

DNA and Music:

A comparison of 'DNA music' and the issues of authentic representation.

By Darren Curtis

DNA music has been in the mainstream since the mid 1980's.¹ (DNA is Deoxyribonucleic acid, a chemical found primarily in the nucleus of cells. DNA carries the instructions for making all the structures and materials the body needs to function). Since then it has undergone a musical and scientific transformation, which has allowed a cross-synthesis of the arts and sciences. In the exploration of 'DNA music', the composers have moved away from just mapping one musical parameter to the DNA code, to the complete mapping of the inner workings of the DNA code, to the maximum of musical parameters. It is these parameters Timbre, Duration, Intensity, Pitch/Frequency which are at the basic structure of music. Likewise DNA is composed of many parameters, which make it what it is. The first question which must be raised is - what is music? Addressing this question at the fore-set allows an open mind to the complex issues around mapping the DNA code to a given musical system. This paper will first explore the musical and scientific viewpoint of DNA music. Following that there will be an analysis of two 'DNA music' composers; Susan Alexjander and Peter Gena. Both composers have collaborated with scientists to compose 'DNA music'. Both composers 'DNA music', represent a large cross section all DNA music. With this in mind the issues of authenticity must be addressed. What is authentic representation of the DNA parameters transcribed into the musical parameters?

DNA is made up of four bases; Adenine, Guanine, Cytosine, Thymine. The abbreviations of these bases are as follows A for Adenine, G Guanine, C for Cytosine, and T for Thymine. It is these four nucleonic bases that allow for life to be made possible. It is from these bases and there inner and connecting relationships, that 'DNA music' comes about. It is the uses of all aspects of the DNA code to the mapping to different musical parameters that artist and scientist explore this cross-synthesis. Since that time, composers and scientists alike have created DNA music from the literal to the fantastic. ²

First we look at the scientific viewpoints of the 'DNA music'. It was Hayashi and Mankau in 1984; which is the time when DNA music was entering the academic

¹ See footnote 2. (DNA's extended name is Deoxyribonucleic acid).

² Unknown. "A discovery worthy of a Nobel prize." DNA deoxyribonucleic acid. <http://www.chm.bris.ac.uk/motm/dna/dna.htm> (10 June 2005).

mainstream, wrote concerning the importance of DNA translation into musical form.

*“Sir – Recent progress in gene cloning and DNA sequencing techniques has produced an enormous amount of base sequence data. ...We propose an acoustic method to minimize the distress of handling such information. One certain advantage of this method is that the sequences are now more easily recognized and memorized. After we could memorise without difficulty increased at least three fold. In addition, a computer equipped with a sound generating system can sing back the sequence to facilitate the confirmation by ear. Lastly this practice may help to bring back some of the pleasure of decoding the mysteries of life from computers.”*³

This statement expresses the idea, that transcribing DNA into music is to make the study of genetics more pleasurable. The genetics role in this case of DNA music, seems to be one of escaping boredom. This is the first viewpoint and maybe the most abstract exploration of mapping DNA code into musical form. Researcher Holdfaster explores this idea further in his book ‘Golden, Escher and Bach. He describes a parallel between the ‘Genetic Code and musical recording process’. This may be a trip into the fantastic but it expresses how one aspect of the musical processes can be applied to the DNA code. Let us entertain the following possibilities to understand what Holdfaster expresses. Where we see, the nucleus as the ‘throne room’, the DNA as the ruler, the mRNA as the long piece of magnetic recording tape and the ribosome as the tape recorder.⁴ With this in mind, Holdfaster writes:

“Now we come to another lovely parallel between tape recorders translating tape into music.....Imagine a collection of many tape recorders, arranged in a row, and evenly spaced. We might call this array a “poly recorder”. Now imagine a single tape passing serially through the playing head of all the component recorders. If the tape contains a single long melody, then the output will be a many voiced canon, of course, with the delay determined by the time it takes the tape to get from one tape recorder to the next.”

