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Biodiseño: el proyecto que educa a la naturaleza

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Abstract: The paper explores the field of biodesign by demonstrating, through a review of the scientific literature and the illustration of design research experiments developed by the authors, how design can design hybrid artefacts by instructing nature in the direction of design thinking. We will investigate the possibility of apply critical design thinking to the pursuit of people's well-being, increasingly compromised by technological and hyper-connected stress, by proposing new products and rituals based on biology and its cooperation with the human. Specifically will be illustrated a project that proposes a reinterpretation of the use of the symbolism of shapes and colours of the ancient Etruscan peoples through an experimental decoration using living nature in order to generate on a series of ceramic vessels, after numerous experiments, a new bio-ornamental chromatic aesthetic, characterised by its fractal and branched morphology.

Keywords: Biodesign - Etruscan civilization - Contemplative wellbeing - Living decoration - Inspiration from archaeology.

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Introduction

The paper describes the *Bio Ornamentum* research and experimentation project aimed at exploring the opportunities of using biodesign principles to generate a new form of living ornamentation in which design instructs nature to create patterns, designs and colour effects determined by the growth of living organisms directly on the objects.
Decorations are often made with paints and materials characterised by high environmental impact. The minimal-sustainable approach leads to mono-material artefacts, in order to avoid the separation of different materials components in the disposal phase, and to reduce decorations as much as possible to elude their environmental load. This orientation results in a drastic reduction of the expressive power of designers.
In response to this problem, the *Bio Ornamentum* project proposes a new form of experimental decoration, made by a living organism of the species known as *Physarum polycephalum*, belonging to the class of *Myxomycetes* (Martin and Alexopoulos, 1969). This new form of ornament has been applied on a series of vases of archaeologically inspired ceramic vessels evocating the archetype of design history.
The *Bio Ornamentum* project proposes a new bio-ornamental aesthetic resulting from the collaboration between designer and organism and characterised by fractal and branched morphologies.

Bio Ornamentum: biodesign as an opportunity to establish new balances between humans and nature

The integration of biology in man-made products development has its atavistic origins in the observation of nature, which could be considered an ideal master of design. Nature-inspired design is implemented in contemporary design culture in different declinations from biomimetic design that transfers nature's logic, processes and structures to design (Benyus, 2002) to biodesign that employs biology in the artefacts' production processes (Myers & Antonelli, 2012).
Nature generates, consumes, and reuses biological systems applying circular logics and processes to optimise consumption of matter and energy. This paradigm is the opposite of the human one, that devastatingly impacts on ecosystem balances, overwhelmingly imposing materials and processes that are hardly bio-compatible. Incorporating living biological systems in the creation of artefacts, to make them more tolerable by the ecosystem, is the answer that biodesign offers to contribute to SDGs achievement. In their projects, biodesigners generally employ synthetic biology techniques to manipulate living matter, included genetic manipulation, to reach properties and performance that could be appropriate to design needs. (Oxman N., 2020).
The *Bio Ornamentum* project was born within the framework of the Hybrid Design Lab, a research, teaching and design laboratory established in 2006 in the south of Italy at the Vanvitelli University and transferred to the University of Naples Federico II in 2023.

