Artistic Molecules, Microbes, and the "Listening Microscope"

"New Media" is Very Old

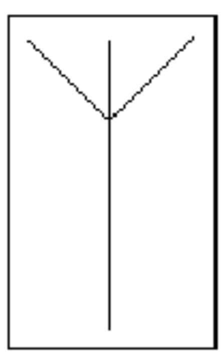
Joe Davis

Many people will recall predictions made 20 or 30 years ago about a forthcoming "computer age". Computers, it was said, would become so ubiquitous and pervasive that no aspect of daily life would remain completely untouched. These predictions of course have proved true. Now I have become convinced that there are changes looming on the horizon that are so sweeping and so dramatic that the revolutions and transformations associated with the so-called "digital age" will almost certainly shrink by comparison. Ironically, although I have found a "new" medium it is in fact very, very old. Some say it is older than the earth itself. That medium is DNA (deoxyribonucleic acid), the family of biochemicals and to some extent, the organisms that interact with it. Over the last 15 years or so I have explored some of the possible interfaces of molecular biology, microbiology, and the arts. The exhibition at Ars Electronica "Next Sex" will feature objects and substances that characterize several of the important steps I have taken in the process of that exploration.

It is at least topical at this point to note that my introduction to molecular biology stemmed directly from a project pertaining to extraterrestrial communications I had mounted with colleagues from Harvard and MIT in the early 1980's. That project, called Poetica Vaginal was a project to transmit human vaginal contractions into deep space for the purpose of communicating with aliens. Problems associated with interstellar radar transmission and the search for extraterrestrial intelligence automatically led me to consider the "universal" language of biology; convenient and economical production of astronomical numbers of individual entities (messages); robust media (bacterial spores and viruses) that could survive both environmental rigors of the space environment and periods of "geologic time" that would be required for the "journey out".

Molecular Artworks

At Ars Electronica I plan to install a novel instrument I have recently developed and several examples of my work constructed from synthetic molecules of DNA. If possible I will also exhibit the recombinant bacteria that now host my molecular artworks. The first of these artistic molecules, Microvenus, contains a coded visual icon representing the external female genitalia and by coincidence, an ancient Germanic rune representing the female Earth . That work was carried out with molecular geneticist Dana Boyd at Jon Beckwith's laboratory at Harvard Medical School and at Hatch Echol's laboratory at University of California, Berkeley. Later, I learned to sequence or "read back" DNA molecules (including this one) with Shuguang Zhang and Curtis Lockshin at Alexander Rich's laboratory at MIT. Techniques used to encode visual messages for extraterrestrial intelligence were co-opted to encode the Microvenus graphic information and a short decoding primer into a 28-mer DNA molecule.



***Microvenus* icon**

10101
01110
00100
00100
00100
00100
00100

***Microvenus* bit-map**

(PRIMARY STRAND)
5'-CTTAAAGGGGCCCCCCAACGCGCGCGCT-3'
| | | | | | | | | | | | | | | | | | | | | | | | | | | | |
3'-GAATTTCCCCGGGGGGTTGCGCGCGCGA-5'
(COMPLEMENTARY STRAND)

Double-Stranded *Microvenus* DNA

Another molecular artwork to be exhibited, Riddle of Life, is the culmination of an interesting but little known episode in the history of science. In the fall of 1958, biophysicist Max Delbrück sent a mysterious telegram to George W. Beadle at the Nobel prize ceremonies in Stockholm, Sweden. Delbrück had composed his telegram in a form that reflected some new and exciting ideas about the nature of DNA and the operation of the genetic code. It was also an important precedent for the idea that extrabiological information - in this case, English language - could be contained in genetic form. The telegram was sent as one continuous 'word' with 229 letters:

ADBACBBDBADACDCBBABCBCDACDBBCABBAADCACA
BDABDBBBAACAACBBBABDCCDBCCBBDBBBAADBADA
ADCCDCBBADDCACAADBBDBDDABBACCAACBCDBABA
BDBBBADDABDBBDABDBACBADBBDBACBBDCBBABD
CACABBACDAACADDBBDBBBADDBADAXBBADDBA
DAACBCDCACABBABCABCBBDBACBDDACDBDDCBDC

The key to unraveling the message was that it mimicked the triplet operation of DNA. In Stockholm, Beadle managed to crack Delbrück's code and read the English sentence:

"BREAK-THIS-CODE-OR-GIVE-BACK-NOBEL-PRIZE-LEDERBERG-GO-HOME-MAX-MARKO-STERLING."

Beadle replied with a slightly different triplet code of his own. When Beadle's telegram arrived at Delbrück's laboratory at Caltech, the return message was deciphered:

"GWBTOMDIMSUREITSAFINEMESSAGEIFICOULDDOTHEFINALSTEP"

Evidently, Delbrück and the group at Caltech weren't ready to let the recent Nobel laureate have the last word. So, they rallied with yet another mysterious message.

At a formal lecture after the Nobel prize ceremonies in Stockholm, Beadle was presented with a molecular model constructed from toothpicks (Delbrück had airmailed it to the presiding officer). Each toothpick was stained with one of four colors. Like the coded telegrams, the toothpick model also contained an English language message, but with a code made up of colors rather than letters. This time, Delbrück chose to encode a poetic message that embodied a theme important to the history of both the sciences and the arts. The model contained the message,

"I am the riddle of life. Know me and you will know yourself."

