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On the Evolution of Art and Nature Relationship: Bio-Informed Art

Abstract: Scientific and technological developments triggered creative thinking and the emergence of innovative products in many fields such as art, architecture, engineering, nanotechnology, and medicine. The main reason behind this might be the formation of new dynamics by blurring the sharp distinctions between disciplines. Different meanings and concepts with the changing dynamics also lead to the reshaping of interdisciplinary relations. The effects of bio-inspired/bio-informed paradigms in many disciplines including art have been analyzed. The first part of this study presents the traces of the environment with examples from the prominent movements in the art of painting developed in the period from the first works of humanity to the middle of the 20th century. Second, paintings, sculptures, and installations shaped by the understanding of bio-art that has become widespread in recent years are included. It was understood that art has experienced paradigmatic shifts as a result of interdisciplinary relations with fields such as technology, biology, synthetic biology, and biotechnology, and this interaction with established connections led to the development of innovative approaches in art.

Keywords: Bio-informed paradigm; Bio-art; Biotechnology; paradigm shift in art; Transgenic art.

Introduction

Many "transferences" have been made, from the past to the present, through copying/mimicking/learning/interpreting/mimesis of "nature". Discussions about environmental issues (climate change, energy, and resources, ecology, and sustainability) are a visual source of inspiration for "nature" (*as a model*) beyond being a benchmark (*as a measure*) and a mentor (*as a mentor*).[1] Different perspectives facilitated distinct approaches. These approaches have created an interdisciplinary field to

[1] Janine M.Benyus, *Biomimicry: Innovation Inspired by Nature* (New York: Morrow, 1997), 4.

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generate insights towards biological phenomena, objects, functions, structures, and principles discovered in "nature" by scientists/scholars/designers.[2] "Nature", which is a source of inspiration for numerous fields of study such as architecture, art, engineering, medicine, robotics, materials, fashion, agriculture, and economy, is considered an unlimited and tangible resource that contributes to the production of creative solutions together with the developments in science and technology.

Every discipline related to design connects to "nature", and this changes perspectives, understandings, research areas, and practices through developments in science and computational technologies. This study focuses on the "nature-art interaction", driven with the question of "How has the effect of biological knowledge and inspiration from "nature" on art?". Besides, the artistic products that have emerged with "nature-oriented approaches" from the past to the present were also analyzed. First, the concept of "nature" in "paintings" in the art movements up to the 1960s, starting from those made by primitive people on stones, was examined. Second, applications that have changed with the scientific and technological innovations in art, from the second half of the 20th century, are examined through examples of "bio-art." Several examples of sculptures, paintings, and installations produced with the concept of "bio-art" are included in the section of "Paradigmatic Changes Created by Biological Knowledge in Art" to read the change of biological paradigms more accurately. The methods of reflecting the biological information in the examined works were also discussed.

Traces of Nature in Art

Artistic work is defined as *a metaphorical representation of humanity's existential encounter with the world*".[3] Art is generally defined as a visual object (usually painting, drawing, or sculpture) appreciated for its beauty or emotion.[4] Another definition depicts it as a technical process used in painting or representing something.[5]

The works of the artist and the interaction between art and "nature" had constantly changed.[6] The artist's perception of "nature" and point of view towards "nature" determined the connection between art and the artist. Moreover, different meanings of "nature" have developed, and various designs occurred with these changes throughout time. Most debates on art since ancient times have been conducted over the interaction between "human," who assumes the role of an artist, and "nature,"

[2] Renee L. Ripley and Bharat Bhushan, "Bioarchitecture: bioinspired art and architecture – a perspective," *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, 374, 2073 (2016): 1–36.

[3] Juhani Pallasmaa, "Newness, Tradition and Identity: Existential Content and Meaning in Architecture," *Architectural Design* 82, 6 (2012): 17.

[4] Ripley and Bhushan, "Bioarchitecture: bioinspired art and architecture – a perspective."

[5] Herbert Read, "İnsani Sanat ve İnsanlık dışı Doğa," (Çev. Cemal İ. Çakır), *Sanat Dünyamız* 92 (2004): 57–59.

[6] Sevil Saygı, "Çağdaş Sanatta Doğa Algısı ve Ekolojik Farkındalık," *Art Design Journal* 7 (2016): 7–13.

which becomes material for the artist.[7] Therefore, the interdisciplinary connection between biology-knowledge, "nature", and art is discussed in this section.

The Change of Art-Nature Connection in Art History

The applications that refer to "nature" are increasing to create new inventions and innovations in several fields such as architecture, engineering, materials, and nanotechnology. Besides, mimicking, interpreting, and being inspired by "nature" has been the primary source of many art practices.[8] It can be asserted that the connection between "nature" and art has developed with a morphological approach for centuries.[9] The examples discussed in this section are limited to the art of painting, and notable works are included within a timeline.

The timeline starts with the pictures/drawings that primitive humans made on cave and natural material surfaces, which is thought to be important in forming the artistic image. It should be noted that people began to express themselves with the materials they have obtained from "nature". Various animal symbols and motifs carved on the obelisks in the Göbeklitepe campus during the Neolithic Age, in what is now Turkey, are exemplary. These naturalistic depictions on stones, including the realism of humans and "nature", can be interpreted as narrative and monumental features.

Renaissance Art developed simultaneously with great scientific discoveries, and natural scientists' observations of "nature" and developments in mathematics affected art. Mannerism transformed "nature" into fantastic variations with human portraits, vegetation, animals, and natural objects.[10] Baroque art did not use "nature" through a particular filter but was interpreted as an abstracted observation.[11] The fragmentation, diversity, and visual reality of the ideal understanding of "nature" changed with the increased impact of science. Despite all these changes, the artists were still inspired by "nature" and mimic the visible reality instead of ideal "nature".[12]

Impressionism, the first modern art movement, depicts "nature" as it is.[13] The Post-Impressionist movement aimed to reflect the harmony in "nature" instead of a momentary reflection of "nature".[14] Moreover, *the Art Nouveau* movement, known to refer to "nature" frequently, created used animals and plants, which reflect "nature",

[7] Read, "İnsani Sanat ve İnsanlık dışı Doğa," 57–59.