In the first phase of the research, the project was based on the investigation of a new form of bio-based decoration drawing reference from the historical-anthropological aspects of ornamental decoration throughout history. In particular, the way in which the concept of the artefact in ancient civilisations has been characterised through the archetype of the ceramic vase was investigated. Through its shapes and decorations it is possible to tell the story of different human civilisations since the origins of manufacture (Gombrich, 1984).
The investigation focused on the ancient roots of the Campania region in southern Italy, and specifically on ceramic finds from the Etruscan period in Campania. The Etruscan civilisation was indeed the most important pre-Roman Italic civilisation in terms of cultural contribution. These ceramic finds are distinctive for the sophistication of their phytomorphic decoration, based on the representation of natural elements, emblematic of the relationship between man and nature (Steingraber, 1985). This ornamentation, that could be considered as an ancient form of Italic biophilia (Koshenina, 2020), inspired the conception of a new bio-generated ornament.
In the first phase of the project, a method of bibliographic, iconographic and museum research was conducted drawing on the rich reservoir of images and artefacts traced in the Campanian Etruria museums and necropolises. These are less well known than the Greek-Roman ones, but they have a great cultural and anthropological importance too. Finds from the Pontecagnano National Archaeological Museum *Gli Etruschi di Frontiera*, the *Campania Provincial Museum* in Capua and the *Agro Nocerino Provincial Archaeological Museum* in Nocera Inferiore were analysed.
Following the most significant archaeological discoveries, since the beginning of the 20th century, the Etruscan civilization has exerted a particular fascination in artists and designers for their artefacts characterised by essential lines and simple shapes that are the basis of a unique capacity for synthesis and expressive elegance. In Etruscan artefacts, colour was extremely important as it helped to accentuate the symbolic and emblematic value of the representations. (Steingraber S., 1985).
The search for design references then turned to the ritual vases related to nature, found in the ancient Etruscan cities of Capua and Pontecagnano, characterised by black coloured fictile forms in Etruscan bucchero (Rasmussen, 2008).
The bucchero technique was developed to imitate the more expensive Greek pottery made of metal. The Etruscans succeeded in creating a unique made in Italy product, characterised by a shiny black surface, obtained by firing without oxygen. The same technique have been used by Gio Ponti in 1951 to create the *Buccheri* series of vases that clearly recall Etruscan vases. The prototypical Etruria aesthetic inspired Ettore Sottsass who created , in the early 1990s, an elegant mirror named *Etrusco* and reissued it in the early 2000s by *Glas Italia*.
The black color and the archaeologically inspired shapes of the vases are both an emblem of ancient sacredness and contemporary minimalism. An experimental approach was adopted on them with the intention of arriving at a new form of hybrid decoration performed through the designer's ability to instruct the living organism *Physarum polycephalum* to transmute into ornamentation.

Physarum polycephalum belongs to the group of *Myxomycetes*, classified under the kingdom of *Amebozoa*. Its vegetative phase is a unicellular plasmodium consisting of networks of protoplasmic veins and many nuclei. During this phase the organism seeks out food, bacteria and dead organic matter and explores the environment by forming a network of tubules (pseudopods) where cytoplasm flows back and forth circulating nutrients and chemical signals. (Adamatzky A., 2019).
It is able to perceive various stimuli at a distance and to approach them in order to reach food sources or to escape the presence of unfavourable environments, such as the presence of natural repellents, through a chemotaxis mechanism. Within the veins, the nuclei interact with each other through biochemical reactions, accumulating traces of nutritional substrates in the environment and forming a spatial and distributed memory of the interactions performed, as well as perceiving and migrating towards or away from certain chemical gradients. This particular type of memory is essential for the organism's collective intelligence that is tangible for its survival despite the absence of a nervous system. (Adamatzky A., 2019). These complex networks have great visual appeal by design, but also demonstrate the organism's ability to solve spatial problems. The growth of the network develops at a speed of more than 1 cm/h and dynamically redistributes itself according to its nutrient sources, turning into a fan-shaped morphology to ensure better adaptation to nutrient uptake. (Adamatzky A., 2019).
The decorative procedure enhances a critical experiment focused on the emergence of a new and unusual bio-ornamental aesthetic, characterised by the fractal and branched morphology of the organism (Ball, 2016). According to the biodesign approach, decoration is proposed as the result of a synergetic relationship of cooperation between human and organism.

Following the study of biological scientific articles demonstrating the ability of the organism to grow and stabilise on different material substrates, the possibility of growing the plasmodium on ceramic artefacts was explored. (Dussutour, A., Latty, T., Beekman M. and Simpson S., 2010; Adamatzky 2010).

