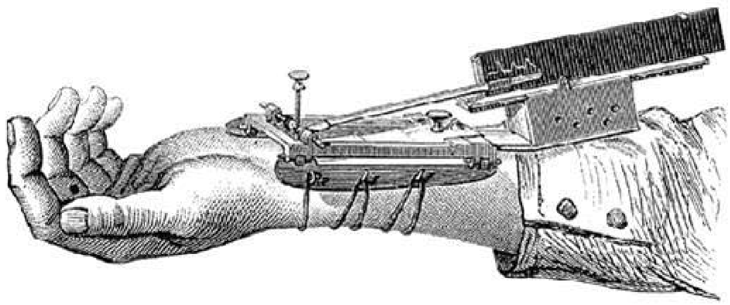

Figure 1 An illustration of Étienne-Jules Marey's sphygmograph.

This reference places the sound heard, not as a series of individual notations to be counted, but as a "qualitative impression" that could be understood as a whole experience. Bergson's theory demonstrates that time can exist without space by using sounds of footsteps as an example. In one instance, the sound of the footsteps is heard in the form of a rhythm; we place these sounds together as a sonic object.

In another version, we hear the sounds of the footsteps, individuate them and count them as points. Bergson suggests that these points exist in space and can be understood by the existence of the interval between the sounds. Take away the sounds and you are left with the interval and that interval is space. "If we count them, the intervals must remain though the sounds disappear: how could these intervals remain, if they were pure duration and not space? It is in space, therefore, that the operation takes place."[4]

In Bergson's book, *Time and free Will* quoted above, we encounter concepts of space as intervals marked by duration to become packaged into an object that remerges in space. This sonic object is the personification of vibration.

Pythagoras (6th century BC) is thought to have described a stone as frozen music. He intuited that the mathematics of frequency which occur in processes such as planetary rotations, cycles of the seasons, right down to the atomic world of elemental matter, are not just lifeless pieces of data but reveal movements, rhythms, relationships and meanings which may be loosely translated as "stories." Stories in turn generate meanings and artistic expression. The word "mathema" comes from the Old French "mathein," "to be aware; to awaken."[5]

Bergson's concepts were looking at duration as a means of breaking down the relationship between the object and its space. The problem lies in the way space and duration are perceived in the initial stages. Renaissance perspective has played a significant role in controlling and objectifying space as Jean Gebser points out that: "the whole cannot be approached from a perspectival attitude to the world, we merely superimpose the character of wholeness on to the sector, the result being the familiar 'totality.'"[6] So, with Gebser, our perspectival attitude towards the world denies us the comprehension of the object's potential and our ability to intuit. We only see the object from one point of view and not as a totality. The totality of duration, rhythm, space and pattern that is inherent within an object, needs to be spatially reconfigured so it can be seen as whole.

Bergson comments on this question when talking about the successive notes of a tune:

In a word, pure duration might well be nothing but a succession of qualitative changes, which melt into and permeate one another, without precise outlines, without any tendency to externalise themselves in relation to one another, without any affiliation with number: it would be pure heterogeneity.[7]

If we were to make a comparison between footsteps and patches of data transmitted to be reassembled between nodes as examples of contemporary durational objects, how does that alter our concept of time? When we put in more concepts, larger than just footsteps, as rhythms and patterns, then we are confronted with an ever-increasing compression into multi-narrative objects in time. Each individual rhythm and pattern when seen as an object or a sound file having its own identity is placed alongside other object is a multi-narrative event.

Nowadays compressed packages of duration become transmitted in real time to be processed through a standard concept of quantifiable time. These concepts of time, when linked to Marey's sphygmograph, demonstrate how the vibration of the pulse can be seen as an object in one's gaze to be comprehended. This drawing of a sound wave became a recognised image that reflects the time of its making, a sound as a sonic object which contained the duration and vibration of its existence.

The Atomic Force Microscope

I want to now bring us back to the AFM created in 1986 as a device that works on the same principle as Marey's sphygmograph. The AFM which is not an optical microscope has three main imaging modes: contact, non-contact and tapping. The AFM can also be used in a non-imaging force spectroscopy mode. The AFM consists of a micro-scale cantilever with a sharp tip (probe) at its end that is used to scan the surface of the sample. The AFM cantilever is typically silicon or silicon nitride with a tip radius of approximately ten nanometres. In order to be imaged the samples must be thin and small enough to be placed on a sample stage. In contact mode the cantilever continually touches the surface whereas in tapping mode AFM imaging relies on the oscillating cantilever/tip continually tapping the sample surface.