[8] İrfan Aydin and Yeşim Zümrüt, "Doğa ve Sanat Ekeseninde Farklı Yaklaşımlar," *Journal of Art and Design* 4, 4 (2013): 53–78.

[9] Ayşe Azamet and İnam Karahan Çağatay, "21. Yüzyılda Biyosanat," *İdil Sanat ve Dil Dergisi* 63, 8 (2019): 1455–62.

[10] Ripley and Bhushan, "Bioarchitecture: bioinspired art and architecture – a perspective."

[11] Adnan Turani, *Dünya Sanat Tarihi* (İstanbul: Remzi Kitabevi, 1992), 457.

[12] Read, "İnsani Sanat ve İnsanlık dışı Doğa," 57.

[13] Abdullah Ayaydın, "Empresyonizm (İzlenimcilik) Akımının Güncel Bakış Açısıyla Bazı Yönlerden İncelenmesi," *SED-Sanat Eğitim Dergisi* 3, 2 (2015): 83–97.

[14] Paul Signac, *Paul Signac* (New York: Parkstone International, 2013), 160.

with regular compositions and dynamic decorative forms.[15] Cubism reflected the abstract aspects of art as the subconscious, in three dimensions, with mathematical measurements and geometrical forms instead of copying "nature".[16] "Nature" was expressed through the unconscious mind in the surrealism trend. [17]

Optical art (*Op Art*) is an art movement that uses geometric shapes and lines, making the viewer feel blurred and moving. Bridget Riley, one of the leading artists of the movement, stated that "nature" is not only a landscape for itself but also the dynamism of visible forces.[18] "Nature" is depicted in a way that reveals the perception of popular culture reality in Pop Art.[19] Table 1, which includes all these movements, reveals that "nature" in art has evolved into different meanings in the historical process with the changing social, scientific, and technological developments, starting from the object phenomenon. "Nature", an unlimited resource, has been interpreted through social, subjective, objective, and scientific aspects such as pure formalism, mathematical proportions, light, color, and texture.

Paradigmatic Changes Created by Biological Knowledge in Art

Many disciplines were influenced and transformed by advances and developments in science and technology. This progress and development have created interdisciplinary fields. Disciplines such as design, architecture, philosophy, music, history, mathematics, psychology, anthropology have been interactive with art since the 20th century.[20] Interdisciplinary methods were tested through this interaction.

The close connection between technology and art was revealed with Modernism, and this interaction has created potentials that can lead to radical change and transformations in all plastic arts.[21] It has also undergone radical transformations with the widespread use of digital tools, biotechnologies, the internet, and the view of art as a transaction place by the end of the 20th century.[22] The artists did not remain indifferent to the global developments and ecological problems, as they sought different

[15] Abdullah Ayaydın, "Art Nouveau Akımına 21. Yüzyıl Perspektifinden Bir Bakış," *Ulakbilge Sosyal Bilimler Dergisi* 3, 6 (2015): 59–73.

[16] "Art History Timeline: Western Art Movements and Their Impact," https://www.invaluable.com/blog/art-history-timeline/, acc. on March 3, 2022.

[17] Nathalia Brodskaïa, *Surrealism Genesis of a Revolution* (New York: Parkstone Press International, 2012): 103–6.

[18] Simon Rycroft, "The nature of Op Art: Bridget Riley and the Art of Nonrepresentation," *Environment and Planning D: Society and Space* 23, 3 (2005): 351–71.

[19] Selda Gümüşay, "İnsanın Yaşam Alanlarıyla Kurduğu İlişkinin Resmin Olanaklarıyla İncelenmesi," unpublished MA Thesis (Çukorova University, Social Sciences Institute, 2008).

[20] Fırat, Arapoğlu. "Disiplinlerarası Sanat Bağlamında Mekansal İletişim," *Aurum Journal of Social Sciences 4*, 1 (2019): 27–54.

[21] Cemalettin Sevim and Gamze Boz, "Hazır-Nesnelerin ve Teknoloji Sanatta Kullanımı ve Seramik Sanatına Yansıması," *Journal of Art and Design* 1, 1 (2011), 111–35.

[22] Mario Savini, "Transgenic Art. The new nature as aestheticization of life," in *The New and History art*science 2017/Leonardo 50 Proceedings*, ed. by Pier Luigi Capucci and Giorgio Cipolletta (Noema: Ravenna, 2018), 188–93.

ways to explain these problems to people in this process. Due to the environmental problems and ecological deterioration, ecological sensitivities have developed with the change of "nature", leading to "paradigmatic" changes in art.

Paradigm, which means "series, examples, and sequences of values",[23] provides perspectives on scientific fields and has the potential to change their structure. This change in structure affects the perspective of the cases and the way they are analyzed. The concept of paradigm, which contributes to the philosophy of science literature, was first discussed by Thomas S. Kuhn in 1962. Kuhn (1995) defines the concept of paradigm in *The Structure of Scientific Revolutions* as scientific achievements that are universally accepted, set a model for the scientific community for a certain period, provide new perspectives with producing sample questions and solutions. Kuhn uses the term paradigm, which he also calls competing scientific approaches, with a slightly broader perspective, to encompass all the values, rules, beliefs, conceptual and experimental tools, whether explicit or implicit, that a particular scientific approach uses to question and address "nature" and find a set of relations in "nature".[24] There is a perceptual change in a paradigm shift, and scientists following the new paradigm adopt new tools and focus on different dimensions. Likely, a scientist looking back to an issue with the previous tools would still discover new phenomena. Joseph Priestley saw phlogiston, while Lavoisier saw oxygen with the help of a clue from Priestley. Lavoisier's world completely changed after discovering oxygen. Although the world does not change with a paradigm shift, scientists start working in a different world.[25] Kuhn's (1995) views on the paradigm and the structure of scientific revolutions such as paradigms as an exemplary model, worldview change and paradigms as a new way of seeing, and paradigm as a tool or a way of using a tool[26] might be effective in revealing the paradigmatic character of bio-art. Therefore, conditions that enable artists to change their worldview and create new ways of understanding are accepted as paradigm shifts.

