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Re-Imagine the Behavior of Living Matter: The Colorless Color and an Artificial Nano-Structure in Contemporary Art

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Abstract

This article presents two case studies in which life science phenomena are reassessed, during the project based artistic research I conducted as a PhD student. As an artist and life scientist, I acknowledge the valuable contribution of time in the continuous reshaping of my worldview. Structural color resulting from the genetic modification of a non- pathogenic colony of flavobacteria and the lyotropism phenomenon of liquid crystals of synthetic biomolecules are the two case studies. What they have in common is the fact that the change in the self-organization of the microcosm is perceived through the change in color and form. A new perspective on the behavior of living matter is formed, with a multitude of correlations of different fields. At the same time, through the creation of a database, the research maps the interaction between the life sciences and contemporary art. Projects include the artistic practice of the archive supported by digital media, experimentation with the synthesis of liposomes, the organization of an interdisciplinary workshop, collaboration with the pharmaceutical nanotechnology laboratory and with the iGEM biotechnology team. Metzger's “auto-destructive” art movement is re-approached and connections with Prigogine and Stengers' book “Order out of Chaos” emerge. Issues of reinterpreting the human and the non-human, being and becoming, the artificial and the natural are raised. The artistic mediation of biological phenomena is related to Nagel's thought that on the counterpoint of the excessive and reductive objectification of the sciences, there is a reconciliation of man with his personal inner perspective.

Keywords: Re-imagine • Artificial biomaterials • Genetics • Nanotechnology • Self-assembly • Bio-art

Introduction

It is difficult to pinpoint the exact date which marks the beginning of the use of bio-materials and the experimental devices of genetics as new media in artistic practices, which is roughly placed in the 1930’s [1]. In contemporary art, in the context of interaction with the life sciences, unlike early hybrid models the new approach takes place at the molecular level e.g. genes, proteins, cells, tissues, yielding complex artificial concepts, alongside public experiments of ecological and social connotations [2]. After all, the ability to control color, shape and structure through biotechnology, and so do algorithms in the artificial sciences, is the ability to describe objects and phenomena that arise in the natural world as a result of human design and intervention [3].

Thomas Nagel stresses the necessity of a multifaceted perspective. He argues that the subjectivity of consciousness is an irreducible feature of reality, without which we could not do science, and it must occupy a fundamental place in any credible worldview, as important as that occupied by objectivity. What is the course of the "schematization" that takes place between contemporary art and the life sciences, in terms of the organization and shaping that takes place, in the process of interpreting the world? [4].

Richard Feynman is considered the father of nanotechnology, as he expressed unexpected, ingenious and intuitive ideas at a point in time when they were not scientific reality. He placed himself in a process of constant revision and reinterpretation of reality. In his interviews and writings, he reflected, invented and constructed creative conditions with nature at the center [5].

What ceremonies do we believe in? Every morning we brush our teeth. What is the evidence that brushing our teeth does any good against cavities? And you start wondering. Are we all imagining that, as the earth turns and the orbit has an edge between light and dark, that along that edge all the people are doing the same ritual–brush,

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brush, brush for no good reason? Have you tried to picture this perpetual line of toothbrushes going around the earth? Take the world from another point of view.

Monroe Breardsley argues that as an object changes, the best way to understand its change is to think of it as a loss or gain in abstract properties that are unchanging.

Mapping change as a function of time. The construction of an interactive database

The mapping method is haunted by a larger set of events that are correlated with each other [6]. Mapping the interaction of the life sciences with contemporary art has proven to be a challenging process. The first attempt was based on organizing the data on the basis of geographical location. But such information seemed pointless. What is the point of an archive, in which the quantification of information leads to a patchwork of works distributed in different parts of the planet?

In the second phase of the process I decided to introduce the parameter of time as an indicator of change. "...for this is time, the number of movements before and after". The time factor in a system is crucial, since no change is irreversible. In other words, there are no natural paths that allow a system to return to its original state through the reverse succession of intermediate states [7].

When referring to a phenomenon, we usually look for the time and place of observation. We ask "where" and "when" the event occurred. Therefore, I made a transition, jumping to the perspective of the phenomenon, that is, the event. I turned to group phenomena, which is the subject of sociology, and to the experiential part of phenomena, which is the subject of philosophy and art.

The development of pharmacology and plant taxonomy constitutes a significant form of control as much of nature as of society (...) The work of natural scientists classifying and naming natural objects accelerated the control not only of nature but of cultures.