The cantilever in contact mode, when lowered (like the stylus of record player) to within a few nanometres of the surface, is affected by an attraction to the surface called the Van der Waals' force. The cantilever then moves in a raster scan across the sample surface, recording the topographical data via a laser beam that is projected from the head of the cantilever to a photodiode. The data is gathered from the XYZ coordinates to be converted into series of representational typographical images.

The AFM can be used to image and manipulate atoms on a variety of surfaces. The atom at the apex of the tip "senses" individual atoms on the underlying surface when it forms incipient chemical bonds with each atom. Because these chemical interactions subtly alter the tip's vibration frequency, they can be detected and mapped.

The sphygmograph that records the vibration of the pulse is now replaced by the AFM that records in a similar way the vibrations of the atoms of the blood cells themselves. These vibrations become the basis of our sonic understanding of the worlds and, therefore, the infinite smallness of the atomic world.

The Art of Vibration

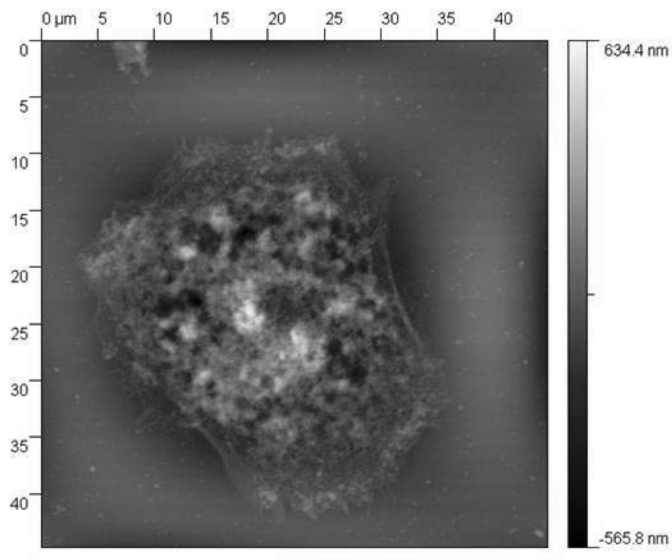

Figure 2 Image of a skin cell scanned using a gold coated cantilever with an AFM in contact mode.

In 1988 a sound art work was produced by composer Susan Alexjander, who worked with cell biologist David Deamer at the University of California after he released *DNA Suite* and *DNA Music*.[8] These were sound recordings based on the data mappings of sequences he gathered of adenine, thymine, guanine and cytosine (DNA bases) along the helix. Together the pair worked on a project that resulted in creating compositions, purely based on the chemical composition of the four DNA bases. Their molecular vibrations were measured using an infrared spectrophotometer. The process involved exposing each DNA base to infrared light and measuring the absorbance of their wave-lengths and then transcribing light into sound with the help of a Yamaha synthesizer. The compositions were released in 1990 on cassette titled *Earthday*. Subsequently the compositions were released on CD titled *Sequencia* in 1994 as three original performances—"Eikos," "Sequencia" and "Pataphysical Thymine"—created on traditional instruments plus electronic keyboard.[9]

In 2002, Adam Zaretsky, a bio-artist working in a laboratory at the Massachusetts Institute of Technology, discovered the "Humperdinck Effect," in which the vibrations of "loud, really awful" lounge music applied for forty-eight hours spurred antibiotic production in E. coli bacteria. Zaretsky at that time met with Oron Catts and Ionat Zurr who collaborated together as part of *The Pig Wings Project* in developing the *Dynamic Seeding Musical Bioreactor by Tissue Culture and Art Project* (see Figure 3). This part of the project was experimenting with submitting the bone marrow cells, as they were being cultured, to audio vibrations. The work looked at using irregular vibrations to distribute the cells throughout the scaffolding. The audio vibrations were taken from a Napster search for songs with "pig" in the title.

Figure 3 Dynamic seeding of pig mesenchymal stem cells onto/into degradable polymer scaffold in shape of wings, using a vibrating speaker that played pig songs; by Ionat Zurr.