The perception of "nature" by the artists who address, mimic, abstract, and emulate "nature" aesthetically, and the view of the artists today, begin with the reflection of the differentiation on art in the social structure after the 1960s.[27] An example of this is an earthen mound covered with grass, which artist Hans Haacke at Cornell University and MIT called *Grass Grows*.[28]

The Matsys Design Studio, which explores new and holistic connections between bio-informed forms, material systems, growth, and behavior designs on many

[23] "Türk Dil Kurumu Sözlükleri," https://sozluk.gov.tr/, acc. on February 27, 2022.

[24] Thomas S. Kuhn, *Bilimsel devrimlerin yapısı*, ed. by Nilufer Kuyaş (Istanbul: Alan Yayıncılık, first edition in 1962, 1991), 10.

[25] Ibid., 87.

[26] Tan Kâmil Gürer and Atilla Yücel, "Bir paradigma olarak mimari temsilin incelenmesi," *itüdergisi/a* 4, 1 (2005): 84–96.

[27] Sevil Saygı, "Çağdaş Sanatta Doğa Algısı ve Ekolojik Farkındalık," *Art Design Journal* 7 (2016): 7–13.

[28] See: Hans Haacke, *Grass Grows*, soil and turf, 1967–69, Earth Art, Andrew Dickson, White Museum of Art, Cornell University, Ithaca, New York, https://bombmagazine.org/articles/shifting-connections-hans-haacke/, acc. on February 27, 2022.

scales, including art, design, architecture, and engineering; adopts a design philosophy that combines biological, synthetic, and topographic issues with natural materials and energy. *Chrysalis (III)* work, designed by the studio, examines the self-organization of barnacle-like cells through a layer. It was observed that cell-like structures limited by a reticulated surface in the digital environment are organized in a balanced way.[29] Oregon, the *photovoltaic sculptures*, developed by Dan Corson in 2013 in Portland and part of the city's public art collection, were designed from tropical plants. Each statue has solar cells that help store solar energy during the day and shine at night.[30]

Another example is the *Blooms* series, a design by John Edmark based on the spiral geometry found in pinecones and sunflowers. After studying plant geometry for many years, Edmark created patterns with 137.5 degrees, which is called the "golden angle" in many plants. Produced by "nature's mathematics", *Blooms* are sculptures are obtained by three-dimensional printing that become animated when rotated under a flashlight.[31]

The bio-informed works we see in installation art, which can also be described as works of art that can be experienced, are the works of Brazilian artist Henrique Oliveira in *Palais de Tokyo*, Paris. They are about the organic growth of tree branches, which he made in 2013 at the art center for the *Baitogogo* project, which is a good example. The artist combines the architecture of the *Palais de Tokyo* with plants, reflecting an existing grid of columns and beams as if they were transformed into twisted branches, emphasizing that they derive from tumor-like physical pathologies. The curators say that Henrique Oliveira revealed this work through architectural anthropomorphism.[32] A biomimetic, interactive installation work, designed for the Live Sydney festival in 2015 for the *Arclight* project, that provides a dynamic environment interaction and works with solar energy was designed. The origin of the design is the Australian mangroves and strangler fig trees.[33] Peter Krsko explores bio-inspired problem solving in his sculptures, which he designs to create original works of art, using natural structures, systems, and materials, and combining techniques and approaches from both art and science. The artist designs installations to observe 'nature' and combines it with art through scientific methods, which are inspired by the structures created by spiders, using different materials and

[29] See: *Chrysalis (III) design*, 2012, Cherry veneer (outer) and poplar veneer (inside), 190cm x 90cm x 90cm, Center Pompidou, Paris, France, https://www.matsys.design/chrysalis-iii, acc. on February 26, 2022.

[30] See: Dan Corson, *Nepenthes*, 2013, fiberglass, LED lights, solar cells, Portland, Oregon, USA, https://inhabitat.com/dan-corsons-solar-powered-sculptures-in-portland-oregon-are-inspired-by-quirky-tropical-plants/, http://dancorson.com/nepenthes, acc. on February 27, 2022.

[31] See: John Edmark, *Blooms*, sculpture design created with flashlight animation, https://bigumigu.com/haber/3b-baski-hareketli-heykel-serisi-blooms-2-ile-devam-ediyor/, https://www.fastcompany.com/3067660/these-mesmerizing-biomimetic-sculptures-look-like-theyre-growing-as-you-watch, https://starts-prize.aec.at/en/blooms2/, acc. on February 27, 2022.

[32] See: Henrique Oliveira, *Baitogogo*, 2013, recycled plywood, Palais de Tokyo, http://www.henriqueoliveira.com/portu/comercio_i.asp?flg_Lingua=1&cod_menu_obras=1&cod_Serie=1&cod_Artista=1, https://www.dezeen.com/2013/08/09/baitogogo-by-henrique-oliveira-at-palais-de-tokyo/, acc. on February 27, 2022.

[33] See: Matsys design, *Arclight*, 2015, 18 bundles 2.4-7 m high, riveted polyethylene sheet and rod, Sydney, Australia, https://www.matsys.design/arclight, https://www.australiangeographic.com.au/blogs/ag-blog/2013/11/mangroves-a-vital-ecosystem-in-need/, https://www.npr.org/2021/10/14/1046109839/the-mighty-mangrove, acc. on February 27, 2022.

thin polyethylene films.[34] It was observed that the social, scientific, and technological developments and the possible consequences of these developments affect artistic approaches as in other disciplines. Artists do not remain indifferent to these changes and innovations, but they use scientific and technological developments as materials, methods, and mechanisms for production.

Living Art Experience: *Bio-Art*

"Nature", which is reflected in art as mathematical measurement, aesthetics, interpretation, and mimicking, has begun to be regarded as an art and design problem with the biotechnological developments in the 21st century. Biology's rise to hottest natural science status has led to overuse of biological metaphors in the humanities. It has also produced a range of biotechnology methods that provide artists with new means of expression.[35] The materials of artists who combine art and science with biological processes such as growth, development, evolution, and deterioration are now mycelium, bacteria, enzymes, cells, living tissues, and organisms in petri dishes.