A database consists of a set of files, which are characterized by a high degree of organization. Because of the logical relationships it allows, it provides the possibility of multiple connections, the correlation formulas [8]. This reasoning has given rise to a series of secondary considerations, in relation to the conceptual design of the database. These in turn took shape and formed the entities and fields of entities (attributes), which can be seen as reflections of the case studies [9].

Literature Review

The comparative study of the selected projects, conducted in my dissertation, is based on the attributes of the database.

The attributes of the public sphere, the societal aspects and the "eco-innovation" in the two case studies

The artistic intervention I attempt comes in the form of experimentation, and accumulates ideas in different areas, causing ideological conflicts. For example, organization and order are issues of the macrocosm and social power structures. In contrast, in the microcosm the issues are reversed, giving value to out-of-balance systems and disorder [10].

The phase transitions of living matter can be seen in the light of the conceptualization, reframing and restructuring of some societal aspects of everyday life, such as the transitions of social phases [11]. Which, with the influence of time, lead to the change of social regimes. Therefore, and in the light of the technological subjectification of the phenomenon of life, I decided to include in the database, the field of the public sphere as a space of action in which a bio-artistic event unfolds (or not).

23rd of June 1961, auto-destructive art, machine art, auto-creative art. Each visible fact absolutely expresses its reality. Certain machine produced forms are the most perfect forms of our period. In the evening, some of the finest works of art are dumped on the streets (...) Auto creative art is art of changed movement (...) Aim at the integration of art with the advances of science and technology. The immediate objective is the creation with the aid of computers of works of art whose movements are programmed and include "self-regulation". The spectator by means of electronic devices can have a direct bearing on the action of these works. Auto destructive art is an attack on capitalist values in the drive to nuclear annihilation [12].

The microcosm has the power to convey the transitions of events in the macrocosm. Even when we refer to the transition from a tree to an ecosystem or from a biomolecule to a social structure. Technological subjectification, through my artistic practice, involves the parameters of the public sphere and the interaction of the work with an ecosystem. The definition of the public sphere, according to Habermas, is intertwined with social life, which has a catalytic effect as a mechanism of reproduction in the formation of public opinion. It fulfills a necessary role between society and the state, that of the mediator. And in ideal situations, state power (or "public power") is controlled in democratic terms, in the free access of the citizen to its public activities [13].

Wodiczko's work "Porte-Parole Mouthpiece" has immigrants displaying a device on their face in public spaces, a "democratic trick". It demonstrates the deprivation of the immigrants' right of expression in the public sphere [14]. The work bridges with my research through Haraway's metahumanist gaze. Which embraced the idea of the cyborg, transcending Cartesian thinking and the nature/artifact dichotomy [15].

The Critical Art Ensemble group, in the context of political skepticism and critical delineation of the powerful influence of bioscience on democracy, incorporates the public sphere into its activities [16]. In the work “Target Deception, 2007” the element of fear is removed as a symbolic gesture that emphasizes its connection, as an auxiliary factor, in the process of an attempt to appropriate power. A performance with choreographic elements and a public experiment unfold in parallel, with the aim of recreating a test of microbial warfare. Could a biological weapon be unleashed in an urban area, or not?

The field of “eco-innovation” is a loanword I invented. It refers to contemporary art that interacts with the life sciences and turns to today’s ecology. Speaking of ecology, the attention shifts from the organism to the system. It refers to thinking about the forms and processes through which the system/environment relationship is stabilized. The management of the system-environment relationship is placed in a context of greater complexity. Bateson argues that in an ecological approach to nature one should not ask “what is something made of-Earth, fire, water, etc.”, but should ask “what is its pattern?” Spela Petric, in the installation "PL'AI", builds a cyborg. The biological and technological fusion is a new factor, of a different and complicated world, resulting from climate change.

Living matter and color. A multifaceted environmental and social challenge

In the first case study, I was concerned with addressing ecosystem degradation due to the synthetic paint industry. The latter I studied in the opposite direction previously, when I was doing research in paint chemistry. Back then the aim of the experimental process was to artificially age polystyrene paint pigments and to study their resistance to the effects of air pollutants, UV radiation, humidity and, by extension, their non-change over time. I went back to the archive of the bio-scientific research I had carried out at the time. I went back through the photos (Figure 1), the posters, the thesis text, all my notes and observations.