Instructing organism to decorate objects

Experimental tests were conducted to determine how to induce the organism to travel along traces predefined by the designer in order to build decorating branches according to the predetermined design. Different types of nutrients, culture media and environmental thermo-hygrometric conditions were tested to arrive at a protocol capable of setting favorable conditions for plasmodium development.
To formulate different types of plasmodial patterns several strains of *Physarum polycephalum*, known by the name of the continent or country of origin: Japanese, American and Australian, and two unknown *myxomycete* species from France and the Philippines, were tested. The choice fell on *Physarum polycephalum*, spe-

cifically the Australian strain because of its faster growth rate, larger ramification size and extensive scientific literature confirming its safety for human health. (Stephenson, S. L., Schnittler, M. and Novozhilov, Y., 2008; Barnett, 2008).
In the first experimental phase, petri dishes with several kinds of organism-friendly culture media and strategically placed nutrient sources were used to exploit the organism's ability to branch out in the direction of food. Various oat flakes were placed according to a pre-determined pattern in order to trace a pathway that would unite individual nutrients by the organism's exploratory action through its plasmodial network. The choice of the strategic positioning of the nutrients made it possible to observe and control the motility of the organism and its decision-making process influenced by the availability of the nutrients. This experiments were also aimed to stimulate the organism's radial spread within the available space in order to plan different possibilities of decorative patterns and ways of overcoming possible growth difficulties. (Adamatzky 2010).
The experiment was conducted for 7 days and demonstrated how the organism develops a connection on the shortest possible path between two or more food sources. In fact, the plasmodium is able to perceive stimuli at a distance and approach them in order to continue growing and exploring. It also has an ability to optimise reticulations by transforming its network into simpler and more efficient branches. (Adamatzky, 2009). (Fig. 1)

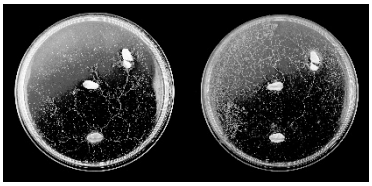

Fig. 1 *Bio Ornamentum:* Growth experiments according *to a path pre-established by the positioning of the nourishment sources.* **Time:** 10 h **Temperature:** 22° C **Humidity:** 80%. **Time:** 20 h **Temperature:** 22° C **Humidity:** 80%. (credits: Marco Fiume)

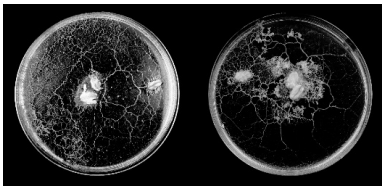

Fig. 2 *Bio Ornamentum:* Branch modification experiments *by modulating environmental parameters.* **Time:** 5 st day **Temperature:** 25° C **Humidity:** 90%. **Time:** 6 st day **Temperature:** 20° C **Humidity:** 70%. (credits: Marco Fiume)

In the following research phase the relationship between growth and environmental conditions was experimented. The tests started from the reported scientific evidence that *Physarum polycephalum* thrives at temperatures between 19° C and 25° C and when humidity levels are between 80% and 100%. It has been verified how to influence the plasmodial ramifications by modulating the main environmental parameters in order to obtain patterns with specifically designed visual characteristics.
At this stage, growth was controlled by modulating the parameters of humidity, temperature and the amount of nutrients, sometimes reaching almost extreme levels. The experiments were

carried out on several crops for 7 days. The cultures were subjected to increasing and decreasing humidity, temperature and food in order to test the direct changes on the protoplasmic veins. These experiments showed that by increasing humidity it was possible to obtain progressively wavy, undulating and dense protoplasmic veins, while when humidity decreases the organism tends to produce shorter, sparser and straighter veins. (Adamatzky, 2019). (Fig. 2) On the other hand as nutrient sources rise the plasmodium is able to generate thicker, more robust and better-defined veins that are less sensitive to environmental temperature changes. In a food shortage, instead, it pushes its exploratory range beyond its limits. Within a short time the organism is able to move quickly over medium distances in search of immediate sustenance. In this phase, the protoplasmic veins are reduced to a minimum or withdrawn completely from previous sources of nourishment, in order to concentrate energy efforts on new destinations.
After tests on petri dishes, the organism was directly grown on ceramic material demonstrating the same behaviour observed in petri dishes. (Fig. 5) To obtain the colour variations, it was fed with nutrients soaked in food pigments of different hues to visually make the veins evident on the black background of the pots. (Fig. 3, 4) (Fig. 9)