Artists research "nature" to explore it artistically and transform it into an artistic product thanks to the accessibility of scientific processes and technological tools. Therefore, bio-art, an interface of biotechnology that emerges in universities and private research centers,[36] supports the views presented that science and art can be combined through different approaches. However, bio-art is considered a movement in contemporary art that includes biological materials, processes, and living things (cells, tissues, organisms) with scientific experiments and tools.[37]

Scholars also define bio-art as an application method that utilizes DNA, cells, genes, digital datasets, codes, living tissues, and/or digital information that produces new life forms.[38] However, there are four specific sub-fields, includes works of artists who are curious about working with living or semi-living tissue, evolution, degradation, growth, and biotechnology,[39] namely bio-art, biotechnology art (involving the use of biotechnology in a broad sense), transgenic art (involving genetic engineering and also considered a subfield of biotechnology art), synthetic biology, and

[34] See: Peter Krsko, *Stabiliment Statue,* 2017, thin polyethylene, Olbrich Botanical Gardens, Madison, USA, http://www.peterkrsko.com/projects/stabilimentia.html, acc. on September 4, 2020. See also: "Zoethica: Bioinspired Art and Science," http://www.olbrich.org/events/Zoethica.cfm, acc. on February 27, 2022.

[35] Jens Hauser, "Observations on an Art of Growing Interest. Toward a Phenomenological Approach to Art Involving Biotechnology," in *Tactical Biopolitics: Art, Activism, and Technoscience*, ed. by Beatriz da Costa and Kavita Philip (Cambridge, Massachusetts: Massachusetts Institute of Technology, 2008), 84.

[36] Ali K. Yetisen, Joe Davis, Ahmet F. Coskun, George M. Church, and Seok Hyun Yun, "Bioart," *Trends in Biotechnology* 33, 12 (2015): 724–34; Azamet and Çağatay, "21. Yüzyılda Biyosanat," 1455–62.

[37] Cf. https://www.wikizero.com/en/BioArt, acc. on February 27, 2022. Marietta Radomska, "Uncontainable Life: A Biophilosophy of Bioart," PhD Thesis, (Linköping: Linköping University, 2016), https://liu.diva-portal.org/smash/get/diva2:916178/FULLTEXT01.pdf%20, acc. on February 27, 2022.

[38] Eva Šlesingerová, "Biopower imagined: Biotechnological art and life engineering," *Social Science Information* 57, 1 (2018): 59–76.

[39] Radomska, "Uncontainable Life: A Biophilosophy of Bioart."

biorobotics.[40] Bio-art is a contemporary art form that utilizes biotechnology and scientific methods to explore living systems as artistic subjects.

Historical development in the field of bio-art, the pioneering programs, and initiatives at the intersection of biology and art are detailed in Figure 1. It can be understood that there have been many developments in biology and bio-art since 1928 when Alexander Fleming discovered penicillin. Moreover, academies such as the New York School of Visual Arts and Bio-art Laboratory, Synthetic Aesthetics, Finnish Bio-art Society were established to conduct bio-art studies.

Pier Luigi Capucci explored the connection between organic and inorganic living spaces and the sub-branches of bio-art in 2008 (Figure 2). This diagram illustrates the four branches of bio-art and their content. There are branches such as the genetic art in which DNA is used, transgenetic art in which genetically modified organisms are used, and biotechnological art fields in which chromosomes and genetically modified or unmodified organisms and tissue culture are used.[41] Transgenic art, a sub-branch of bio-art, is defined as a new art form based on genetic engineering techniques to transfer synthetic genes into an organism or transfer natural genetic material from one species to another and create unique organisms. Molecular genetics enables the artist to design plant and animal genomes and create new life forms. The "nature" of this new art is defined as the birth and growth of a new plant or animal and the "nature" of the interaction between society and the transgenic organism.[42]

Such artworks bring together different thoughts, perceptions, values, and emotions and aim to create a language specific to the culture of the time. Based on recent scientific developments, it emphasizes the importance of "nature". This field of art produces objects that are not in "nature", bridging the gap between natural and artificial, reality and simulation, biological and synthetic.[43]

The first study in the field of transgenic art was conducted between 1986–1987. Joe Davis, an artist and researcher at MIT who works with dyes, genes, and bacteria, used molecular biology tools and techniques and produced *Microvenus*.[44] This work is a synthetic piece of DNA with an encoded visual symbol introduced in a bacterial dish.[45]

The Tissue Culture and Art Project, a research and development project initiated in 1996 to explore the use of texture technology as a means of artistic expression, through the construction/growth of a new object class/asset class, different dimensions of "semi-living" were examined. The objects used in the study are complex

[40] Šlesingerová, "Biopower imagined: Biotechnological art and life engineering."

[41] Nora S. Vaage, "Amplifying Ambiguities Art on the Fringes of Biotechnology," (PhD Thesis, Bergen: University of Bergen, 2016).

[42] Cf. Eduardo Kac, "Transgenic Art," https://www.ekac.org/transgenic.html, acc. on February 27, 2022; originally published in *Leonardo Electronic Almanac* 6, 11 (December 1998): n/p/n.

[43] Savini, "Transgenic Art: The new nature as aestheticization of life."

[44] See: Joe Davis, Microvenus, 1986–1987, Synthetic DNA molecules in a bacteria dish, University of California, Berkeley Hatch Echols Laboratory, https://www.digitalartarchive.at/database/general/work/microvenus.html, acc. on April 5, 2022.

