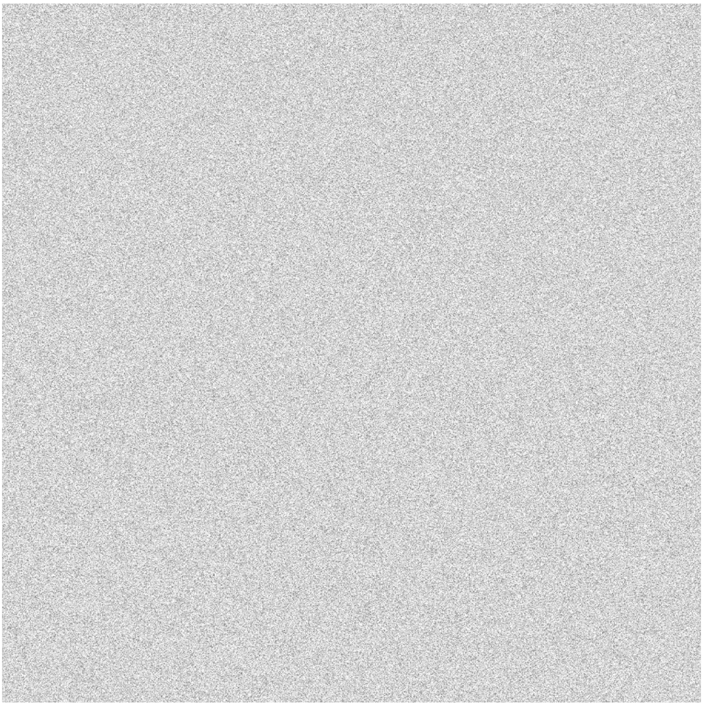
INTRODUCTION



MANAGING CREATIVE DISTURBANCES

by Markus Schmidt

"It is difficult to make predictions, especially about the future" is a well-known proverb that can easily be applied to the history of technological innovations, particularly at a time when there was no way that early developers could have anticipated the various ways in which the technology at hand would be used and implemented thereafter. What can be deduced from this historical observation is that today's scientists and engineers will also have difficulties foreseeing how their findings and inventions will alter everyday life in the future. This is not to say that predictions or probable scenarios of the future cannot be made, but just that the set of skills necessary for designing technical innovations is most likely insufficient to foresee the variety of societal and biological ramifications that these innovations will incur.

For example, while we cannot have any idea about what early humans thought about when they first controlled the use of fire, we do know that its skillful use had many implications that changed the course of human evolution. A significant amount of time was used to chew our food, resulting in the typical proto-human skull geometry that allows for strong muscles and large teeth, in addition to long intestines to digest the raw food because our ancestors before *Homo erectus*, much like chimps today, ate raw vegetables, fruits, and meat. When *Homo erectus* started to control fire and used it to cook food, the nutrient uptake was greatly enhanced, and the effort required to chew was significantly reduced. This resulted, among other factors, in an evolutionary adaptation that led to more delicate jawbones and skulls and finally to the human face with which we are all familiar. This accompanied changes in the length of our intestines (and certainly in the composition of its microbiome), leaving more time at hand for other things than chewing, such as social interactions, developing more tools, etc. So, one might say that 'fire technology' massively changed what it means to be human, and that the use of fire is now encoded in our genes (Gowlett, 2016; Parker et al., 2016).

More recent examples of far-reaching inventions include the discovery of electricity, the internal combustion engine, antibiotics, computers, nitrogen fertilizers, the contraceptive pill, the Internet, and digital currencies. While we are still dealing with the positive and negative consequences of these innovations, scientists and engineers around the world are already building the next technological toolbox, which is certain to give rise to yet another complex set of societal, economic, and environmental ramifications.

Each research field commonly undergoes three stages, roughly speaking: 1) Description, 2) Analysis, and 3) Synthesis (Danielli, 1972). The previous centuries have proven this progression for physics, from the description of how a bird flies, to the analysis of the laws of aerodynamics, to the application of these laws in novel forms such as the design and construction of an airplane for example. The same can be said of chemistry, from the description of the different forms of matter, such as the element fluorine, to the scientific analysis of its characteristics, such as fluorine being the most electronegative element known to exist (Jaccaud et al., 2020), to the creation of a large number of synthetic molecules with characteristics not found in nature, such as polytetrafluoroethylene, also known as the non-stick pan coating Teflon™.

