A Blueprint For Bacterial Life –
Can a Science-Art fusion move the boundaries of visual and audio interpretation?

Presentation for 22nd CHArt Conference
Birkbeck College University of London
10th November 2006

Computers and the History of Art

I am a Fine Art Printmaker, but my work extends to installation and film, often with the use of sound. My scientific colleagues at The Scottish Crop Research Institute have sequenced a bacterial plant pathogen for the first time in the UK. It is also the first enter-bacterial plant-pathogen to be sequenced worldwide.
Just to put it into context, the analytical tool that they have developed, Genome Diagram, is probably the most advanced comparative genomics visualisation tool available worldwide and it is being adopted by an increasing number of Genomics Labs Internationally (such as the Sanger Institute, in Cambridge; and the Universities of Minnesota and Madison in the United States).

I was approached over two years ago with a view to collaboration, mostly in the hope that artistic expression, communication and methodologies might help the wider community understand their complex scientific discovery and at the same time generally raise awareness of their research. For me, this was not really enough. I was more interested in looking into the question of whether a Science – Art fusion could move the boundaries of visual and audio interpretation.

During a pilot study something occurred which made us realize that our collaboration reached beyond the initial objective, into deeper research issues on the possible usefulness of artistic methodologies, the role of the artists in the visualization of complex data, and the subsequent impact upon scientific understanding and insights.

To tell you about this I need to begin at the beginning. As an artist, I found the images that the scientists had created in order to represent the genetic data, very beautiful and without a doubt they lent themselves to artistic expression and exploration.

Immediately, however the question arose: Can the collection and visualization of a huge amount of data derived from their study of a genome really enable the production of works of art with high impact and resonance? And more generally, what effects do artistic expressions, communication and methodologies have upon our understanding of complex scientific discovery?

Sci / Art projects are commonplace now and as many of you will be aware there are various ongoing debates I refer back, for example to C P Snow's position where he proposes the issue of their being " Two Cultures". However, encouraged by our initial discovery added to our particular combination of expertise and now our firmly established teamwork, we believe that our collaboration is different and that is the basis of this talk.

For me the beginning means looking backwards. Printmaking has been referred to as the ' Poor man's painting'. But this pejorative phrase indicates an underestimation of this discipline. Maybe more correctly printmaking should be described as a group of media, which utilize ancient and modern techniques and technologies. This would include **my own definition of printmaking,** which amongst other things attempts to convey complex ideas, insights or just data as digital animation.
Why would a Scientist approach a Printmaker. We don't actually have much in common and he only knew of my work by reputation. At this stage the scientists were working with computer print-outs.
Dr Leighton Pritchard works at the interface between biology and computing. Apparently his first thoughts when this project was suggested, concerned the aesthetic value inherently present in scientific information, even in the absence of a context. The presentation of scientific information has a deserved reputation for being literal and representational, with a minimum of embellishment and extrapolation. This is often required for the clear and precise dissemination of accurate information. The guiding theme in preparing for scientific figures for publication is often that they should be interpretable without reference to the main text.

What exactly is 'print'?
An edition is a numbered set of identical prints. In commercial terms, the numbering is a safeguard of the value of the prints, and professional artists' plates or blocks are cancelled after an edition has been completed. This convention adds the necessary 'aura'[i] (in Walter Benjamin's famous use of the term) to make each single print a work of art. This tradition of limitation continues but seems barely relevant in what I have recognized through my practice over the past 30 years. For me, contemporary printmaking is neither defined nor confined by tradition or medium. The essence of contemporary printmaking *(shall we say)* lies in a process of empirical experimentation, discovery, analysis, resolution and critical reflection – the *pursuit* of the image - the *unlimited* image. The limitations placed upon the artist in this sense therefore, are mostly technical. The best printmakers make art that goes beyond the limitations and continues to break with tradition. However, In order to illustrate the impact that successive technological breakthroughs have had on printmaking it is perhaps important to note *the* most important breakthroughs in this tradition.
I hope that the following potted history of Printmaking will offer an insight into how artistic reinterpretation can enhance the understanding and offer new insights into routes for analysis of scientific data.