[45] Savini, "Transgenic Art: The new nature as aestheticization of life."

organisms that can survive outside the body and grow in predetermined ways. These objects are presented as a concrete example that questions the deep-rooted perceptions of life and identity, the concept of self, and the position of humanity concerning other living things and the environment. *Anxious Babies* created in this context are composed of degradable polymers and surgical sutures.[46] Endothelial, muscle, and osteoblast cells (skin, muscle, and bone tissue) grown on/in the polymers were added to sterilized infants.[47] This work is considered the first attempt to explore the possibility of combining the technological knowledge of tissue culture and related technologies with an artistic application.[48]

C-LAB, an interdisciplinary organization in London that focuses on contemporary art, science, and technology, has developed *The Cactus Project* in 2001.[49] This is a living work of art, human hair, created by adding keratin genes to cactus cells. Transformed cells were regenerated as transgenic cactus. This study aimed to create a cactus with externally produced human keratins, morphologically similar to hair, in cactus cells.

The "semi-living" concept crystallizes considering the life forms produced in the laboratory in defining these biological issues that cannot be classified in traditional taxonomies. Architect Philip Beesley works on semi-living sculptures to analyze how future home environments can breathe.[50] He also used liquid-supported artificial cells in the *Sargasso* project,[51] which share some characteristics of natural living cells.[52] Beesley used the *Near-Living Architecture* concept for these studies.[53]

The Australian Government and Australian Council arts fund and advisory body supported Oron Catts, Ionat Zurr, and Robert Foster in 2014 to create a closed artificial environment with *Hela (Henrietta Lacks)* cells[54] and polymer structures with

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[46] See: *Half-Living Worried Baby H statue*, 2cm x 1.5cm x 1cm, 2000, https://www.interaliamag.org/articles/tissue-culture-art-project-oron-catts-ionat-zurr/, acc. on February 27, 2022.

[47] "The Tissue Culture & Art Project," *Interalia Magazine*. https://www.interaliamag.org/articles/tissue-culture-art-project-oron-catts-ionat-zurr/, acc. on February 27, 2022

[48] Oron Catts and Ionat Zurr, "The Art of the Semi-Living and Partial Life: from Extra Ear to In-Vitro Meat," in *Ciência e Bioarte-Encruzilhadas e Desafios Éticos* ed. By Palmires Fontes da Costa (Portugal: Edição e Artes Gráficas, SA: Caleidoscópio, 2007), 37–57.

[49] See: Laura Cinti as a living work of art: The Cactus Project sources: http://www.lesmutants.com/cintiVO.htm, http://thisisalive.com/the-cactus-project/, acc. on February 27, 2022.

[50] Kevin Holmes, "Philip Beesley's Stunning Semi-Living Sculptures," https://www.vice.com/en/article/kbgyva/philip-beesleys-stunning-semi-living-sculptures, acc. on February 27, 2022

[51] See: *Sargasso*: Toronto Luminato Festival, 2011, http://philipbeesleyarchitect.com/sculptures/1035_Luminato/index.php, acc. on February 27, 2022.

[52] Philip Bessley, "Living Architecture System Group," https://www.philipbeesleystudioinc.com/, acc. on February 27, 2022.

[53] *Near-Living Architecture: Work in Progress from the Hylozoic Ground Collaboration, 2011–2013*, ed. by Philip Bessley (Toronto: Riverside Architectural Press, 2014).

[54] Taken from a patient with uterine cancer named Henrietta Lacks, they are defined as immortal cells in medical literature. These cells, which live outside the human body and reproduce in a laboratory environment, can reproduce independently. Çağrı Zeybek Ünsal and Nükhet Örnek Büken, "Henrietta Lacks' in Ölümsüzlüğü: Tıp Tarihinin Gılgamış Destanı," *Turkish Journal of Life Sciences* 3, 2 (2018): 248–54.

the slogan "Art is like a living organism."[55] These cancer cells consume their nutrients, produce serious waste during the exhibition process and turn their environment into death chambers. Thus, the zone will no longer exist at a certain time.

Another experimental study conducted by the scientist-artist Zachary Copfer analyzes different works of art that are revealed by combining the photographic process and microbiological applications. This study uses the technique called "bacteriography" which uses a living bacterial colony and ultraviolet rays in a petri dish. The end product results from the harmful emission of radiation into a petri dish coated with a live bacterial emulsion. The resulting products are a bacterial plaque that grows to form a photographic image.[56]

The American Society for Microbiology launched the Agar Art Competition in 2015 to share the world of microbes and bacteria with the public. The work with the first prize award in the competition held in 2020 had different types of mushrooms in petri dishes. *Candida albicans* and *Candida dubliniensis* colonies were formed to flourish leaves and vines. The blue color of the gardener's hat and watering pot were obtained through *Candida tropicalis* colonies. Moreover, *Candida krusei* was preferred for pink apron and pink flowers. Grapes were made by *Candida glabrata*'s lavender and mauve colonies, while the gardener's white dress was made of *Candida parapsilosis*.[57] The "The Bacterial Shadow of the Wolf" study by Barış Halaç, Sevgin Can, M. Cemal Adıgüzel and Nilüfer Erzaim from Istanbul University Faculty of Veterinary Medicine Microbiology Department, Turkey, was selected for the first prize in the competition opened by the American Microbiology Society in 2016.[58]

Yoko Shimizu, who conducts bio-art studies in laboratory conditions, started her research on how photosynthesis can produce a work of art. She observed that chloroplasts build starch according to graphic patterns by sticking black and white transparent plastic films to cabbage seedling leaves. She then applied a chemical process on the leaves using iodine to visualize the graphics created by the photosynthesis process.[59] According to the artist, the beauty of the images created by this natural process shows that there are endless possibilities in the context of artistic designs in 'nature'. Selin Balcı and Ayşe Gül Süter conduct bio-art studies in Turkey. Selin Balcı, who combines biology with photography

[55] See: Art experiments with Hela cells; source: https://tcaproject.net/portfolio/better-dead-than-dying/, acc. on February 27, 2022.

[56] See: Zachary Copfer, *Leonardo da Vinci, Charles Darwin, Albert Einstein*, 2014, Serratia Marcescens bacteria in a 9x9 cm petri dish, http://www.sciencetothepowerofart.com/portraits, acc. on February 27, 2022.