Delbrück and Beadle had ingenious ideas for expressing human language in the form of DNA, but in 1958 no synthetic, or artificially constructed nucleic acids were available. I organized a project to create DNA corresponding to Max Delbrück's toothpick molecule with the Laboratory of Molecular Structure at MIT Biology (Alexander Rich Laboratory), and the Burghardt Wittig Laboratory at the Institute for Molecular Biology and Biochemistry at the Free University of Berlin, Germany. Max Delbrück's RIDDLE OF LIFE molecule that was first conceived of over 40 years ago actually first came into existence in Berlin in December/January, 1993-4 .

The third molecule, Milky Way DNA, is described elsewhere in the AEC "Next Sex" publications.

A Question of Two Plants Singing

Part of my installation at Ars Electronica is undertaken in collaboration with Katie Egan and pertains to a question about two "singing plants". At a point in time now almost exactly two years ago, a young pre-med student approached me with an interesting question. She had recently returned from South America where she had carried on field work in the Ecuadorian rain forest. There she had encountered a Native American brujo or "medicine man". The brujo had told her that a given species of plant in the mountains sings a different song than the same species of plant in the valley. The student wanted to know if it was possible to "listen" to plant cells.

All acoustic phenomena, including "sound", are the result of mechanical movements of physical objects within or upon the surface of a solid, gaseous, or liquid acoustic medium such as steel, air, water, etc.. In the case of the acoustic phenomena we call "sound", the movement of physical objects occurs at or close to audio frequency so that the resulting waves or pattern of waves passing through an acoustic medium do so at audio frequency. When these audio frequency waves impinge on the human listening apparatus (the inner ear) the result is that "sound" is perceived in the human brain.

To begin with, it seemed to me that the problem wasn't that cells are naturally "mute". Many of them - and their flagella, cilia, pili, etc., - are normally at least partly engaged in activities that appear to occur at audio frequency. Further, no non-dormant living organisms are known to exist in vacuum or otherwise outside of an acoustic medium.

At the time, there were to my knowledge no existing microphones of sufficient sensitivity to register microacoustic signatures of individual (microscopic) cells. The function of conventional microphones generally depends on the mechanical motion of crystals or diaphragms that react to impinging sound waves. Sound waves generated by individual cells or microorganisms are simply too weak to effect such movements in mechanical listening apparatus.

Conventional microphones translate audio frequency sound waves into audio frequency electrical (electromagnetic) signals. These electrical signals may then be routed through amplifiers, equalizers, and other electronic audio equipment and eventually into speakers or earphones where electric signals are transduced back into "sound". At the speaker, sound is created when a electromagnetically-driven diaphragm or crystal produces corresponding sound waves in surrounding air

At the turn of the last century Alexander Graham Bell built what was probably the world's first optical transducer of sound waves. He called it a "photophone". Instead of translating sound into electrical signals, Bell built an apparatus that turned sound waves into audio frequency pulses of light. He also built "detectors" that would convert audio frequency pulses of light into electrical signals that could then be converted into sound. To construct my audio microscopes I also used optical detectors and specially illuminated stages and microscope slides that allow only light reflected from the surfaces of specimens to enter the objective lens of microscopes . These optical signals are then transduced into electrical signals via detectors mounted on the microscope eyepiece. The electrical signals are subsequently routed through more or less conventional audio equipment so that they may then be perceived as sound in the ear/brain of the user/observer.

At early stages of this work I was surprised to find a wide range and diversity of information in the microacoustic world. At lab we find organisms on almost a daily basis that we have never seen or listened to before. We therefore now routinely listen to organisms for the first time. Different organisms make different sounds in the way that say, the sounds of horses are perceived as different than the sounds of sheep. My experiments with spectrum analysis tend to reinforce that notion. I found that slightly different acoustic signatures corresponded to slightly different species of microorganisms. Paramecium multimicronucleatum for instance, has a slightly different audio signature than Paramecium caudatum. The signatures of a given species however tend to be uniquely distinct to that species. So as it turns out, the two plants of the same species must indeed "sing the same song", unless perhaps the Ecuadorian brujo knows of some exceptional organism unlike those we have observed to date.

The Farm

In order to maintain a supply of many different organisms Katie Egan and I have learned to maintain a wide variety of wild protist cultures. We call this collection of microbial cultures "the farm". "The farm" now includes many species of ciliates, nematodes, euplotes, rotifers (bdelloids), motile algae and other tiny invertebrates. As we are artists still, with little or no ambition to become scientific taxonomists, many of our organisms are referred to in lab by our own names for them such as "green scudders", "red wierdos", and "scary finbacks". Because many of these organisms originated as "wild" organisms it is possible that some of them have not yet been scientifically classified anyway. We also are fortunate to have available a variety of typical laboratory microorganisms in reasonably pure culture including E coli, Bacillus, Pseudomonas, and others.

The existence of the farm has itself spurred us on to other work. We are for instance now pursuing a microfabrication project that will allow us to "go fishing" for microbes with equipment that is basically analogous to an anglers "rod and reel".

We will install both the audio microscope/spectrum analyzer and elements of "the farm" at Linz. The installation will feature a "library" of captured sound and video from a variety of organisms as well as real time examinations of organisms from "the farm" and of organisms we hope to obtain locally.

Note: *The preparations for our installations at Ars Electronica are now partly supported by the MIT Council for The Arts.*