Mechanical Western Printmaking was invented early in the Middle Ages with the woodcut. Printmaking quickly developed as the first efficient way of imparting information and ideas, and especially for the Christian Church for the motivation of piety and reflection. However, early woodcuts were done by a crude method of carving into a block of wood. The very nature of the process meant that the viewer was not provided with much more information than an iconic or graphical representation of the object depicted. Further information such as perspective or temporal issues was largely ignored. It would take the 'new' concepts of the Renaissance to ensure that techniques and new technologies were developed in order to get more complex information across.

As time went on printmakers began copper engraving, then etching, then wood engraving. The world was changing even though Galileo might recant his 'heresies'.

The media theorist Marshall McLuhan claimed "the increasing precision and quantity of visual information transformed the print into a three-dimensional world of perspective and fixed point of view."[ii]

The next major printmaking breakthrough came at the beginning of the 19th Century when a man called Aloys Senefelder developed a process called lithography. Over a period of fifteen years through a wonderful mixture of chemistry and physics with art, craft, skill and luck, Senefelder made it possible to print multiples of an illustration drawn upon a perfectly flat stone surface. He was a Bavarian dramatist who found it too expensive to make enough copies of the plays for his actors. Senefelder lived from 1771 to 1834 and lithography is the result of his search for a cheap means of printing copies of plays. Lithography is the natural process for the draughtsman. Of all the printmaking processes it is most like drawing. The artist can work with pencil, ink or crayon. Rather than etching where the artist uses a needle to draw through a wax ground onto metal before putting the plate into acid, with lithography the artist makes the tonal variation and nuance of the mark at the time of drawing.

Stone lithography grew to become a widespread success towards the end of the 19th and right through the 20th Century. As a result of this breakthrough came a revolution in the dissemination of images including offset lithography, utilizing thin metal plates and high- speed printing machines, along with the photographic transfer of images.

This dramatic development of the pre-electronic age is repeated by the new 'stone' of the latter half of the 20th Century and digital age: " Silicon" with the opportunities it gives to combine art with electronics, algorithms, and binary code. The silicon chip has reinvented print and brought with it the next revolution in image production, manipulation, dissemination and distribution, in short - contemporary printmaking!

It is important to recognize that the basis of artists' printmaking is still the traditional craft of woodcut, linoleum block, etching, stone lithography and screen-printing. But the artist/printmaker's knowledge, the skill, the artistic integrity and the determination means that at the beginning of this new century many are using these techniques combined with digital imaging processes to address new dimensions and contexts. Photomechanical techniques were a printmaking mark of 20th Century Art. In the 21st Century we are in an age of electronic and digital technology, new media, and installation strategies. It has been possible to incorporate printed elements for example screen prints and etching, into installation and public works.

Currently artist/ printmakers define themselves in many different ways. There is a renewed interest in the traditional techniques such as mezzotint, chine colle` and photogravure, whilst simultaneously there are rapid developments in the field of non-toxic printmaking technologies. Again, remembering those early experiments by Senefelder, printmakers now appropriate materials such as Photo polymers and commercial silicon to develop methods of printmaking.

So we have established that throughout the history of western art, artists have made prints. With the advent of digital technology contemporary Printmaking incorporates ancient *and* modern techniques and allows for an increasing precision and quantity of visual information to convey complex ideas and insights. In the past I have created large-scale installations using printed elements on different materials. Various Printmaking methods (including digital media) were used in an attempt to continue and develop the work of the installations, rather than to record an event simply by documentary photography. This again relates to Walter Benjamin's comment: "even the most perfect reproduction of a work of art is lacking in one element: its presence in time and space, its unique existence at the place where it happens to be."[iii]

Although the installation 'event' is inevitably lost, the creative dynamic continues as themes and subjects occur and reoccur through the various media. In scientific terms this might be thought of as of as a transition or 'tipping point' where new possibilities open up.