[57] See: Joanne Dungo, *The Gardener*, 2020, CHROM Candida, Candida albicans, Candida dubliniensis, Candida tropicalis, Candida krusei, Candida glabrata, Candida parapsilosis, Chromagar in agar petri dishes, American Society for Microbiology, Washington, the USA, https://asm.org/Events/ASM-Agar-Art-Contest/Previous-Winners/2020, acc. on April 5, 2022.

[58] See: Barış Halaç, Sevgin Can, M. Cemal Adıgüzel, Nilüfer Erzaim, "The Bacterial Shadow of the Wolf," 2016, bacteria in agar petri dishes, American Society for Microbiology, Washington, USA, https://asm.org/Events/ASM-Agar-Art-Contest/Previous-Winners, acc. on February 27, 2022

[59] See: Yoko Shimizu, Vermeer's Girl with a Pearl Earring, 2020, cabbage seedling leaf, Brooklyn, New York, USA; source: https://yokoshimizu.com/portfolio_page/photosynthegraph/, acc. on February 27, 2022.

and art, works on mold fungi,[60] and Ayşe Gül Süter works on crystallization with sweat and tears. The samples examined by the author show that bio-art is an artistic practice that represents the communication established between plastic arts and biological sciences. It was observed in these studies that biological processes, bacterial environments, living tissues, genetic sciences are used as art tools instead of brushes and paints. These studies are produced both in workshops and laboratories.

As the examples illustrate, the number and quality of studies on bio-art are increasing gradually. It is noteworthy that biological knowledge and the way the artist learns about "nature" have changed. Besides, paradigmatic transformations in art have also begun to direct interdisciplinary developments and innovative technologies.

This productive relationship between the natural sciences and the arts reveals new and different ways of looking at the environment. In this case, new fields in which nature is handled in art emerge. Artistic language will make it easier to understand the working principles of nature and science.

Discussion and Conclusion

It is necessary to include the discourses of the artists who produce works in this field to understand the reasons behind artists' works on bio-art and understand what is meant by these works of art. Selin Balcı, who defines herself as an interdisciplinary artist, stated that she produces bio-art works by growing, changing, and dying to preserve and document all organisms living on earth and create a synthetic world and a historical record of living things over a certain period.[61] Artist Ayşe Gül Süter, referring to her inspiration as the plants and sea animals she observes with a microscope, explains her purpose as opening the doors of people's perception and showing the beauty and diversity of life in "nature" with a combination of the real and the imaginary.[62]

Artist Ani Liu says that the task of designers and artists is to raise critical issues.[63] Moreover, she states that new technological and scientific tools are accessible today and offer unique opportunities for artists. Another argument was that synthetic biology, which is one of these tools, shapes the concepts about the meaning of being human and leads to the definition of biology as an art and design problem. The author also emphasized that the roles of artists, designers, scientists, and businesspeople can be discussed in the laboratories where these developments are experienced.

Several companies, laboratories, and museums cooperate and support the production of bio-art works that combine science and art.[64] Yoko Shimizu, who works as

[60] See: Selin Balcı, Earth I, 2019, Epoxy coated mold Diptik on the board, each 35.5 x 27.5 cm, https://www.artnivo.com/magaza/kimdir/selin-balci/, acc. on April 5, 2022.

[61] "Selin Balci," https://selinbalci.com/, acc. on February 27, 2022.

[62] "Ayşe Gül Süter," https://www.pgartgallery.com/ayse-gul-suter, acc. on February 27, 2022.

[63] Ani Liu, "Smelfies, and other experiments in synthetic biology," https://www.ted.com/talks/ani_liu_smelfies_and_other_experiments_in_synthetic_biology#t-13291, acc. on February 27, 2022.

[64] "Ars Electronica," https://ars.electronica.art/news/de/, acc. on February 27, 2022.

an artist at Ars Electronica Future Lab, one of these organizations, says that bio-art enables us to learn and explore more about "nature" and natural processes as a combination of biology and art.[65] She states that they aim to develop natural and creative technologies and to combine art technology and society with the studies conducted in this laboratory.[66]

Amy Karle also states that science and art coexist in "nature", and there is a lot to learn from "nature". She also emphasized that artists empower themselves with new technological and biological tools, and they also contribute to the development of technology and science.[67]

One of the reasons why artists train life forms by learning scientific techniques and processes is to discover works of art that work aesthetically and think about the value of "nature". Microorganism developmental processes such as photosynthesis, growth process, movement, energy, and natural life processes such as scientific and technological developments as an art process and product show that art perspectives have changed and can therefore be interpreted as a paradigm shift. Furthermore, bio-art applications contribute to science and art in the context of new questions and technologies and inform the masses/society by critically looking at biotechnological applications and developments.

Yetisen et al. also state that bio-artists develop interdisciplinary relationships that blur the distinctions between art and science.[68] Moreover, the authors state that biotechnology can produce artistic responses, initiate new science and engineering concepts, encourage cooperation, and contribute to the development of scientific literacy. On the other hand, Pentecost emphasizes that the artist who aims to make an impact on the use of science and related biotechnologies must creatively reshape both scientific and artistic practice.[69]

As a result, bio-art, which offers new methods in the art, is vital in developing new methods for scientific research. It also leads to new developments while presenting the artistic products of the artists with scientific methods. The paradigmatic changes in observing and addressing "nature" indicate that philosophical discourses, the zeitgeist, scientific and technological developments led to different perspectives in the field of art and others.

Thus, this study discussed the effect of "nature" on art through examples. The examined examples revealed that the interaction between art and "nature" has increased and evolved to an unprecedented dimension with developing science and

[65] "Integration of Art and Science," https://www.tedxtokyo.com/tedxtokyo_talk/integration-of-art-and-science/, acc. on February 27, 2022.

[66] "Inside Futurelab – BioArt," https://www.youtube.com/watch?v=vBXvVOf-mrs, acc. on February 27, 2022.

[67] "Amy Karle Visualizes Internal Experiences through Bioart – Brought to you by Hyundai," https://www.youtube.com/watch?v=UYOXnBYdTIY, acc. on February 27, 2022.