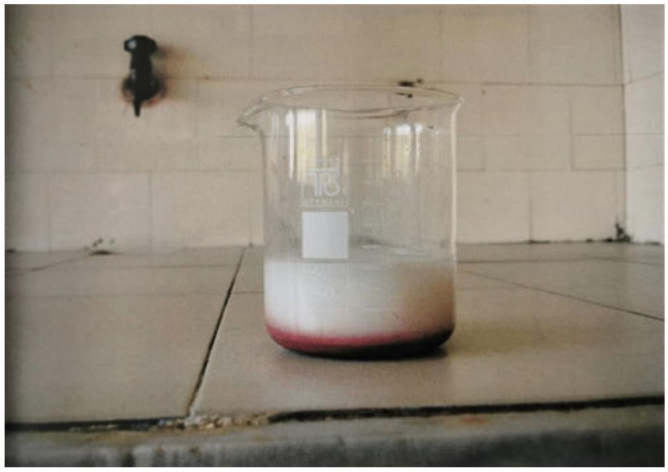

Figure 1. Study of the stability of synthetic iron oxide pigments in chemistry lab. Searching through my old archives.

At the time I thought that highlighting the durability of acrylic paints would underline the great importance and contribution of these relatively new materials, in the field of art. And from this point of view of the value of an unchanging object over time, for example a painting with acrylic paints it might be so. Through a series of quantitative determinations, spectroscopy, colorimetry and other scientific techniques, I concluded that the change in chromaticity and durability of most samples, under extreme environmental conditions, was small to negligible. For those samples that did change, a deeper study two years later would claim the following:

The greater colour difference is caused by high temperature and humidity, whereas paint layers containing TiO_2, and especially the mixture of the forms rutile/anatase, prove very susceptible to ultraviolet radiation, demonstrating a significant colour difference and extended molecular changes.

Therefore, the selection of synthetic acrylic dyes for their durability-my only concern at the time-proved to be apt and successful. And this fact, the shift in the direction of my reflections, and research field through my fine arts studies is surprising to me. It highlights a shift in my personal perspective on the value of the attributes, which cannot be left unaddressed.

The paint production industry has a dark side. The main chemical compounds involved in the production of synthetic paints are mostly toxic. They are heavy metals, iron oxides and aromatic amines. All of them are harmful to human health and to the planet's ecosystem. The large amount of deposition of synthetic dyes in nature is mainly due to the textile industries. However, the discovery and rapid development of the artificial dye industry for textiles has had a profound influence on the democratization of modern clothing [17]. The latter had, up to that time, been the prerogative of the wealthy social classes.

In the film “Purple”, Akomfrah presents ecological landscapes that are in a state of extinction. From the Alaskan interior, the desert environments of Greenland, the volcanic Marquesas Islands in the South Pacific and the Tahitian Peninsula. The human interacts with the non-human, and the phenomenon of life is threatened in precarious environments that are being affected [18].

I have attempted to re-imagine the concept of color. How can we free ourselves from the existing binding and deeply entrenched notions of the ways of producing color? And how is it possible to envision, with the help of genetics and contemporary art, an innovative and revolutionary use of color? How can we re-approach living matter, reprogram it, study its organization and behavior, to create new biomaterials with structural color properties?

Discussion

First case study: Genetic modification of flavobacteria and structural color

Synthetic biology offers the tools to address the toxicity, water pollution and the waste of non-renewable energy sources that occur during the current industrial production of paint and dyes. Through the technology of structural paint, which is based on natural optical phenomena due to biological microstructures, unhealthy working conditions seem to find a solution [19].

The iGEMs used *Flavobacterium* bacteria, which produce structural paint (Figure 2). This is a natural phenomenon, due to the microstructure of the surface of their colonies [20]. It is estimated that through their genetic editing, the bacteria will secrete an extracellular cellulose matrix. The latter retains its structural color, so that it can be used as a model and innovative biomaterial. In this case, the manipulation of the living matter does not make it the innovative biomaterial itself. On the contrary, it is carried out in order to free it from this problematic condition.

Figure 2. Cultures of *Flavobacterium johnsoniae* IR1 strains showing structural colour: A workshop with iGEMs.

The interdisciplinary workshop I organized was attended by fine arts students and the iGEM biotechnology group. Everyone had the opportunity to sit at the same table and exchange knowledge and ideas, on the theme of color. To envision a world in which nature transforms living matter into color. The six joint activities of the workshop include an online exhibition, the organization of a workshop, an event with talks by experts, the demonstration of biofilms, online meetings to exchange material. The digital projects of the participating students, resulting from the workshop, were created in 3D digital design software. They were then published on the iGEM research team's website, and announced at scientific conferences as part of the whole body of research on structural color.