And this is where the science takes precedence. Dr Ian Toth is an expert on bacterial pathogenesis, molecular approaches to host/pathogen interaction, genome sequencing and functional genomics. Dr Leighton Pritchard as I said before is a scientist working at the interface of biology and computer science (and creator of Genome Diagram) concentrating on how micro-organisms cause disease on plants. Both scientists won the international race to sequence a plant pathogen from the same family as *E.coli* and the Black Death bacterium. They pioneered the software called "Genome Diagram", which enables simultaneous visualization of billions of gene comparisons of hundreds of fully sequenced bacterial genomes, including those of animal and plant pathogens. The results have helped to identify the acquisition of foreign DNA by pathogens, potentially representing novel mechanisms involved in disease (represented by clearly defined white "spokes" radiating from the centre of the image; and also to trace the evolution of this gene acquisition (and loss) over millions of years. Black Death (*Yersinia pestis*) and Blackleg (*Erwinia*) diseases of humans and potatoes respectively, seem worlds apart but without this foreign DNA these bacteria are remarkably similar. At root, DNA transfer is the single most significant source of the outward differences between the diseases caused by these closely related bacteria. The acquisition of foreign DNA may culminate in a microbe changing into either a human or plant pathogen, the point at which this occurs again being a 'tipping point' in that microbe's evolution. This foreign DNA in turn leads to novel biological traits being introduced into the microbe and incorporated into existing regulatory circuits such as quorum sensing. As pathogen populations grow in their host, they produce a regulatory hormone that gradually increases in concentration. At a critical (or quorate) population, the concentration of that regulator hormone becomes sufficient to trigger a series of events essential to symptom development and disease initiation. The point at which this trigger occurs and true disease begins is yet again a 'tipping point', this time dividing invasion from the successful outcome of disease. Thus 'tipping points' in both the visualization of biological data and in the biology itself can be related to the artistic event.

Genome diagram, even in its scientific context, is a fairly abstract figure. The map after all represents biological concepts that do not really exist. Most of the processes and entities with which modern microbiology concerns itself are invisible to the naked eye. Aspects of genomics are similarly invisible. Each genome is the result of 4 billion or so year's worth of evolution on this planet.

My first experiments began with a series of prints where I removed all trace of the relationship of the genome diagram to thing it described. It was a scientific image stripped of its' contextualizing information. In other words the image, a circular map of genes and their relationship to other bacteria, represented something essentially invisible that could only be " seen" in an abstract representation. Then I concentrated on subtleties of colour and tonal variation. I began by focusing on the precision and quantity of visual information and I created a series of etchings, screen prints and animations. With the screen prints I used a very subtle range of silvery blues and grays and worked with some very specific inks, (known in the trade as interference inks. They have a sort of shine that allows for a slight three-dimensional quality.)
It was from looking at those prints the scientists noticed the occurrence of new elements and a very specific event of gene acquisition. My approach was to simplify the diagram into a tonal variation and in so doing I re-contextualized the data in such

a way that it revealed information that the scientists had completely overlooked. Their scientific approach to the data was systematic and empirical. Purely by chance my artistic re-interpretation of the scientific data contributed to a new insight. Rather than simply identifying genes unique to a pathogen, the screen prints revealed the presence of other genes present in all of the bacteria, possibly representing genes essential to all forms of bacteria.

As far as we were concerned this was a breakthrough. It was as though our project drew a comparison between the Genome diagram and 'The work of art in the age of its' technical reproducibility' (I refer of course to Walter Benjamin's essay, written nearly a hundred years ago but still as relevant today)

We had taken this scientific visualisation tool outside the fields of biology and medicine and placed it into the context of interdisciplinary art. Inspired by this we are now exploring the dynamic nature of biological systems using both visual and sound disciplines (and their associated media), and we are going beyond obvious interpretative frameworks. Our goal is to ensure that the relationship of the artwork to the data is reflected and maintained not merely as content but also as elements and structural process.

Walter Benjamin used the term " aura" to refer to the feeling of awe created by unique or remarkable objects such as works of art or relics of the past and argued that the proliferation of mass production and reproduction technologies harbour the potential elimination of reflection and imagination causing the decay of the 'aura'. As a printmaker I use current reproduction techniques that allow for a rich diversity of visualization in order to address this idea of the 'aura'.

In recent years the rapid development of computer technology and computer graphics has enabled advanced visualization techniques; an essential part of the huge data-generating potential of genomic technologies. Both scientists and artists are exploiting the latest technologies. Our project enables scientists and artists to share and resolve problems surrounding current uses of visual and audiovisual techniques from different perspectives.

In the pilot stage we dealt with the linear data of the genome sequence creating images, animations and simple sound based upon the data translated through MIDI. We aim to progress to the more complex systems arising from the sequences' emergent properties.