Until the 21st century, biology never really made it beyond the analytic stage, for the most part. What if we could not just describe and analyze wild type organisms collected in nature, but instead design and construct forms of life that cannot be found in nature? This is exactly the goal of synthetic biology, a relatively young research and engineering discipline that aims to engineer living matter.

Synthetic biology: research and global challenges

Synthetic biology is one of the 21st century's most important scientific and engineering fields. The variety of methodologies and applications range from engineered biosystems (cells, tissues, and organs) to the production of biomolecules (for medicine, food, or industrial applications), to biocomputing processes (storing, retrieving, and processing data in organisms), and even to biomachines or engineered living materials. What has been called the (immanent) Biorevolution is expected to have a far bigger economic impact than the Internet, and at the time of writing synthetic biology market estimates expect the top 400 biology applications to have a direct global impact of up to $4 trillion/year over the next 10-20 years (Chui et al., 2020).

At Biofaction, we work together with universities, research organizations, companies, and NGOs to better understand the societal ramifications of these new biotechnologies. Among others, we investigate biosafety issues (Pei et al., 2022), explore how different stakeholders see the opportunities and risks presented by these technologies, engage citizens in two-way conversations about synthetic biology, stimulate a creative process to think about the societal and environmental ramifications of synthetic biology, as part of the BIO·FICTION Science Art Film Festival for example (Schmidt et al., 2013; Youssef & Schmidt, 2020), and support the interaction between artists and scientists (Kerbe & Schmidt, 2015; Schmidt, 2018).

We undertake this work as part of several previous and ongoing research projects that demonstrate the diversity of research and engineering areas in which synthetic biology is (or can be) involved. Our recent involvement in three research projects gave us the opportunity to explore synthetic biology from different perspectives.

In Newcotiana, the goal was to apply New Plant Breeding Techniques to convert tobacco plants from a traditional crop associated with cigarettes, smoking, and cancer to a new crop that produces life-saving pharmaceutical ingredients instead (Hoelscher et al., 2018).

In SinFonia, the project aspired to replace the toxic processes used in synthetic chemistry, in the creation of polyfluorinated compounds, with a new set of biological processes that would support a more environmentally friendly production process (Calero et al., 2020).

Industrial production has massively affected the environment since the 19th century, with numerous, unsustainable processes generating tremendous amounts of waste. In Madonna, the aim was to come up with new chemical reactions, carried out by living organisms, to reverse this process in a sustainable way. The ultimate goal is to turn industrial waste into a resource, thereby closing the cycle of production (de Lorenzo et al., 2016; de Lorenzo, 2017).

Art and science: setting up the artist-in-residence program

The scientific work required to reach these goals is clearly the most important in terms of reaching each project's objectives. A relatively small portion of the efforts, however, also go into questions of biosafety, standardization, life cycle assessment, bioethics, citizen engagement, exploitation of project results (both commercial and open access), and science communication. In addition to these activities, we aim to add yet another perspective on the work being carried out, namely by inviting artists to the laboratories who might help to shape the future in this field (Schmidt, 2018). In this book, we wanted to look very closely at the direct interactions between artists and scientists in order to learn how initial expectations and assumptions are revised, to which degree the interaction alters previous plans and conceptions about the other party, and what artists and scientists might learn from the encounter. This is a striking contrast from monographs by artists, or other publications, featuring completed artworks inspired by science or curatorial reflections about the artworks.

Biofaction initiated the organization of the artist-in-residence program. In Newcotiana and SinFonia, we had the opportunity to fund one artist each, and we could invite two artists to take up residencies in Madonna. First, we explored participating researchers' interest and willingness to host an artist in their laboratory. Scientists would not receive any remuneration or other material benefit from doing so (they already earn a salary), but would receive the opportunity to interact with an artist. The different projects have different numbers of participants (ranging from half a dozen to about 20), and we could easily find researchers willing and interested to host an artist in all projects, from either project coordinators (for SinFonia and one of the Madonna residencies) or from principal investigators (for Newcotiana and the other Madonna residency). It was the first time all of the participating scientists, their staff researchers, and lab technicians ever collaborated with an artist.