I created an archive of photographic documents, videos, reflective thoughts and feelings. The archive, after second and third readings and the completion of the workshop, took the form of a digital diary (Figure 3). In it I alternated drawings, gifs, texts, visualizations of molecules (Figure 4), which were gradually generated for me. Each time, a new thought had to take shape and was imposed on me as an imperative. It was a relentless and persistent effort to re-approach the scientific research of the iGEM biotech team from other perspectives.

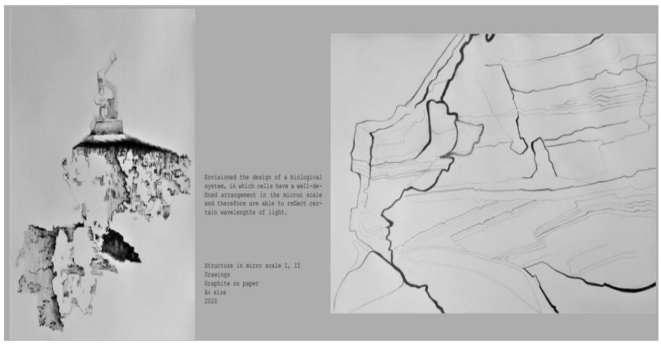

Figure 3. Drawing structures in micro scale I, II. Graphite on paper.

There is no linear progression in terms of images and texts in the construction of this diary. Instead, it is characterized by multiple returns and reinterpretations. By my willingness to re-imagine what I have already said. Each time I return to the original texts, which were in the form of notes, and to the original images, which were in the form of quick digital and analogue drawings and photographic documents. Over time new networks of ideas emerged. Sometimes instantaneously and sometimes gradually, in response to researching the literature. In each case, each step triggered the creation of new images, associations, networks and so on. The complexity of the path resembled a chaotic experience, a system of thinking out of balance.

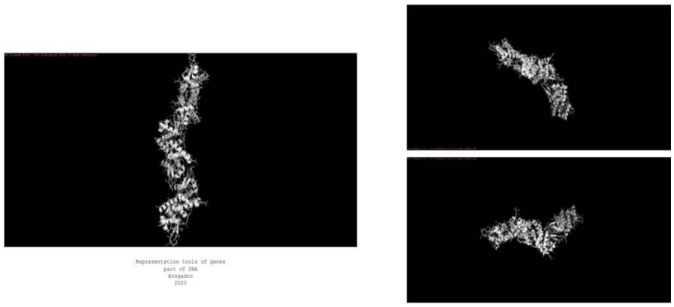

Figure 4. Visualization tools of genes part of DNA, Avogadro molecular editor.

I felt the need to further explore the behavior of living matter through structural color, and its potential role in 3D printing. I turned to the study of international nanotechnology literature in relation to structural color. There are synthetic polymers with dendritic structures that produce the optical effect of structural color in a controlled manner. The nanostructures that give rise to this optical effect are obtained by a process called “self-assembly”.

Unfortunately, the anti-pandemic measures against COVID-19 did not allow me to experiment with the biomaterial in the 3D sculpture printing laboratory I had designed. But it is an experimentation that I intend to carry out in the near future. But the phenomenon of “self-assembly” accompanied me in the second case study.

Living matter and the change of self-organization. Social lyotropism and Metzger's liquid crystal state

Prigogine and Stengers demonstrate that most of reality is characterized by disorder. I chose to turn to the thermodynamics of artificial biomolecules, because it contributes to a review of the importance of time and the ontology of randomness. According to the article “Fractal Artificial Life: Looking for Creativity at the Edge of Chaos”, fractal patterns are indicators of universal forms of self-organization, leading to critical situations on the verge of chaos. Hans Haacke, in “Condensation cube”, treats physical fluid systems as tiny living universes, which have their own arrangements, and are subject to processes of constant change and interaction.

Technology creates negative entropy in some systems, but the overall ecosystem is driven into greater disorder as it is doomed to decay. Plants resist the chaos, slow its inevitable onset, hold back light

as much as they can, and laboriously build up energy reserves. The book “Planthunter: Truth, Beauty, Chaos and Plants”, contributes to a rethinking process about the importance of plants, finding value in the practice of gardening. Nature and living matter are changing.