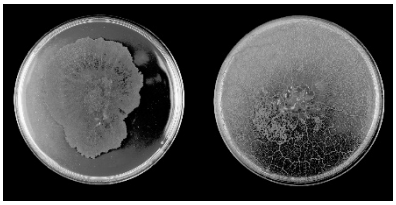

Fig. 3 *Bio Ornamentum: experiments of pink pigmentation on Physarum polycephalum using nourishment colored with food pigments.* **Time:** 1 st day **Temperature:** 24° C **Humidity:** 80%. **Time:** 2 st day **Temperature:** 24° C **Humidity:** 80%. (credits: Marco Fiume)

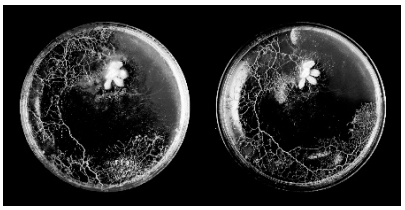

Fig. 4 *Bio Ornamentum: experiments of blue pigmentation on Physarum polycephalum using nourishment colored with food pigments.* **Time:** 3 st day **Temperature:** 24° C **Humidity:** 80%. **Time:** 4 st day **Temperature:** 24° C **Humidity:** 80%. (credits: Marco Fiume)

Fig. 5 *Bio Ornamentum: growth of Physarum polycephalum on ceramic material according to a pattern pre-established by the positioning of the nourishment sources.* **Time:** 4th day **Temperature:** 27°C **Humidity:** 78%. **Nutrition:** rolled oats **Colourant:** none **Intervention:** nutrient placement. (credits: Marco Fiume)

A theca-incubator including a humidifier and an air heater was designed to manage the humidity and temperature ambient conditions in order to allow the organism to continue growing and decorating in any place. (Fig. 6) In the controlled-atmosphere incubator, the pots are kept like archaeological relics and require periodic care to keep the decorative motifs that adorn their surfaces alive. (Fig. 7) The innovative living decoration is physically and visually altered over time by both environmental stimuli and symbiotic relationship with the designer, who is able to manage the food location and the growing parameters to orient and modulate the decoration according to his design thought. (Fig. 8) At this point, two different sales opportunities have been hypothesised. In the first scenario, the plasmodium is stabilised with coagulant fixatives based on ethanol and acetic acid to stabilize the branches in their decorative morphology. In this case the vase can be purchased and used like any other vase.
In the second option the pots are sold together with their theca-incubator so that user is given the task of looking after the decoration. There is a transfer of responsibility from the designer to the user, with a conceptually great significance. The paradigm in which the generative process concludes at the end of production is reversed. The user has the opportunity to continue the decorative process of his or her own vase by personalising it and associating a contemplative experience to the care.

Fig. 6 *Bio Ornamentum: first yellow living decoration of Physarum polycephalum on ceramic vases, obtained by controlling its ramifications by modulating environmental parameters and positioning of nourishment sources.***Time:** 9th day **Temperature:** 27°C **Humidity:** 78%. **Nutrition:** rolled oats **Colourant:** none **Intervention:** none. (credits: Marco Fiume)

Fig. 7 *Bio Ornamentum: first colored living decoration of Physarum polycephalum on ceramic vases, obtained by controlling the ramifications by modulating the environmental parameters and the positioning of colored nourishment with food pigments.* **Time:** 12th day **Temperature:** 27°C **Humidity:** 78%. **Nutrition:** rolled oats **Colourant:** food pink and blue **Intervention:** Placement of nutrients soaked in food pigments. (credits: Marco Fiume)

Fig. 8 *Bio Ornamentum: first colored living decoration of Physarum polycephalum on ceramic vases of Etruscan inspiration.* (credits: Marco Fiume)

Fig. 9 *Bio Ornamentum: detail of the living blue and pink decorative patterns of Physarum polycephalum, obtained on black ceramic vases* by modulating the environmental parameters and the positioning of colored nourishment with food pigments. (credits: Marco Fiume)

Biophilia and well-being

The use of natural forms and structures in artefacts broadens the expressive possibilities of designers by offering a lexicon based on morphologies, tessellations, symmetries, but also discontinuities and inhomogeneities that the human eye recognises as akin to its own biological matrix.

