AN ALCHEMY OF DNA: EXPLORING THE CHEMISTRY OF BIOLOGY THROUGH BIOART

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Abstract

This statement is a reflection by artist Anna Dumitriu on her residency with biochemist Robert K. Neely at the University of Birmingham, which led to the creation of The Chemistry of Biology: An Alchemy of DNA, a sculptural and bio-digital installation that premiered at Birmingham Open Media in October 2017. Their project explored the chemical nature of DNA, the enigmatic “instruction book of life” through new super-resolution laser imaging technologies using fluorescent molecules, enabling them to physically observe a region of DNA containing a scarless CRISPR edit to a bacterial genome, building on an earlier project, Make Do and Mend.

This article is a reflection by artist Anna Dumitriu [1] on her residency with biochemist Robert K. Neely in the Department of Chemistry at the University of Birmingham [2]. The residency enabled her to deeply explore the biochemistry of DNA and build on previous projects in which she worked with CRISPR genetic modification and whole genome sequencing. The project focused on chemistry, which was very much a new area for her, but it had become increasingly apparent that it was an area she needed to explore further because it was so central to her artistic research and practice within the field of bioart.

Dumitriu has an in-depth background in creating visual artworks and BioArtworks working with microbiology and synthetic biology, and has previously created bodies of work focusing on whole genome sequencing technology and genetic modification, reading the entire DNA sequence of an organism and modifying that DNA as part of the process of making her work. However, Dumitriu had many unanswered questions, specifically about the biochemistry of DNA sequencing.

Exploring Biochemistry

Through an earlier EU-funded art residency with the MRG-GRAMMAR Project, Dumitriu learned about a synthetic biology technique called CRISPR. Her collaborators actually suggested that, based on the directions of her research interests, Dumitriu would have great synergy with the research of Neely’s lab at the University of Birmingham and his work on the EU BeyondSeq project and introduced them. They successfully applied for a Leverhulme Trust Artist in Residence Grant, and in early 2017 Dumitriu began collaborating with Neely and his colleagues and research students to creatively explore the impact of new developments in chemistry on biotechnology and begin to understand how fluorophores are used in whole genome sequencing. The project enabled Dumitriu to creatively explore the importance of chemistry in revealing the “instruction books” of organisms, from viruses to human beings, as well as look at the role of chemistry in antibiotics.

She worked in the lab to shadow researchers to understand Neely’s work. Dumitriu extracted long strands of DNA through a laborious process. She learned to attach fluorescent dyes to the DNA and used an open source robotic device [3] to comb it on to glass microscope cover slips, which enabled her to create microscope slides that could be viewed under a laser microscope. Using the Neely lab’s techniques, it is possible to visualize the DNA sequence in the form of fluorescent DNA “bar codes” [4].

Dumitriu had an E. coli strain that she had previously created in an earlier project with MRG-GRAMMAR [5] sent to the lab. In that project she had edited the DNA in the genome of this bacterium using the CRISPR technique to cut out a fragment that made the organism resistant to the antibiotic ampicillin and scarlessly repair it (using homologous recombination) with a section of DNA encoding the phrase “Make Do and Mend” (converted from ASCII code to the base-4 system to represent the four DNA bases). The aim of that work was to “patch” the bacterium back to its pre-antibiotic era (pre-1941) state, referencing the popular government World War II slogan that encouraged people to repair things rather than throw them away. It was a great opportunity to be able to use that strain at the Neely lab, as it can only be handled in labs that have a license to handle genetically modified organisms (Dumitriu normally works in clinical microbiology labs with unmodified pathogens).

Can We Physically Observe a CRISPR DNA Edit?

Dumitriu’s question to Neely was: Would it be possible to actually “see” the CRISPR genetic modification using his innovative DNA bar coding technique? During her time at the lab she worked alongside the team as they learned to identify E. coli bacteria using the technique, but to be able to identify a specific section of DNA would be a scientific innovation. It would be the first time that a CRISPR edit in a bacterium had been seen under the microscope using the DNA bar coding approach.

After many struggles, as the DNA strands Dumitriu extracted became tangled due to the mixture of dyes attached to them and the physical properties of DNA (think of it like hair washed without hair conditioner), the team finally succeeded in combing the DNA, looking at it under the microscope and finding the DNA bar-codes of the section of her E. coli genome that contained the phrase “Make Do and Mend.” The DNA bar codes containing the genetically modified sections were identified through image analysis software. The resulting image of the DNA, with the CRISPR edited fragments visible, was vast, and the file size strained the limits of Dumitriu’s computer. She worked with a huge still image that contained all the fragments she had managed to “comb” to create a video work that captured the experience of searching for the fragments on the microscope slide. She had to cut up and rejoin the images digitally and worked with digital artist Alex May to create visual effects that revealed the significance of the data by highlighting the genetically modified sections of the DNA. The video installation was accompanied by a sonification of the data the experiment produced. The installation also included sculptural elements focused on the raw chemical nature of DNA.