But apart from the changing beauty of the various concrete things that exist in the world, there must be a Beauty that appears in all of them.

The concept of social lyotropism is a means of connecting the deterministic chaotic behavior of artificial nanostructures, biological and social systems. My ongoing project "Institutional mechanism for the production of negative social entropy” involves the creation of an organism, based on the seemingly random emergence of order out of chaos in social systems out of balance. One of the aims of the project is the spontaneous process of transition from the individual person to the empirical events of collective activity.

Gustav Metzger, a German artist and political activist, introduced and developed the concept of “auto-destructive art”. The purpose of Metzger's movement was to draw attention to the destruction of previous beliefs. Destruction also represents the chaos caused by the government, since politics was the main driving force.

Auto-destructive art is the transformation of technology into public art. Auto-destructive art is art which contains within itself an agent which automatically leads to its destruction within a period of time not to exceed twenty years. Other forms of auto-destructive art involve manual manipulation. There are forms of auto-destructive art where the artist has a tight control over the nature and timing of the disintegrative process, and there are other forms where the artist's control is slight.

In interviews, Metzger expressed his distaste for politics and commercialism, arguing that the “aesthetics of abhorrence” tended to reinforce an existing idea of a corrupt, unjust, capitalist system. In his experimentation, heat-sensitive liquid crystals were placed on small glass surfaces. They were then inserted into a large projector. As the liquid crystals were heated and cooled, they changed color to produce ever-evolving patterns. Here again art “collapses”, in order to be recreated as science. The public demonstration of Metzger's multifaceted metaphor of self-destructive art referred to the liquid crystalline state as a transitional and ever-evolving action in the public sphere.

For example, in the liquid crystal projections you have temperature, which guides the progression of the work. And the temperature variations (...) In fact will register as changes in colour and in movement and in interaction. And I think that is a contribution which you can describe in terms of auto-creative art.

The structural polymorphism of the artificial biomolecules of research, relates to the evolving phenomena of life. Liquid crystals belong to soft matter, such as human cells. It is characterized by special properties due to the various molecular organizations of molecular lattices. Therefore, respect for harmony and hierarchy of structures is of functional importance. It regulates the balance of events that unfold in nature and contributes to the understanding of the natural processes surrounding the phenomenon of life. But how does the study of an artificial biomimetic model through a metahumanistic approach to nature contribute to the study of complexity? And how does the emergence of complexity find application in areas of everyday life?

Second case study: The composition of artificial liquid crystals and phase transitions of bio-materials

In the second case study the experimental process was the object of experimentation in a move to reframe and create a new conceptualization of molecular synthesis. Initially, using the semi-structured interview method, I contacted the research team of the pharmaceutical nanotechnology laboratory. I recorded the audiovisual material of our discussion, transcribed it, took notes and created links to the literature. I then moved inside the lab (Figure 5).

Figure 5. Synthesizing an artificial nanostructure in laboratory of pharmaceutical nanotechnology, still image in a film.

I discussed again with the researchers, this time freely. Two films emerged, in which the function of living matter and it’s self-assembly is reinterpreted. The three levels of complexity are developed, its social valuation, the connection between human behavior and the biophysical functions of matter, the reflection on the prevailing technocratic perspective, the anxiety about the changing concept of memory in the Anthropocene era. The next time I was in the lab, I digitally recorded the chemical composition of the liquid crystals of an artificial biomolecule, the liposome (Figure 6).

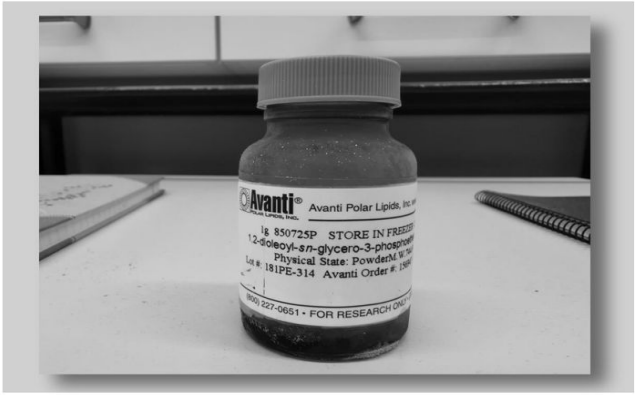

Figure 6. The raw material: A chemical composition of the liquid crystals of an artificial biomolecule, still image in a film.