My partner and I noticed that the DNA image resembled a score of music. It was a tenuous idea, but Dr Leighton Pritchard trained originally as a chemist and has a view of biological information that is correspondingly physical and chemical. By using a series of mathematical notations he translated the different amino acid letters into sequences of musical notes. I quote " Aside from the biological and physical meaning of this letter 'A ' inside the computer, it is not even represented as a letter. When my finger hits the 'A' key on the keyboard it initiates a series of electrical pulses. These pulses are interpreted by the computer as a binary number. When we need to 'write' the character to the screen, a different series of electrical pulses is used. These represent not the letter itself, but an image – patches of light and dark on a larger canvas. The use of different font types will result in different patterns, and so different pulses, but still the same recognisable symbol. These representations are at once inexact but precise."

My daughter Genevieve, who is a music student at the Birmingham Conservatoire started to work on Leighton's musical note sequences. By developing the scale, tonality and starting octave of the melody, and the intervals for each base transition she fulfilled the second stage to translate it into the auditory sphere. We used the findings from my prints and this new work to gain our first Art Science grant from the Mylnefield Trust.

When the data is set out in a linear way it gives it a musical appearance whereas Genomics are non-linear or may perhaps be better described as simultaneous events – with very different 'musical' or time structures. That leads to the idea of soundscape(s) where all component elements are present at any point on a time line (structurally more like a painting or print than music) but fluid or not fixed. As well as the animations and music, we're now developing the concept of Genome Diagram into a multimedia installation event based on the genetic plasticity and evolution of bacterial pathogens. To further develop this we have recently involved the soundscape artist David Cunningham. David Cunningham works with the creation and manipulation of sound by electronic and acoustic processes with a particular emphasis on the integrity of the materials, their innate structure and context. This emphasis on process is a key element in this project, an approach that can creatively maintain the precision of the source data. The primary motivation for developing the installation is to introduce sound and spatial aspects through open, interrogative and responsive modes of thinking, experimentation, processes and techniques, involving time and space.

A unifying thread of our research is that by de-contextualising scientific data, we obtain a complementary viewpoint to the scientific interpretation. Fine Art practice emphasizes subjectivity and ambiguity whereas science practice attempts to identify objective truths. Despite the contrast between the two approaches they can be unified because both disciplines thrive on lateral thinking and observation. As well as refining our mechanisms for creative development our collaboration aims to enhance scientific visualisation of complex data, and for it to impact upon scientific understanding and insights. Common to both artists and scientists is the use of advanced visualisation tools and the principles of new media:

"Numerical representation; modularity; automation; variability; and cultural transcoding."[iv]

Research development will also continue to involve production, analysis of visualizations in print, digital imaging, 2D and 3D (HiDefinition) animation and sound. By using animation to create time-lapse video clips we will create new dimensions to the expression and interpretation of the data. Our test animations already show movement and uptake/deletion of foreign DNA.

The impact of hybrid technology has enabled a reinvention of the artist's language. If the computer outputs from the analysis of the genome sequence are translated into art, we think that we can show that it is possible to aid in the discovery of new pathogenicity determinants. At the same time my challenge as the artist is make sure that the data - derived from the study of a genome, the scientific process, and analysis - enables the production of works of art.

By way of a conclusion I would like to leave you with this thought. The development of printmaking has enabled a reinvention of the artist's language. What does the aesthetic manipulation of the image look like in the 21st century? To a greater or lesser extent in a culture such as ours, artists will always continue to strive to communicate on social and psychic levels. With the advent of digital technology printmakers can go as far as any artist is capable of going. They can create continuous experiences of moving time and space: a simulation of human consciousness through technology. ‘A blueprint for bacterial life and art.’ So much for the ‘poor man’s painting’.

---

[i] Benjamin, Walter. “The Work of Art in the Age of Mechanical Reproduction”, essay, 1936

[ii] McLuhan, Marshall. Understanding Media, Routledge & Kegan Paul, London, 1964, p173

[iii] Benjamin, Walter. “The Work of Art in the Age of Mechanical Reproduction”, essay 1936

[iv] Lev Manovich, The Language of New Media, MIT Press, 2001, page 20