In contrast to the scientists, the residency did come with a modest financial stipend of €7,000 per artist in order to pay for the trips to the labs, to cover the costs incurred during their stay, provide means to buy some consumables and materials needed, and include the artists' personal fee. The access to the laboratory and ability to investigate what the researchers were doing, how they did it, and how they made sense of it was probably more important than the material support, particularly since a laboratory is not the kind of place where you can just knock on the door and waltz on in.

Having defined who the hosting scientists would be, Biofaction published an online call[1] for applications with information about the three research projects on various websites and on social media channels. The online call closed on June 30, 2020, having received over 150 applications for the four aforementioned residencies, with Madonna receiving about half of the applications and the other two projects about a quarter each. Applications came from European countries and the UK, but also from outside Europe such as Argentina, Armenia, Brazil, Colombia, Egypt, Lebanon, Japan, Mexico, Russia, South Africa, and the USA. Four artists were selected after a detailed evaluation process, involving the Biofaction team, two external art curators (Jens Hauser and Claudia Schnugg), and also the respective principal investigators of the research labs who volunteered to the residency in the final phase.

The artists came from different artistic fields, ranging from music and composition, to photography, filmmaking, and visual art. All of the artists had at least some exposure to science in their previous careers: Lara Tabet was a medical doctor as well as an artist, Eduardo Reck Miranda had previously collaborated with several researchers in a variety of different fields, Isabelle Andriessen looked back at one intense collaboration with a scientist, and Karel Doing, while not having collaborated with scientists previously, learned about it through conversations with his partner who is a microbiologist.

All of the preparations and selection process worked like a charm, but once the matchmaking was completed, we found ourselves amid the COVID-19 pandemic. The labs promptly closed and by the time they reopened, their administration only allowed parts of their staff back in, excluding non-essential outsiders like the selected artists. These and other events, including the complete move of one lab with 80+ people and equipment into a new facility, put a severe delay on our initial plans because we could not postpone the residencies indefinitely, but had to complete them before the official end of the projects' lifetime. Luckily, time windows did open, and thanks to the efforts of the scientists and artists, all four residencies finally took place in 2021 and in the first half of 2022.

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[1] The online call for submissions can be seen at the following link: https://www.biofaction.com/wp-content/uploads/2020/04/CALL-FOR-ARTIST-IN-RESIDENCE-2020-21.pdf.

Karel Doing – Julian Ma (Newcotiana)

In Newcotiana, photographer and filmmaker Karel Doing was selected to spend time in Prof. Julian Ma's lab at the Institute for Infection and Immunity at St. George's University of London. This was the first residency to take place since both parties were based in the same country, thereby easing the otherwise difficult cross-country COVID-19 travel restrictions. All of the artists were encouraged to introduce themselves to the lab team with a presentation about their own work. This had the effect of extending the number of people with whom Karel would later interact, so in addition to Julian Ma, early-stage researchers Cathy Moore and Kathrin Göritzer also became collaborators. Sharing their reflections about the residency in their chapter, it became clear that the scientists were first and foremost curious about what this collaboration would bring about. The researchers tended to categorize the residency as a form of science communication in the beginning. It became quite clear that Karel Doing's intention was not to do science communication, at least not in a straightforward way, but rather to focus on the kind of equipment, machines, and work routines that take place in the lab. While the researchers were most proud of their latest, fanciest, and very expensive machinery, Karel noted that researchers referred to a number of life hacks ranging from aluminum foil and other 'household' products to fix specific problems of their workflow in many cases. He also spent more time on artefacts, like the form and shape of research results, than the scientists would have deemed necessary, given that they were more interested in the results' abstract meaning, rather than their aesthetic appearance. Karel's focus reminded the researchers about the materiality of the machinery and physicality of the methodology that they were using, and how they were becoming accustomed to it over time.

The focus of Karel Doing's first period in the lab is not uncommon for artists who enter a laboratory for the first time. Research laboratories have a niche aesthetic with gloves, lab coats, pipettes, etc., and rules (no eating or drinking in the lab) that set it apart from other places. Observing a newcomer in the lab is always a good reminder for the scientists to perceive many details that they had previously gotten used to. After this initial 'lab phase', Karel continued with his own line of work, the so-called phytography (Doing, 2020), developing photos of tobacco plants using tobacco plant sap extracts as a developing medium and as a kind of vegetative self-portrait. Although the technique that Karel used to produce his phytographies is not the same as the New Plant Breeding Techniques deployed by Newcotiana, both show that you can do something unexpected with tobacco plants. Instead of just turning these plants into cigars and cigarettes, the plant could be transformed into a molecular factory for pharmaceuticals and cosmetics or, alternatively, one could use the plant to produce an organic developer to make analogue photos, as Karel did. The researchers and the artist convincingly demonstrated that the use of tobacco plants can be expanded beyond the status quo in ingenious ways in both cases.