The artificial biomaterial, the liposome, simulates the function of the cell and is used to study the complex behavior of living matter. Through its construction the concepts of irreversibility and randomness, systems far from equilibrium and the way they are linked to the spontaneous phenomenon of life were explored. My artistic practice was enhanced by the research team's archival collection of electron microscopy photographs. These contributed to my morphological and hermeneutic approach, when comparing different methods of documentation (Figure 7).

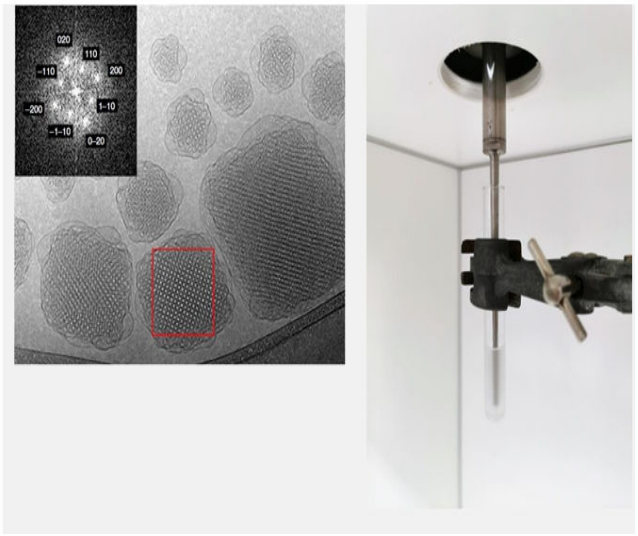

Figure 7. Comparison of documentation and visualization methods of lipid synthesis. (Left: Electron microscopy photograph of cubic liposomes, archive of D. Demurtas, 2015. Right: Sonification of a liposome, Photo by author, 2022.)

The microscope images I observe are nothing but a moment in time. At each subsequent and previous moment, the organization of the biomaterial has been altered. Liquid crystals are divided into two broad categories, thermotropic and lyotropic. Thermotropic crystals change their organization as a function of temperature. So they refract light differently, yielding unexpected results. Light is differentiated in the public sphere. In the urban landscape of Athens, apartment buildings diffuse light in a different way than natural ecotopes. Suppose I am trying an experiment, through a visual installation. I will synthesize thermotropic liquid crystals of cholesteryl derivatives, based on a protocol. I will repeat the experiment in different parts of the public sphere, filming the process of change. The visual installation of the liquid crystals in the natural light of the public sphere is an artistic experiment, currently in progress, that functions as a relational practice of connecting the phenomenon of lyotropism to society.

About my future aspects, in the second case study, the experimentation with the liquid crystals of biomolecules that I compose (Figure 8), decided to test in the light of different landscapes. I believe that the public sphere and the environmental conditions will be key aspects of this ongoing project.

Figure 8. Experimentation with the liquid crystals of biomolecules that I compose.

Conclusion

The transition from the scientific laboratory to the studio, and by extension the inclusion of remote areas and urban space, necessitated a broadening of the delimitation of territories. In both case studies, there were interactions and interventions, which I cautioned in a direct or indirect way. In the two case studies of structural color and lyotropism of the liquid-crystalline state of the artificial biomolecules, the environment and ecology were repositioned in a post-humanist, post-anthropocentric condition. I think they served as a cluster of biotechnological and physical components, interwoven in more complex systems that happened to occur. My artistic intention was in line with post-humanist philosophy. I believe that man ceases to be the focus of his environment, but instead becomes aware of and redesigns a continuous interaction with it. I conclude that the latter can be formed through a new hybrid spiritual state, involving the genetic modification of living matter, the study of its self-organization, techno-scientific aesthetics and its functions. But at the same time it contains the questioning of the human disposition to manipulate nature, critical thinking, and the emergence of the randomness prevalent in nature through its prevailing complexity, increasing entropy and chaos. Living matter and its “self-assembly” served to produce innovative artificial bio-mimetic derivatives. My artistic practice was based on the constant revision of my scientific knowledge. In my need to return to it and through art to re-format it. By presenting these practices and offering them for experimental testing, they are put to the use of the whole of society. Through this practice based research I assume that the creation of new knowledge is not simply a matter of processing objective or experimental data and information. Rather, it also depends on the flow of knowledge through the subjective expression, inspiration or intuition of individuals.

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