...As the tape passes through the head of the recorder it is “read” and converted into music or other sounds. Thus magnetic markings are “translated” into notes. When a “tape” of mRNA passes through the “playing head” of a ribosome, the “notes” which are produced are amino acids, and the “pieces of music” which they make up are proteins. Thus DNA as the base code provides the structural

³ Kenshi Hayashi and Nobuo Munakata. “Basically musical”. *Nature*. 310 (1984): 96.

⁴ Douglas Hofstadter. *Godel, Escher, Bach: An Eternal Golden Braid*.(New York: Vintage Books Edition, 1980) 519.

*framework, thus the notes amino acids are formed into proteins “pieces of music”.*⁵

This example of the fantastic is a good analogy of what musicians and scientists are exploring that relate to connecting the DNA code to musical processes. One group of researchers who have given the most plausible theory of cross-synthesis is the geneticists the Ohno's. Here is what the Ohno's wrote about authentically connecting the DNA code to musical composition.

*“... the principle of repetitious recurrence pervades both the construction of coding sequences in the genome, which can be regarded as being representative of nature and musical composition which can be regarded as the most abstract and therefore the most intellectual expression of nature.”*⁶

The majority of 'DNA music' in some way has applied the sequences of DNA bases eg AAGGTT, directly to the musical notes. Even in today's western music, repetitious recurrence is still the hallmark of musical composition. An example would be a musical theme is developed which is then varied in different ways. This is also the case according to the Ohno's in the Life Code DNA. On deeper examination we find that the ancient Greek thinkers, developed musical systems based on natures working. These remain in some form in our western music today. Likewise many composers like Bartok, Debussy and Mozart wrote musical compositions using the laws and sounds of nature. With this in mind, let us examine two significant 'DNA music' composers- Susan Alexander and Peter Gena. It must be noted that both composers work, represent a broad cross-section of the majority of 'DNA music'. This also includes collaboration with scientists.

First we look at the composer Susan Alexander; here is a comment of what has been said about her work: *“Her compositions are fusing science and art, producing music that is collaboration between her and DNA itself.”*⁷. The intention of the composer is best expressed in this statement.

Is the body creating music? Are we, as the composer Charles Ives felt, walking, talking musicians, capable of creating our own symphonies? The answer seems to be an increasingly obvious “yes”, as we study the body, its brain waves,

⁵ See footnote 4.

⁶ Susumu Ohno and Midori Ohno. “The all pervasive principle of repetitious recurrence governs not only coding sequence construction but also human endeavor in musical composition”. *Immunogenetics*. 24.2 (1986):71-78.

⁷ Dr. David Whitehouse. “Sci/Tech: Listen to Your DNA.” *BBC News Online*. November 26, 1998. <http://news.bbc.co.uk/1/hi/sci/tech/22591.stm> (7th March 2005).

*heartbeat, and rhythm of the blood circularly, endocrine cycles, right up to the microwave level of organ vibration.*⁸

This then brings us to the question - What is music? Is it certain states of different vibration resonated together, is it a collection of frequencies or sampling noise ordered? Is it an organized sequence events or musical ideas. If it is any one of these answers then we must remove all preconceived ideas of what music is and start rethinking our pre-conceptions. For Alexjander implies it is anything that vibrates together. In her work she has collaborated with biologist Dr. David Deamer who worked as a cell biologist at the University of California - Davis in 1988. What Alexjander proposed was to measure the actual molecular vibrations of all four DNA bases. This was done by taking a spectrophotometer and by exposing each base to infrared light. Next they measured each base and the wavelength it absorbs. It was then possible to identify a unique array of approx 15 different wavelengths for each DNA base. Since each base has a slightly different atomic structure it vibrated in a unique manner. In turn these numbers represent a wave-length "scale" on the light spectrum. The next step was in translating these wavelengths into the sonic spectrum. This sonic spectrum falls within the human hearing range which is from 20 Hz – 20,000 Hz.⁹ Let us now look deeper into her understanding of this process:

*"An important key to understanding how we can actually hear high, fast light vibrations is the Law of the Octave. These law states that any vibration of sound (or light) can be doubled or halved, and the same pitch (or light frequency) will result, but what changes is the octave of the sound (or radiation) ... Thus by taking a very rapid vibration of light and halving it many times (about 35 iterations) we can bring this vibration into the range of hearing. This process thus created about 60 pitches which are microtonal of which they exist within the half step of western music and when layered out on the piano operates within 2 ½ octaves.."*¹⁰