Eduardo Reck Miranda – Pablo Iván Nikel (SinFonia)

In SinFonia, the composer Eduardo Reck Miranda was invited to visit the lab of Dr. Pablo Iván Nikel, the coordinator of SinFonia, at the Novo Nordisk Foundation Center for Biosustainability at the Technical University of Denmark in Copenhagen. Eduardo Reck Miranda is an experienced artist, having worked in numerous collaborations with researchers covering such diverse topics as whale communication (McLoughlin et al., 2018), slime mold memristors (Braund & Miranda, 2017), the brain-computer interface (Miranda & Castet, 2014), synthetic antibiotics (Miranda, 2020), and most recently quantum computing (Miranda, 2022). This wide range of topics shows Eduardo's level of curiosity and ability to explore new fields of research, pushing music making beyond conventional bounds. For SinFonia, as the name already indicates, selecting a composer and musician was considered right from the beginning. Pablo, a passionate fan of classical music, chose the acronym for the research project because he felt that it highlighted the many biochemical reactions going on in a cell at any time. Metaphorically speaking, the cell works like an orchestra that turns the elements of carbon, oxygen, hydrogen, nitrogen, phosphor, and sulfur into molecules, thereby transforming them further. The element fluorine, however, is hardly ever used in the cellular metabolism, as its extreme electronegativity makes it almost impossible to control, often disrupting the orchestra with unwanted reactions. The first encounters between the artist and the researchers took place virtually, due to pandemic restrictions, and two more lab members volunteered to contribute, Nicolas Krink and Manuel Nieto-Domínguez, following Eduardo's presentation. Eduardo quickly dived into the research topic that corresponded with the researchers' work in the weeks and months that followed. He then decided to use the enzymes' DNA sequences as informational input for his music making process; this involved partially computer-aided music and part composition.

The three researchers saw the artist's contribution as a sophisticated form of science communication, and they have laid out that Eduardo's questions triggered some interesting thoughts about potential future scientific research experiments in their chapter. Since Eduardo Reck Miranda was taking DNA sequences to make music, his idea or suggestion was to invert this process and to compose the music first, then extracting DNA out of it and to see if the resulting enzyme served any new or useful function. Could this work? Is it worthwhile to test it? The conjecture behind it is that music and genes share similar design principles, and that this similarity (or in other words, the representation of a common principle through different media) could be explored to discover solutions that are not available with contemporary enzyme design methods. Some similarities between music and genes, in particular repetition, were highlighted in the 1980s (Ohno, 1987), and Eduardo Reck Miranda's work is yet another hint that music might be able to reveal some deeper truths about DNA's design principles. Pablo Iván Nikel and his colleagues had not initially expected that the artist would make suggestions that could lead to a unique way in which their scientific work could be designed. Being somewhat surprised, they did not discard the idea right away and considered it in earnest, but eventually decided not to conduct such an unusual experiment (for now, at least). Who knows, though, maybe the cornerstone for a new set of unconventional enzyme experiments has already been laid.

Lara Tabet – Víctor de Lorenzo (Madonna I)

In Madonna, Lara Tabet was selected as the artist-in-residence at Prof. Víctor de Lorenzo's lab of the Molecular Environmental Microbiology Laboratory, Centro Nacional de Biotecnologia, CSIC Madrid, who is also Madonna's coordinator. Following the 2020 Beirut explosion and its aftermath, Lara eventually decided to leave her home country of Lebanon and moved to France. Like in the other residencies, the presentation of her artistic work and subsequent conversations with various lab members led to an extension of the collaborating researchers beyond the principal investigator, including Belen Calles, David Rodriguez Espeso, and Esteban Martínez. Lara Tabet was a medical doctor prior to her career as an artist and was, therefore, familiar with the world of bacteria, metabolic pathways, and lab instruments in general. These elements also featured in her recent photographic work. In the residency, however, she worked with genetically engineered bacteria for the first time.

