

MAKE DO AND MEND: EXPLORING GENE REGULATION AND CRISPR THROUGH A FEAT (FUTURE EMERGING ART AND TECHNOLOGY) RESIDENCY WITH THE MRG-GRAMMAR PROJECT

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Abstract

This article documents the artistic research the author undertook for her FEAT (Future Emerging Art and Technology) residency. It describes her collaboration with the MRG-Grammar consortium and the creation of an artwork that involved editing the genome of a bacterium using CRISPR to reflect on issues related to antimicrobial resistance, bio-hacking and control. The article explores the author's methodology and describes the benefits of long-term embedded residencies to create artworks that are deeply engaged with emerging technologies with a view to enable the public to access the concepts and implications of cutting edge technologies and scientific research, through an artistic lens.

Keywords: CRISPR, BioArt, Synthetic Biology, Antimicrobial Resistance

Controlled Commodities

“Make Do and Mend” is an installation that references the 75th anniversary of the first use of penicillin in a human patient in 1941 and takes the form of an altered antique wartime dress with the mark CC41, the British Board of Trade's “utility logo” (Fig. 1). The holes and stains in the old dress are patched with silk which has had *E. coli* bacteria grown onto it using a dye-containing growth medium. The genomes of the bacteria have been edited using a cutting-edge technique called CRISPR to remove an antibiotic resistance gene accompanied by homologous recombination to scarlessly repair the break with a fragment of DNA encoding the phrase “Make Do and Mend” [1]. CRISPR/Cas9 is a revolutionary gene editing tool that enables researchers to cut DNA accurately at designed positions, thereby facilitating the editing of genomes of living organisms.

We currently face the serious global problem of antibiotic resistance that requires us to protect our stocks of antibiotics and use them in a highly controlled way. The World War II CC41 utility mark showed that goods such as clothes and fur-

Fig. 1. “Make Do and Mend” installation view at LifeSpace Dundee (© Anna Dumitriu. Photo: Anna Dumitriu.)



niture met the UK government's austerity regulations, meaning literally “controlled commodity 1941.” Ironically, then, penicillin and the antibiotics that came after really needed to be far more of a controlled commodity than dining sets, dresses and other goods that received the CC41 utility mark. The issue of control is highly relevant not only to commodities and antibiotics, but also to emergent technologies: there is a lot of discussion today about the regulation of the recently discovered gene-editing technique CRISPR/Cas9 [2], as it has the potential to be used to edit bacterial genomes, viruses and even human genomes and, in some cases, can even be used in citizen science laboratories.

Exploring the Decipherment of Genetic Codes

I worked with Drs. Sarah Goldberg and Roe Amit at the Synthetic Biology Laboratory for the Decipherment of Genomic Codes at the Technion in Haifa, Israel. The lab is the lead coordinator on the MRG-Grammar project [3] which aims to devise a new strategy for deciphering the rules of gene regulation. Using synthetic biology, DNA synthesis and high-throughput analysis, the project aims to generate new types of biological datasets that systematically explore all possible regulatory landscapes.

Working Hands-on with CRISPR/Cas9 in the Lab

I learned hands-on to edit the genome of the TOP10 *E. coli* strain to remove an ampicillin (a penicillin related antibiotic) resistance gene which was part of the bacterium's genome (having previously been inserted into it) using CRISPR/Cas9, thereby literally mending the bacterium in the same way that the dress is mended with the bacteria-stained cloth.

Editing *E. coli* Using CRISPR/Cas9 for Art

Ampicillin is part of the penicillin group of beta-lactam antibiotics so in a way it is conceptually and poetically true to say that, with my artistic genomic edit, I have used today's latest technology to ‘patch’ or ‘repair’ the organism back to its pre-1941, pre-antibiotic age state [4]. But scientifically it is far more complex in that I used a lab strain of *E. coli* that is very well characterized and has had many other modifications so it will never really be the same as it was in 1941.

Dr. Goldberg and I cut out a short region of the *pspG* operon: CAAATTCACCACGCCCTGCGCACCGTCGCGGG GCGTTTTGCTGTAAATCAATAGATTATTTTTG and replaced it with a repair fragment of DNA in the form of an encoded phrase: “Make Do and Mend” converted via ASCII code to base 4 to align to the ATCGs of the DNA nucleotides, making: CATCCGACCGGTCGCCAGAACACACGTTA GAACGACCGTGCGCAAGAACATCCGCCCGTGCGCA.