These songs were then played to the cells by placing a speaker underneath the petri dish. Examples of pig-related MP3s that were played to the pig wings included: "War Pigs" by Black Sabbath, "Fascist Pig" by Suicidal Tendencies, "Da Killing of Da Pigs" by Da Yoopers, "Chokin' this Pig" by Eminem, "Squeal Like a Pig" by the Reverend Horton Heat, "Filth Pig" by Ministry, "American Pigs" by the Angry Samoans, "British Pigs—The Price of Royalty" by One Life Choir, "PigInCheez" by Aphex Twin, "Blue Christmas" by Porky Pig, and of course "Pigs on the Wing" by Pink Floyd.

James Gimzewski coined the term "sonocytology" to name the study of sounds emitted by cells. What Gimzewski needed was a program capable of converting the nano scale vibration into an audio file. The *Nano* exhibition, which took place at the LA County Museum of Art in 2004, was a result of collaboration between N. Katherine Hayles, Robert Sain, Victoria Vesna and James Gimzewski. Its purpose was to bring nanotechnology before a broader audience and to work on visualisation of what is taking place at nano level. Artist Anna Niemetz and a researcher Andrew Pelling (who works with Gimzewski converting the nano scale vibrations to sound files), collaborated on *The Dark Side of the Cell*, a sonic immersive installation for *Nano*, that for the first time utilised cell sonics and were premiered on 2 June 2004. Nano scale imagery of the cells was projected, together with the sonograms of the cells, onto sculptural elements based on the actual inner structure of cells.

My own research, the *Midas Project*, looked at the transition phase between skin and gold by working with Thomas Becker from the Nano Research Institute at Curtin University of Technology. It used the data from the AFM force spectroscopy that only recorded the Z measurement and the motion of the cantilever's deflection. The cells cultured at SymbioticA with the assistance of Oran Catts and Ionat Zurr were placed in an AFM force spectroscopy where one cell was isolated to measure the transitional phase between a single skin cell and skin cell touched by gold on a single-molecular level.

The gold-coated cantilever is manually advanced towards the cell surface until it makes contact (see Figure 4). At the point before contact, the tip of the cantilever is attracted and jumps to the cell's surface (Van der Waals' principle). This process was carried out using four different approaches.

—gold-coated silicon nitride cantilever on to skin cell;

—gold-coated silicon nitride cantilever on to mica substrate;

—silicon nitride cantilever on to skin cell; and

—silicon nitride cantilever on to mica substrate.

From this data, a comparative study was conducted recording a skin cell using a standard silicon nitride tip and then using a silicon nitride tip coated with 26.7 nanometres of gold. Using the AFM force spectroscopy, silicon nitride tips were placed over the cell's surface creating three different deflections. The deflections were three different contact forces for ten seconds each, exploring the morphology of trans-mediation taking place in the space between skin and