Learning about the transformation protocols and techniques used, Lara became eager to genetically modify bacteria to perform two artworks in two separate residency sessions.

The first one involved controlling bacteria's bioluminescence through voice command. The bacteria were genetically modified to contain two new genetic constructs, one for bioluminescence, which involves the emission of light by the cells, and one that would initiate the bacterial cell's suicide when a chemical substance was present. This chemical substance was added to the bacteria using a dispenser controlled by a specific voice command, inducing a suicide reaction that would lead to the dimming of the light produced by the living bacteria. The dimming that took place after the necropoetic voice command was documented through a series of photographs and videos.

Her second artwork was, at least conceptually, less restricted to the laboratory. In response to the situation in Lebanon and the distress of its inhabitants, Lara Tabet collected bacteria from her own feces and transformed them with genes that encode Neuropeptide Y, messenger molecules in the nervous system which cause, among other things, a reduction of anxiety and stress in the human body. The freeze-dried Neuropeptide-Y-producing bacteria would, in the second part of the artwork, be flushed down a toilet in Lebanon, thereby releasing the bacteria into Lebanon's (untreated) wastewater system, potentially leading to a situation in which the bacteria would come full circle into the drinking water supply (how exactly this would happen was not specified).

Subsequently, Lebanese people, upon drinking tap water, would be boosted with an extra level of Neuropeptide Y, thereby becoming more resilient to the on-going crisis of a state on the verge of collapse. When Víctor de Lorenzo and I heard about the plans for the second artwork, we immediately infringed upon the freedom of art, as releasing a genetically modified bacteria to the environment without regulatory approval was out of the question. Flooding the water supply with a mind-altering ingredient, without approval from the human subjects exposed thereto, also resembled an enforced administration program for Soma (even though it was taken voluntarily in *Brave New World* (Huxley, 1946)). To be fair, Lara Tabet had left it open whether the release of the bacteria into the environment was planned for real or only simulated for the sake of the story, but this ambiguity was seen as problematic. Eventually, we agreed that the "scatological gesture", as Lara Tabet termed it, would be clearly marked as a performance with a non-genetically modified bacterium. Lara made effective use of the available scientific and technical know-how, access to machinery, scientific photographic equipment on several floors, even including an X-ray developing machine. When we visited the lab during her second stay, we found her well-blended into the lab, not just because of the white lab coat, but also because she quickly managed to navigate between the CSIC building's different rooms on different floors using different lab equipment for her work.

When asked what the researchers had taken away from the interaction with the artist, Víctor de Lorenzo told us that the conversations with Lara Tabet had indeed led to several reflections and further thoughts about their work, in particular related to the microbiome. In fact, Víctor had already started to talk with other researchers about potential future experiments that targeted the microbiome. How this will materialize in the future remains to be seen, but it is fair to say that the learning process was not a one-way street.

Isabelle Andriessen – Lee Cronin (Madonna II)

Madonna's second residency was awarded to Isabelle Andriessen who visited Prof. Lee Cronin's lab at the School of Chemistry, University of Glasgow. Due to a number of factors, including COVID-19 related travel restrictions, lab closure, and eventually the movement of the entire laboratory into a brand-new building in Glasgow, this residency was the last one to take place in May 2022. Coming from very different directions, both Isabelle and Lee are interested in the life-like behavior of non-living matter. One of the differences between their approaches, however, is the scale at which they operate: Isabelle has worked on macroscopic objects, spanning up to several meters so that it is accessible to gallery visitors, whereas Lee is more interested in meso- and microscopic performances (although part of his extensive work also deals with astrobiology). Second, Isabelle deploys chemical and physical processes such as crystallization, oxidation, and condensation that causes changes to the art objects over the course of weeks and months, while Lee aims to carry out a whole range of physical and chemical processes in a fully automated way that is controlled by algorithms, and which can yield results very quickly. This simple distinction does not capture the full range of activities, nuances, and implications of their work of course, but it does hint at the difficulties involved in bringing their different approaches together. The final outcome of the collaboration did not result in a physical artwork, but in a film; this was for a number of reasons, not least because it is really challenging to apply different lab techniques in a non-scientific setting, but also because Isabelle Andriessen was not looking for a technical extension of her work to the microscopic scale.