[68] Yetisen et al., "Bioart."

[69] Claire Pentecost, "Outfitting the Laboratory of the Symbolic: Toward a Critical Inventory of Bioart," in *Tactical Biopolitics: Art, Activism, and Technoscience*, ed. by Beatriz da Costa and Kavita Philip (Cambridge, Massachusetts: Massachusetts Institute of Technology, 2008), 110–124.

technology. The scientific developments blurred the boundaries of art with disciplines such as microbiology, genetics, and biotechnology, bringing new mechanisms, techniques, materials, and methods. The faculties in producing the work of art with living objects in laboratories facilitated new perceptions, thoughts, feelings.

Art did not remain indifferent to environmental problems and encouraged people to think and produce about these issues. Subjects, concepts, techniques, and materials were selected from "nature" in art and architecture with the awareness of protecting the environment that has started to rise since the 1960s, and even "nature" itself was used as an artistic production technique. This changes with the artist's use of scientific and technological facilities for artistic products or predictions of "nature", science, and technology.

In addition to these, the artist no longer criticizes only the bad aspects that scientific methods cause or cause on living things. The artist creates different artistic products by exploring nature and natural processes using scientific methods. Thanks to the developing science and technology tools, his art will lead science.

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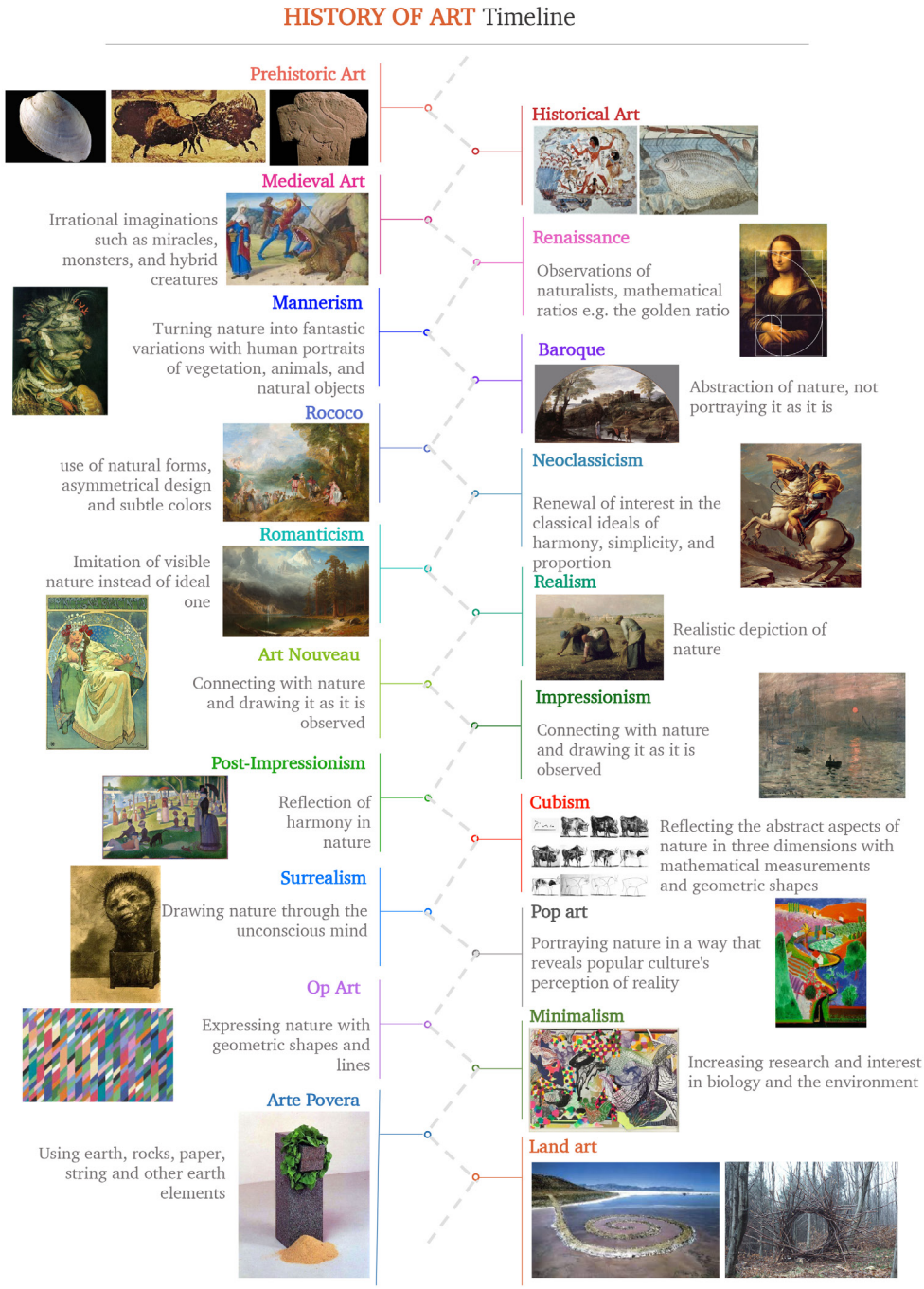

Table 1: The Historical Journey of Art (prepared by the authors)