In other words the same ratio's or light work for the sonic spectrum. Taking in account one factor that the nature of DNA operating in the electromagnetic spectrum and not in the sonic spectrum. The next process was to find a tonal center; a central pitch on which to base this musical composition. Alexjander found this by the most frequently occurring pitch within all the 60 DNA frequencies she mapped via the spectrophotometer. The idea of the tonal centre

⁸ Susan Alexjander. "The Infrared Frequencies of DNA Bases, as Science and Art.." *Our Sound Universe*. <http://www.oursounduniverse.com/infraredfreq.html> (20th March 2005).

⁹ Unknown. "Sensitivity of Human Ear." <http://hyperphysics-phy-astr.gsu-edu/hbase/Sound/earsens.html> (10th June 2005).

¹⁰ See footnote 8.

formed from the basis of Alexander using western European music. Then is Alexander using bias in her DNA music? This bias is acknowledged by Alexander and is done according to her so the music would sound ascetically pleasing, yet at the same time she is implying we are creating a revolution in the cross-synthesis between disciplines. Where is then the authentic principle within Alexander's work? As stated before the Ohno's describe that there is a repetition occurrence between DNA and music. Then if we were to accurately represent Alexander's work then we would play all 15 pitches of each DNA base per base code. This would accurately represent the ideal of musical composition using the theme, variation and repetition, which also occurs naturally in the DNA bases system. To some extent Alexander does this in playing a given code, but westernises it by an accompaniment of a western harmonisation system. Therefore she has not isolated the DNA and treated it separately from her musical traditions. The next issue which must be visited is the authenticity of the spectrophotograph. It has been recently suggested in a paper on the science of spectrometers, that it has evolved and there may be a better technology for more accurate representation of this DNA code.¹¹ Therefore can Alexander and Deamer 'DNA music' be an authentic transcription? We can clearly see Alexander has taken a no-direct approach to mapping both parameters. Alexander's musical composition doesn't deal with the DNA code other parameters. The concepts of rhythm, intensity, duration or even timbre for that matter. What we do find is an accurate system of mapping musical frequencies to DNA Light Frequencies with the most current technology for that time. Therefore we have one parameter that is accurately represented, from the Light Spectrum into the sound spectrum.

Explored next is the work of Peter Gena who has tried to map all the parameters that make up the DNA code and processes, to that of the complete parameters of music. This differs from the work of Alexander; which on took only one factor of the DNA process and mapped it to music. Gena takes his mapping from the basis of the DNA base sequences as Alexander does; the four bases of DNA. Though Gena has developed this to the next level. This incorporates other functions of the DNA process up to the Amino Acid and Ribosome process of the Life Code Transcription. From the paper Physiological approach to DNA music in collaboration with Charles Strom MD we see the parameters of Pitch/frequency, Intensity, Duration, and Realization in a complete synthesis. Basically he has taken the 4 bases of DNA (A C G T) and worked out they interrelated to one another and the finer details that make up these bases.¹² Thus by working with these characteristics he aimed to create an aural representation of the DNA code. His process works on the interrelationships of the bonding of A-T G-C,

¹¹ Thierry Delatour. "Molecular music: the acoustic conversion of molecular vibrational spectra." *Computer Music Journal* 24.3(2000): 48-68.

¹², Peter Gena and, Charles Strom. "A Physiological Approach to DNA music." Online Article. <http://www.artic.edu/~pgena/docs/gena-strom-DNA.pdf> (30th March 2005).

also working with the base pairs in triplet form as they actively work in the DNA transcription process, and even at the start and stop codes that the DNA/RNA as amino acids work upon. He goes into the following topics:

In physio-musical conversion – these are the basic 64 codons in sets of 3 amino acids eg AAA AAG etc for the DNA/RNA as it works in transducer coding. The following parameters are present, he has developed a table of the codons and their corresponding amino acids followed by their dissociation content or Pk(a) and molecular weight. Then the 8 basic timbres of musical system now are related to the 8 classes of amino acids. There are nineteen amino acids in total and each has a distinct pk(a) that help define pitch or frequency, within the musical format. Then there is the Intensity parameter from music which is then adjusted to the hydrogen bonding occurring in each codon. The next factor is duration where the Pk(a) and atomic weights of the amino acids and the sum of the hydrogen bonding multiplied by a temp constant, determine duration in clock ticks. In working with all these factors of transcription from DNA into the musical parameters is the final synthesis of using a software music program, for playback.