Not unlike Karel Doing, Isabelle Andriessen seemed to find great interest in the specific machinery and the sounds and movements that they produce. For her, not only did the machines exhibit the unusual niche aesthetic of a particular scientific tribe, but she also highlighted what could not be seen. Lee Cronin wants to fully automate the chemistry lab, doing away with typical lab tasks, gestures, and movements that used to contribute to chemists' professional identity. It is his vision that chemists will not work in a chemistry lab in the future, a disruptive approach that does not automatically create a huge endorsement among his professional colleagues. This radical vision of a fully automated future was what captured Isabelle Andriessen's interest. While the lab scientists explained their motivation, approach, and goals in a very rational way, Isabelle Andriessen thought about the implications of all of the (rationally justified) steps. The film she produced takes us to a future world in which the machines seem to be alive, carrying out their dutiful tasks and no human being is encountered in the artificial environment depicted.

One could make an analogy with the development of the computer, which started as machines the size of a factory with (mostly female) workers handling punch cards or later carrying magnetic tapes around. A look inside a contemporary computer reveals no human effort, of course, and the computational processes take place on a microscopic – actually a nanoscopic – level. In the film by Isabelle Andriessen, however, we are still on the meso- and macroscopic level, begging the question: where are the humans now, and what do they do? We will see whether these questions will still be asked by humans as we march towards a future in which machines exhibit life-like behavior.

Summary and outlook

All four residencies triggered a learning process among participating artists and scientists alike. The artists got to know the methods and tools used by the researchers, found out more about their conceptual approach, transforming what researchers saw in their daily surroundings, as well as finding (speculative) forms of scientific experiments that the researchers had never considered previously. All of the artists were able to extend their own artistic practices, against the background of the scientific work, by focusing on the tools and machines, on processing the data produced by the experiments, on using the research tools to modify the bacteria from their own microbiome, and on consequently thinking through the scientists' visions from beginning to end.

The participating scientists can also claim to have learned something from the interaction with the artists. It is fair to say that all scientists had somehow expected the residency – at least partially – to be an unusual and creative form of science communication, from which the artist would produce products that would enable laypeople to better understand what the researchers were doing and that this would automatically raise the research's public acceptance. In the written reflections about the residencies, it becomes clear that this initial notion rather quickly gave way in favor of an appreciation of art itself, independent of any utilitarian calculation.

The cost of participating in such a residency was not zero for the researchers, as the two early career researchers in Julian Ma's lab, for example, reported that explaining the research and supporting the artist during his time in the lab took quite some time away from their daily routines and from other important business (something we had already heard from researchers in a previous residency (Schmidt 2018)). This distraction from their actual work, the noise and grain introduced, actually comprises the core of the residency, though. Business as usual, where the artists blend in from day one, would probably not result in interesting outcomes. This leads to the question: was the outcome interesting? In the cases of Karel Doing, Eduardo Reck Miranda, and Lara Tabet, the researchers found it quite surprising and became interested in what 'else' could be done with their tools and methodologies when used in a different context. In the cases of Eduardo and Lara, the researchers were inspired to consider novel research experiments by the conversations and brainstorming sessions with the artists. Eduardo's idea to use music to come up with new DNA sequences for enzymes was eventually seen as being too far out, a bit too 'crazy' or simply as having too low a chance to succeed. Lara's suggestions and ideas, conversely, seemed plausible enough to trigger serious debates and planning among the senior researchers involved, something that they had not expected from the residency.

The four completed artworks will be shown in exhibitions and galleries and the artists will build on their experiences in the lab in the future. We cannot know how this puzzle piece of experience will be combined with other future and past puzzle pieces and what else will come out of it; this also goes for the participating researchers. What if a researcher were to observe their tools and machines more mindfully, drawing inspiration therefrom? What if someone decided to use musical composition to design better enzymes? What we do already know is that some participating researchers have told their colleagues about the artist-in-residence program, thereby triggering interest in having an artist in their lab as well. Looks like the noise and grain are here to stay.