Introducing Top10 *E. coli* Make Do and Mend

The resulting TOP10 *E. coli* Make Do and Mend strain was grown onto silk squares placed in Petri dishes on selective *E. coli* chromogenic agar (Oxoid Limited), a dye containing solid growth media (made from seaweed jelly) that causes the bacteria to grow colorful colonies, with the help of Dr. Heather Macklyne at the University of Sussex. The silk squares were then sterilized in order to be made safe, enabling me to stabilize and remove the genetically modified bacteria from the lab and work with them to repair the CC41 dress. I also received additional collaborative support in the UK from Dr. John Paul, Kevin Cole, Dr. James Price, and Dr. Nicola Fawcett from Modernising Medical Microbiology, and Dr. Rob Neely from the University of Birmingham.

Although what we have done here would not work as a therapy in humans, the piece is very much about exploring the technology and highlighting its future potential. For one thing, I have found that editing bacteria using CRISPR is actually not at all straightforward, and was intensely time-consuming and laborious, although it's a huge improvement on past techniques and is developing quickly. MRG-Grammar co-ordinator Dr. Roe Amit used the metaphor of a minefield to describe the difficulties of editing bacteria, in conversation with me. However, the scientific community is genuinely at a watershed in the research and we now have significant insights into how genes are regulated but we are still a long way from full understanding. So, in a way the artwork I have created asks if new technologies such as CRISPR will enable us to 'mend' issues that past scientific innovations have inadvertently created, such as antibiotic resistance (albeit having saved countless lives) or create further issues. They certainly are enabling us to understand how DNA works better.

Florey and Chain Were Bio-Hackers

CRISPR is a very exciting technology and of great interest to those involved in the bio-hacking and maker culture scene. These biohacking approaches have a strong resemblance to Howard Florey and Ernst Chain's wartime penicillin trials at The University of Oxford, for which they won a Nobel Prize alongside Alexander Fleming. In 1941 there was a huge lack of availability of proper lab equipment and they made do and mended their own lab equipment for fermenting the famous mold from biscuit tins and lidded hospital bed pans. My "Make Do and Mend" project is strongly inspired by Oxford Museum of The History of Science's exhibition "Back From The Dead," which tells the story of the development of penicillin in Oxford, and includes a huge range of important historical objects as well as my growing participatory artwork "Ex Voto" [5] created in collaboration with Dr. Nicola Fawcett (Oxford University) and Professor Maggie Smith (University of York), with contributions from the MRG-Grammar consortium partners.

Make Do and Mend

"Make Do and Mend" was originally a leaflet published by the British Ministry of Information in 1943 during World War Two. It advised readers on how to be fashionable under clothes rationing. It contained economical patterns and advice on upcycling old clothes. The leaflet became a vital handbook for housewives. Specifically, readers were given hints on creating attractive "decorative patches" to mend holes in worn out garments clothes. An updated version was recently republished to enable families to cope with economic austerity [6].

The FEAT Project Residency Methodology

My joint role within the FEAT (Future Emerging Art & Technology) project was as the artist partner in helping to conceive and organise the programme, and also as a pre-selected participating artist. I was involved in creating the ethos of FEAT and in setting out the methodology for the residencies. FEAT was funded as a Horizon 2020 FET (Future Emerging Technology) Support Action of the European Union [7].

Our methodology aims to develop in-depth collaborations through long-term embedded residencies shadowing researchers and working hands on in the lab to understand the research, methods and processes [8]. This methodology was based on a great deal of past experience of working in science settings, particularly my 14-year collaboration with microbiologist

Dr. John Paul and with Modernising Medical Microbiology [9]. The FEAT consortium (Eutema, Waag Society and Youris) were able to raise generous funds for artists to undertake residencies of up to nine months and to absorb as much as possible from the opportunities. It is intended that the outcomes of the FEAT residencies should somehow serve to engage the public in new technologies, and in the case of my work, involves very diverse audiences in issues around cutting edge technologies.

The FEAT project concept also builds on my work as lead artist on the Creative Europe supported *Trust Me, I'm an Artist* project, with ethicist Professor Bobbie Farsides and Waag Society, which explores the ethical implications of artists, particularly bioartists, in labs [10]. In my FEAT residency, I used the raw materials of the MRG-Grammar consortium's research to create artworks and develop ideas for workshops for participants of all ages and backgrounds. I worked with controversial CRISPR technology and combined this with using more traditional craft and fine art techniques such as stitch and sculpture, which in my experience helps draw in audiences to the stories I am trying to tell through an aesthetic approach. The collaboration with MRG-Grammar has enabled me to build on some of my recent projects focusing on whole-genome sequencing and synthetic biology and take those ideas further. I will continue to work with the Amit lab and take the research forward. I have also explored the research of other consortium partners at the Teichmann Lab at the Wellcome Sanger Institute, Cambridge, UK and at the Segal Lab at the Weizmann Institute, Tel Aviv, Israel, and will use that research to develop further artworks. I also have plans to work next with a penicillin-resistant *Staphylococcus aureus* bacterium from my own body.

References and Notes

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