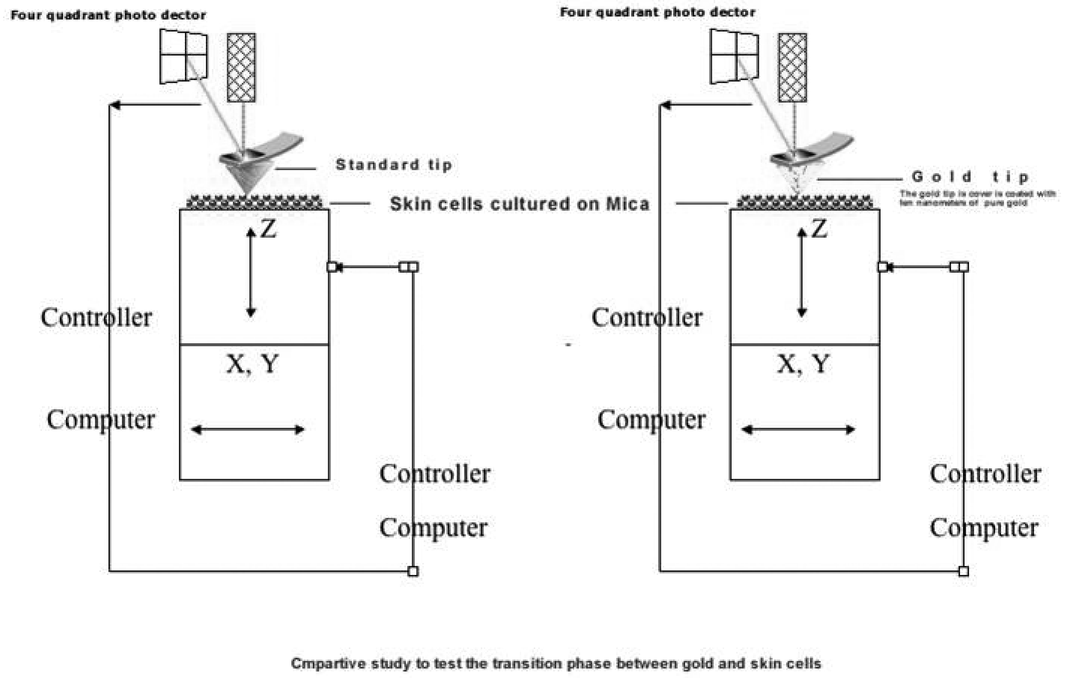

Figure 4 Illustration demonstrating the AFM gold-coated and uncoated silicon nitride cantilever used in the experiment.

gold. In this experiment the concept of skin touching gold has been inverted to that of gold touching skin. The gold coated cantilever acts as a metaphorical finger to gather the data from the skin cell.

The cantilever tip has a radius of curvature of ten nanometres which touches the cell (see Figure 5). The gold coated silicon nitride tip reads the surface interaction of the vibrating atomic particles. The probe in this context is like a metaphorical figure touching a surface to feel what is happening (like feeling one's pulse).

This data from the AFM was extracted to be translated into wave files by Kevin Raxworthy, a masters student in electronic arts at Curtin University of Technology. The sounds are to become the basis for the installation work developed to be exhibited at the *Unsafe Distance* exhibition within the Third International Festival for the Arts, Sciences and Technologies (ENTER3), in Prague, 2007, and which included the art work *Midas*.[10] To translate this data to a wave file, Raxworthy translated the high point as equal to one, the low point as equal to minus one, and zero in the middle. This rescales and normalises the data in order to generate a range compatible with audio wave data. The timescale is based on the sample rate which was one millisecond.

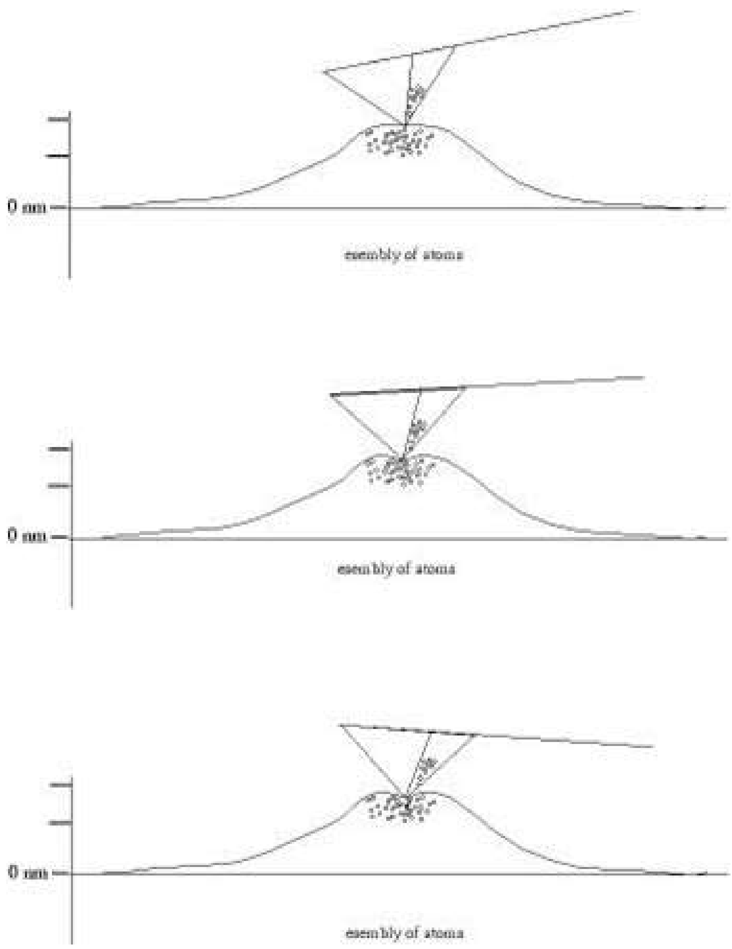

Figure 5 Illustrates the gold coated silicon nitride cantilever approaching the cell and more pressure being applied to the tip. In the experiment the tip was held on the cell for ten seconds to get a reading.