The concept of *Biophilia*, coined by Edward O. Wilson in 1984 (Kellert, Wilson, 1995), describes the innate tendency of humans to feel an emotional correspondence to other natural systems. Other authors from different disciplines ranging from neuroscience, psychology to ecology, such as Orians and Heerwagen (1992), Mealey and Theis (1995), Rolston (2002), Kawabata and Zeki (2004), Ryan et al. (2014), and Hettinger (2017) have studied the primordial human mind instinct to favour natural forms that can be correlated with elements that are not dangerous for the survival such as shelter or food. The eye, and therefore the human brain, recognises organic forms and activates feelings of well-being and serenity (Browning, Ryan, Clancy, 2014).

In the *Bio Ornamentum* project, ornamentation acquires a functionality that lies in its contemplative attitude. From the concept of biophilic design (Kellert & Calabrese, 2015) comes the idea of transforming the vase into an analogical device for meditation and mindfulness. The contemplation of vase, and specifically of fractal morphologies derived from the growth of the organism (Ball, 2016), becomes a relaxation-oriented meditation experience. A kind of visual rehabilitation particularly suitable for people that is increasingly compromised by the stress induced due to prolonged use of digital screens.

The conditions are thus created for a new contemplative aesthetic ritual linked to the decoration of the object and based on the simple action of observing natural details while taking pleasure in them Chatterjee, 2004; Chatterjee & Vartanian, 2016).

A ritual based on the model of visual connection with nature, a scientifically proven model that helps the individual shift visual and mental attention to the natural object to relax the eye muscles and temper cognitive fatigue and psycho-physical stress (Leder & Nadal, 2014; Liu, Lughofer, Zeng, Li, 2018; Louv, 2012).

In this model, it is important to favour real nature over simulated nature and to prioritise biodiversity over surface area or quantity of natural elements. The plasmoid branches fractal patterns naturally stimulate visual and tactile interest. They offer a visual experience of naturally ordered richness and complexity (Browning, Ryan, Clancy, 2014). (Fig. 10)

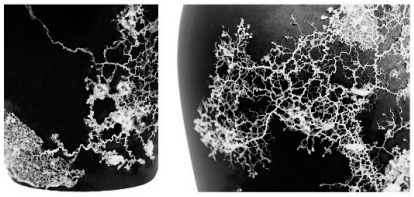

Fig. 10 *Bio Ornamentum: detail of the pink decorative motif obtained from the controlled growth of the branches of Physarum polycephalum on the main vase* by modulating the environmental parameters and the positioning of colored nourishment with food pigments. (credits: Marco Fiume)

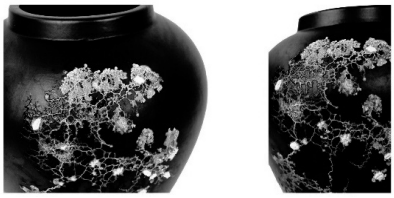

Fig. 11 *Bio Ornamentum: detail of the blue decorative motif obtained from the controlled growth of the branches of Physarum polycephalum on the smaller vase* by modulating the environmental parameters and the positioning of colored nourishment with food pigments. (credits: Marco Fiume)

Colour is enhanced by black ceramics inspired by the archetypal shapes of ritual vessels found in the ancient Etruscan cities of Capua and Pontecagnano. (Fig. 11)

The project was aimed to bring the ancient and the contemporary through a conceptual and symbolic dialogue. Just as the use of vases in the past was connected to gifts and libations offers to the Earth and deities, (Frazer, 1922) the evocation of this animist vision generates the conception of a new contemplative aesthetic rite that re-links the sacred archetype of the vase to nature.