BIBLIOGRAPHY

01. Biofaction. (2020). Call for Artists in Residence. https://www.biofaction.com/wp-content/uploads/2020/04/CALL-FOR-ARTIST-IN-RESIDENCE-2020-21.pdf.
02. Braund, E. & E. R. Miranda (2017). On Building Practical Biocomputers for Real-world Applications: Receptacles for Culturing Slime Mould Memristors and Component Standardisation. *Journal of Bionic Engineering 14*(1): 151-162.
03. Calero, P., D. C. Volke, P. T. Lowe, C. H. Gotfredsen, D. O'Hagan, & P. I. Nikel (2020). A fluoride-responsive genetic circuit enables in vivo biofluorination in engineered Pseudomonas putida. *Nature Communications 11*(1).
04. Chui, M., M. Evers, & A. Zheng. (2020). How the Bio Revolution could transform the competitive landscape. https://www.mckinsey.com/business-functions/mckinsey-digital/our-insights/how-the-bio-revolution-could-transform-the-competitive-landscape.
05. Danielli, J. F. (1972). Artificial Synthesis of New Life Forms. *Bulletin of the Atomic Scientists 28*(10): 20-24.
06. de Lorenzo, V. (2017). Seven microbial bio-processes to help the planet. *Microbial Biotechnology 10*(5): 995-998.
07. de Lorenzo, V., P. Marliere, & R. Sole (2016). Bioremediation at a global scale: from the test tube to planet Earth. *Microbial Biotechnoly 9*(5): 618-625.
08. Doing, K. (2020). Phytograms: Rebuilding Human–Plant Affiliations. *Animation 15*(1): 22-36.
09. Gowlett, J. A. J. (2016). The discovery of fire by humans: a long and convoluted process. *Philosophical Transactions of the Royal Society B: Biological Sciences 371*(1696): 20150164.
10. Hoelscher, M., N. Tiller, A. Y. H. Teh, G.-Z. Wu, J. K. C. Ma, & R. Bock (2018). High-level expression of the HIV entry inhibitor griffithsin from the plastid genome and retention of biological activity in dried tobacco leaves. *Plant Molecular Biology 97*(4-5): 357-370.
11. Huxley, A. (1946). *Brave new world*. New York, Perennial Library.
12. Jaccaud, M., R. Faron, D. Devilliers, R. Romano, S. Riedel, & H. Pernice (2020). Fluorine. *Ullmann's Encyclopedia of Industrial Chemistry*.
13. Kerbe, W. & M. Schmidt (2015). Splicing Boundaries: The Experiences of Bioart Exhibition Visitors. *Leonardo 48*(2): 128-136.
14. McLoughlin, M., L. Lamoni, E. C. Garland, S. Ingram, A. Kirke, M. J. Noad, L. Rendell, & E. R. Miranda (2018). Using agent-based models to understand the role of individuals in the song evolution of humpback whales (Megaptera novaeangliae). *Music & Science 1*: 205920431875702.
15. Miranda, E. R. & J. E. Castet (2014). *Guide to Brain-Computer Music Interfacing*, Springer.
16. Miranda, E. R. (2020). Genetic Music System with Synthetic Biology. *Artificial Life 26*(3): 366-390.
17. Miranda, E. R. (2022). *Quantum Computer Music. Foundations, Methods, and Advanced Concepts.* Springer International Publishing.
18. Ohno, S. (1987). Repetition as the Essence of Life on this Earth: Music and Genes. *Haematology and Blood Transfusion 31*: 511-519.
19. Parker, C. H., E. R. Keefe, N. M. Herzog, J. F. O'Connell, & K. Hawkes (2016). The pyrophilic primate hypothesis. *Evolutionary Anthropology: Issues, News, and Reviews 25*(2): 54-63.

20. Pei, L., M. Garfinkel, & M. Schmidt (2022). Bottlenecks and opportunities for synthetic biology biosafety standards. *Nature Communications 13*(1).
21. Schmidt, M., A. Meyer, & A. Cserer (2013). The Bio:Fiction film festival: Sensing how a debate about synthetic biology might evolve. *Public Understanding of Science 24*(5): 619-635.
22. Schmidt, M. (2018). The Art of Antibiotics: Two residencies. Two artists. Two labs. Morawa Lesezirkel GmbH.
23. Youssef, S., & M. Schmidt (2020). Synthetic Biology and Speculative Bodies: Imaginary Worlds in Selected BIO·FICTION Films. In M. Şahinol, C. Coenen & R. Motika (Eds.) *Upgrades der Natur, künftige Körper*. Wiesbaden, Springer VS: 157-182.