This is a very complex procedure and the intention of this idea can be best described by the composer.

*For the onset, I believed that the musical reading of DNA ought to be rendered literally. As the sequences represent life of many sorts, I am reluctant to tamper with the “score”. The DNA mixer can realise sequences as digital sound and/or prints them out in musical notation. Ideally, performances of the synthesized pieces could be done live from the computer, where the ribosome simulations can be set spontaneously before playing...The Physio-musical conversion of DNA sequences takes place via a series of formulae that were worked out in a manner based on physical properties of DNA and musical parameters. This could not have been possible without the assistance of my friend and collaborator, geneticist Charles Strom, who provided me with the genomes and information regarding the chemical makeup of DNA and the amino acid conversion. Once the sequences are converted by the custom algorithms, the DNA Mixer(which reads lineally, much like the way ribosome’s traverse the mRNA and mix multiple sequences in our cells) can output them directly as digital sound, or as music notation for instrumental performance.*¹³

Gena seems to have taken the mapping idea to a deeper level as this intention states: “DNA ought to be rendered literally”. This is certainly the case from a musical standpoint for Gena uses the broad spectrum of musical parameters for mapping to DNA. One could argue the point, what parameter should be mapped to what process? What is the valid reasoning?. Let us take for example, Gena’s

¹³ See footnote 12.

use of the hydrogen bonding parameters, would it be rendered more literal to map it to musical timbre or duration? What every the system of mapping it is clearly seen that at best it is only a arbitrary mapping that is occurring, which may give us a aural perspective of the DNA code in musical format. To hear this piece and compare it to western European music, it would be akin to the atonal (12 tone row) aural spectra. Overall if we are to compare the sound Alexjander's works, it would be as if we have consonance for Alexjander's work and dissonance for Gena's work. It is clear we must do more research in detailing the DNA parameters to work out some valid system to accurately map the DNA into the sonic spectrum. More collaboration needs to be done between the musicians and scientists.

In the examination of these two case studies, their may be an answer to the most authentic way of mapping DNA bases to music. If we where to take Alexjander's work of DNA bases of translating light into sound. Then use the basis of the Ohno's inherent musical parameters of variation with repetition. Applied some of Gena's DNA parameters to musical parameters, we might gain a closer idea of what DNA might 'sound' like if it was to be present with sonic spectrum.

To then have an authentic ideal the musician must remove all conventional ideas of what "music" is and accurately transcribed the musical parameters to the DNA parameters. If we accept that "music" is an orgained series of events, or as the Ohno's say repetition with variation.¹⁴ Understanding the scientific role in the DNA music is explained as a relationship between nature and musical composition. In that we find the common literal threads or connections between DNA parameters and musical parameters. Only then can a true authentic cross-synthesis occur. Of course neither Alexjander nor Gena has a complete authentic relationship in their work but if the two were joined together, then we might start to gain a closer representation.

Are composers using trying to force 'systems into systems', by trying to fit DNA parameters into western musical systems? It is clear that if we detail very closely all of the DNA parameters in their complexity and lay them side by side with the musical parameters we might be able to gain an accurate representation to transcribe these factors into the sonic spectrum. What is realized that this is just the start of delving deeper into the studies of DNA Music. It is only truly ever going to be authentic in an arbitrary way, were one can argue many points to way one parameter should be mapped to another. To have an accurate representation, ultimately it must be realised that DNA does not emit sound

¹⁴ Susumu Ohno. "Of Words, Genes, and Music." *Springer-Verlag*. Vol: H23 (1988). 131-147.

within our hearing range therefore at best it can only be a representation of what is occurring. Maybe the best musical example would be a “score” that can never be played or heard, save one develop some sort of system to allow the ears to hear the inner worlds.

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