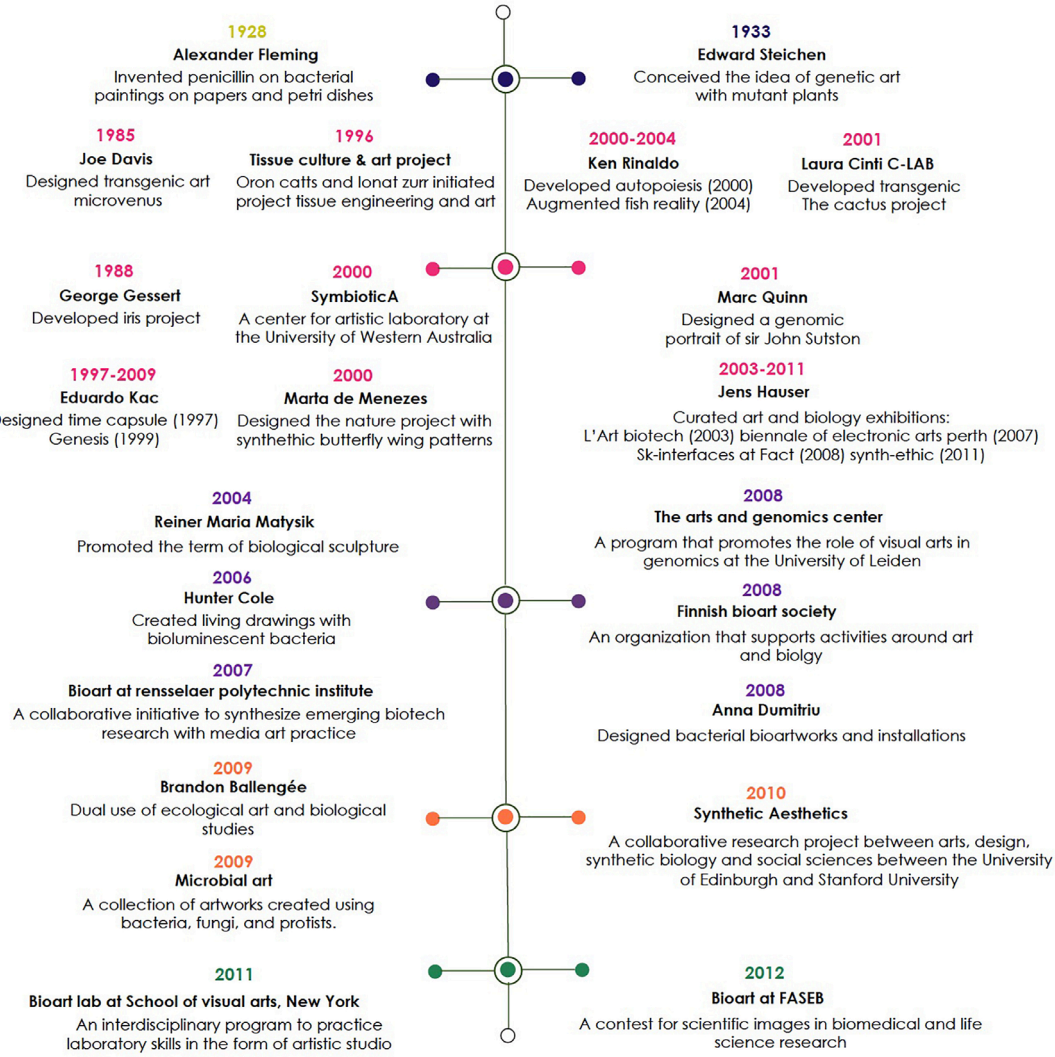

Figure 1: Pioneering programs and initiatives at the intersection of biology and arts; cited from the journal article: Ali K. Yetisen, Joe Davis, Ahmet F. Coskun, George M. Church, and Seok Hyun Yun, "Figure 1. Pioneers, Programs, and Initiatives at the Intersection of Biology and Art," in "Bioart," *Trends in Biotechnology* 33, 12 (2015): 725.

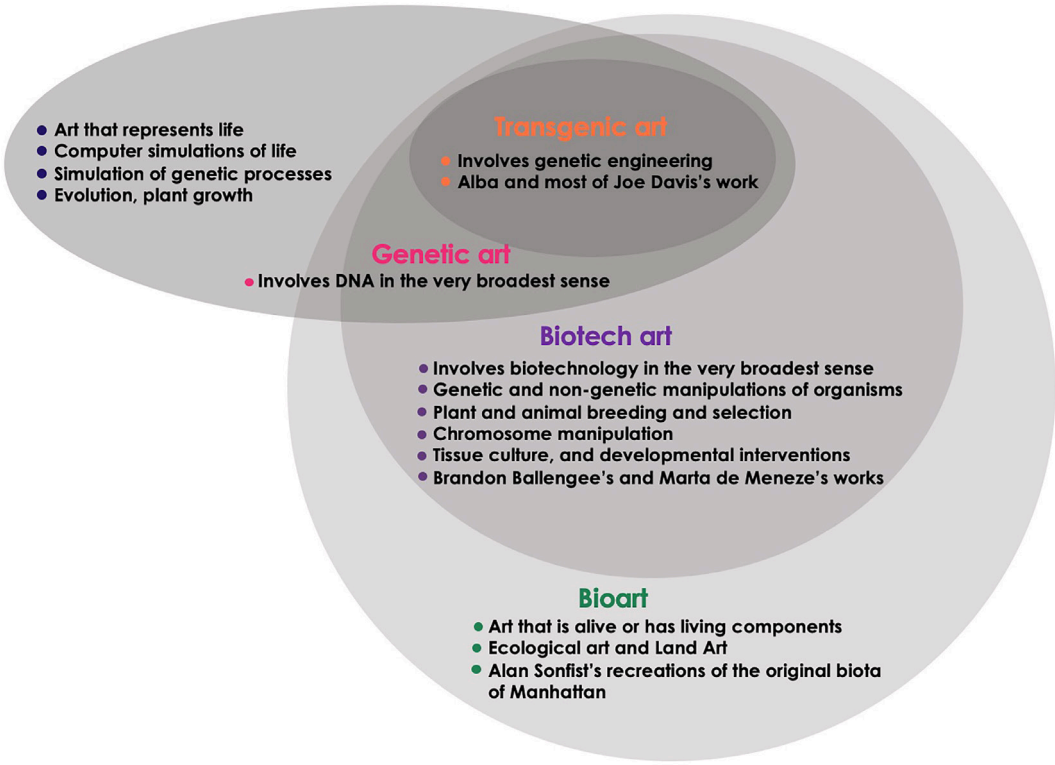

Figure 2: Cited from: Pier Luigi Capucci, "The double division of the living,"[70] 2008. Source NOEMA, technologies and society https://noemalab.eu/ideas/essay/the-double-division-of-the-living/, acc. on February 27, 2022.

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