Vibration Of The World

Elizabeth Grosz states:

> What is transmitted, transformed, and relocated in this movement of forces from chaos to milieu to territory and from rhythm to the refrain to music, is nothing but vibration, resonance. Vibration is the pulse running through the universe from its chaotic interminability to its most intimate inscription on living bodies.[11]

The place of vibration in the world is now at the core of materiality. The atomic vibrations resonate in a constant swarm that cling together under illusionistic manifestations of organisms and objects, natural and manmade. What we find with Marey's visualisation of the pulse's vibration, is a signifier that can be linked with Bergson's theories of duration. The vibrations that Marey's sphygmograph recorded are similar to those recordings of vibrations existing within matter. What Bergson's concepts brought to Marey's visualisations was to see the vibrations not as purely temporal effects but to see vibrations intuitively; personified as a sonic object that is the sum total of its atomic vibrations and understood innately. Sound can be understood in two forms: as a time–based form which is spatial or territorial; or as an object–based form which involves a collapse of vibration, rhythm, pattern, scale, time and space into a memory and understood intuitively.

> What science and art share is precisely the vibratory structure of the universe, the force of chaos itself. Art makes sensation from vibration (sensation after all is nothing but a vibratory difference capable of resonating bodily organs) where science makes a pattern, measurement, ratio or formula.[12]

The vibration that exists at an atomic level is permeated in matter, creating potentially new sonic maps that can be interpreted to generate different understandings of existence. In the same way it was suggested that a mechanic could listen to the pitch of an engine to tell if something was not functioning correctly. The cantilever recording the sounds of atomic vibrations can in time demonstrate the impact of a sonic comprehension of matter. The material world is transmitting continuously as oscillating series of patterns that could be diagnosed to understand their balance. Pattern recognition in the face of swarms of sonic vibrations is a way forward in reconfiguring our position in the world.

Notes

All URLs accessed June 2008.

1. Anne Niemetz, *Singing Cells, Art, Science and the Noise in Between*, masters thesis (LA: UCLA, 2004), p. 39, reproduced on <http://users.design.ucla.edu/~aniemetz/Niemetz_Thesis2004.pdf>.
2. Marta Braun, *Picturing Time: The Work of Etienne-Jules Marey (1830–1904)* (Chicago: Chicago UP, 1992), pp. 16-17.
3. Henri Bergson, *Time and Free Will: An Essay on the Immediate Data of Consciousness* (NY: Harper and Row, 1960), p. 86.
4. Ibid., p. 87.
5. Susan Alexjander, "The Infrared Frequencies of DNA Bases, as Science and Art," *IEEE Engineering In Medicine and Biology Magazine*, 18.2 (March-April 1999), pp. 74–79, reproduced on <http://www.oursounduniverse.com/articles/IEEE.html>.
6. Jean Gebser, *The Ever-Present Origin* (Athens, Ohio: Ohio UP, 1985), p. 18.
7. Bergson, pp. 103-104.
8. David Deamer and Susan Alexjander, *"DNA Music"/"DNA Suite,"* CD (Aptos, CA: no date), see: Alexjander on <http://www.oursounduniverse.com/music_samples.html>.
9. Susan Alexjander, "Microcosmic Music—A new level of intensity," keynote address (Goddard College, Vermont: 2007), reproduced on <http://www.oursounduniverse.com/articles/microcosmic.html>.
10. See <http://c-lab.co.uk/default.aspx?id=8&eventid=93>; <http://enter3.org/index.php?lang=en&node=110&id=26&act=detart>.
11. Elizabeth Grosz, "Vibration. Darwin, Deleuze and the Music of the Cosmos," in *New Constellations: Arts, science and society*, CD-ROM (Sydney: Museum of Contemporary Art, 2006).