Conclusions

Bio Ornamentum proposes an action of renewal, through biodesign, of a form of manufacture that is thousands of years old: the vase decorated with organic motifs. The elaboration of

a natural decoration occurs through a living organism that constantly changes its colour and morphology, embodying and reworking the instances of a historical debate of ancient origin. The density of the organism can be controlled in the way it grows, providing a layering effect that increases or decreases the quantity and quality of ramifications according to the quality of moisture, nutrition and temperature. The ramifications can follow a multitude of scenarios, evolving and evoking dynamic experiences in which the visual experience enhances the emotional state of the user, enriching it in terms of health and biophilic well-being (Ulrich, 2008) . In this scenario, by manipulating the environmental and growing parameters, human interact and exchange information with the plasmodium. The ancient inspired black ceramic enhances the decorative morphology of the ornament while human and organism work together to enhance and nurture the generated aesthetics, gaining knowledge and experience from each other. This new living decoration concept is not only due to the performance of the organism but also to the experience of user and actions inherited from the past. The proposed process reworks, in a contemporary key, that animist conception of biophilic veneration pursued through votive offerings addressed to nature by the Etruscans as well as by all the populations of Mediterranean antiquity. Through the decorative motif, that is the result of biological materiality and constant human dedication, the interactions between two different biological species has been translated into a more direct relationship. The artefact and the creative action become unfinished processes, where the user has the opportunity to participate in the creation and personalization of his or her own environment and wellbeing. The proposed outcome is suitable to be applied to a small art and design production dimension of unique pieces or limited series. Nevertheless, this vision can scale up, by means of specific professionalism and expertise and more sophisticated technological equipment, to be applied into small and medium-sized industrial companies.

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Resumen: El artículo explora el campo del biodiseño demostrando, a través de una revisión de la literatura científica y la ilustración de los experimentos de investigación de diseño desarrollados por los autores, cómo el diseño puede diseñar artefactos híbridos instruyendo a la naturaleza en la dirección del pensamiento de diseño. Investigaremos la posibilidad de aplicar el pensamiento crítico de diseño a la búsqueda del bienestar de las personas, cada vez más comprometidas por el estrés tecnológico e hiperconectado, proponiendo nuevos productos y rituales basados en la biología y su cooperación con lo humano. En concreto se ilustrará un proyecto que propone una reinterpretación del uso de la simbología de formas y colores de los antiguos pueblos etruscos a través de una decoración experimental utilizando la naturaleza viva para generar sobre una serie de vasijas de cerámica, tras numerosos experimentos, una nueva bio - Estética cromática ornamental, caracterizada por su morfología fractal y ramificada.

Palabras clave: Biodiseño - civilización etrusca - Bienestar contemplativo - decoración de vida - Inspiración de la arqueología

Resumo: O artigo explora o campo do biodesign demonstrando, por meio de uma revisão da literatura científica e da ilustração de experimentos de pesquisa em design desenvolvidos pelos autores, como o design pode projetar artefatos híbridos instruindo a natureza na direção do design thinking. Investigaremos a possibilidade de aplicar o pensamento crítico do design à busca do bem-estar das pessoas, cada vez mais comprometidas pelo estresse tecnológico e hiperconectado, propondo novos produtos e rituais baseados na biologia e sua cooperação com o humano. Especificamente será ilustrado um projeto que propõe uma reinterpretação do uso do simbolismo das formas e cores dos antigos povos etruscos através de uma decoração experimental utilizando a natureza viva de forma a gerar em uma série de vasos cerâmicos, após inúmeras experiências, uma nova bio -estética cromática ornamental, caracterizada pela sua morfologia fractal e ramificada.

Palavras-chave: Biodesign; Civilização etrusca - Bem-estar contemplativo - Decoração viva - Inspiração da arqueologia

[Las traducciones de los abstracts fueron supervisadas por su autor]