An Alchemy of DNA

DNA at its base is simply a concoction of phosphorus, nitrogen, oxygen and carbon, and these were included in various elemental forms interwoven with references to alchemy and the history of chemistry. In the work, Dumitriu has attempted to weave together references to historical narratives about the development of human knowledge and understanding; for example, Dumitriu tried to deconstruct what DNA really is and what
it means to us. Dumitriu asked the scientists in the lab the deceptively simple question “What is DNA?” repeatedly, receiving many different answers, from the textbook answer “Well, the ‘instruction book of life—Deoxyribonucleic acid’” to “It’s all about context, isn’t it?” Most telling was the response “I don’t like to think about it too hard,” the implication being that any attempt to really understand the bizarre, invisible, machine-like process of DNA replication and the patterns it creates (“It’s not always necessarily a double helix”) throws our concept of what it means to be alive in question, causing us to confront deep philosophical questions. What became clear was that DNA is itself a complex tangle of elements and chemical bonds that confounds our ability to fully comprehend it.

Dumitriu treasures the so-called boring times in the lab of waiting for some process or chemical reaction to happen, because she filled these times by chatting with her collaborators [6]. During these chats Dumitriu realized the rhetoric around contemporary chemistry and the aims of historical alchemy seem to have striking similarities (although the methods differ, of course), showing to her that our basic human desires have changed very little in hundreds, probably thousands, of years. Both speak of the possibility of changing matter into new forms (creating synthetic life forms?), creating a potential remedy to cure a disease (gene therapy?) or finding the secret of immortality (understanding DNA repair mechanisms?). The scientists found this discussion very thought-provoking, and it led to much reflection for all.

The Final Installation
The final work premiered at BOM (Birmingham Open Media) [7] and took the form of a large-scale bio-digital installation called The Chemistry of Biology: An Alchemy of DNA (Fig. 1), comprising digital and sculptural elements. Mapped across the entire back wall of the gallery was a large-scale projection of the video (using multiple projectors blended together with custom software) that was generated from the microscope image of the DNA with the fluorescent molecules attached. The video was edited to give a sense of how it felt to search and scroll through thousands of images from the microscope, which Dumitriu and the team she worked with had done by eye as well as by using image processing software searching for the edited section of DNA. The video gave a sensation that the DNA strands were falling like rain in the darkened room and that the data was pouring down over the sculptural installation. The sections of DNA containing the CRISPR edits were highlighted with a red “aura” around them, and visitors were transfixed as they joined the search for the sections of the bacterial genome that Dumitriu had modified.

The video work was foregrounded by a sculptural installation that interwove references to modern biochemistry with objects that were symbolic of the aims and historic practice of alchemy. In the center of the exhibition space were almost 100 Bunsen burner tripods (reminiscent of a school chemistry lab). Their triangular tops were threaded together into representations of the alchemical symbols for the four elements: earth, water, air and fire, which reflect the four DNA bases: adenine, thymine, guanine and cytosine.

A trail of handmade balls of bread led through the Bunsen burners. In alchemy bread is traditionally considered a symbol of human knowledge. Into each bread ball Dumitriu had baked one of the four DNA bases in its crystalline form; Dumitriu marked each ball with an alchemical symbol for one of the four elements. The bread was then laid out around the space in the exact order of the DNA sequence of the CRISPR genetic modification that Dumitriu had previously made in the E. coli bacteria’s genome and observed under the microscope. The whole space was sprinkled with salt, a play on the idea that DNA is a salt when in solution, as well as a play on the use of salt in another form of our human attempt to understand and control the world: witchcraft [8]. The salt also contained diamond and apatite crystals, which represent the carbon and phosphate components of DNA. In the center was a carved wooden pestle and mortar containing crystallized deoxyribose, the “sugar” part of the DNA backbone. Trailed through the installation were three inspection lamps whose bulbs revealed the installation but whose power leads were tangled like super-coiled helices.

Audiences were fascinated by the way the piece symbolized the process of science and the significant gaps in our understanding, by reducing the sublime concept of DNA to its raw materials. It revealed an answer to the question “What is DNA?” while at the same time obscuring its activity and significance for all life. The lab team also said that the collaboration changed their preconceptions about artists and were surprised at the depth of engagement artists can have in scientific research. Inspired by this project, Neely continues to develop research around looking for specific sections in the genomes of bacteria and other organisms [9].

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References and Notes
1. www.annadumitriu.co.uk.
5. www.doi.org/10.1162/LEON_a_01466.

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