Evolution Through Art: Biomimesis in EcoLogicStudio's *H.O.R.T.U.S.* Series

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Abstract – In recent years, biomimesis, the practice of using mechanical means to mimic biological functions found in nature, has become increasingly popular in the art world. However, due to the emergent nature of biomimetic art as a field, limited scholarship exists about it. This paper analyzes EcoLogicStudio's *H.O.R.T.U.S.* series in an attempt to expand the current scholarship in the field and to clarify biomimetic art as a whole. First the field of biomimetic art is defined. Next, each individual work in EcoLogicStudio's *H.O.R.T.U.S.* series is demonstrated to be biomimetic, and the biomimetic evolution between the artworks within the series in form, materials, and methods of achieving function is explained. Works like the *H.O.R.T.U.S.* series show the promise of a field that effectively combines multiple disciplines to create highly efficient, self-regulating works which are responsive to urban stimuli. Lastly, I propose that the H.O.R.T.U.S. series is a techno-eco manifesto in a call to action for humanity to consider the role of biomimesis in architectural and technological endeavors.

Keywords – EcoLogicStudio, biomimetic art, biomimesis, bioarchitecture, bioinspiration

INTRODUCTION

The *H.O.R.T.U.S.* series is a set of reinterpreted garden prototypes and artistically-rendered photo-bioreactors, or "apparatus[es] for growing organisms under controlled conditions" [1]. It consists of five works: *H.O.R.T.U.S.* (London, UK 2012); *H.O.R.T.U.S Paris* (Paris, FR 2013); *H.O.R.T.U.S. ZKM* (Karlsruhe, DE 2015); *H.O.R.T.U.S. Astana* (Nur-Sultan, formerly Astana, KZ 2017); and *H.O.R.T.U.S. XL* (Paris, FR 2019 and Tokyo, JP 2019). The *H.O.R.T.U.S.* series was created by Marco Poletto and Claudia Pasquero of EcoLogicStudios. This London-based architectural and urban design firm specializes in environmental design and urban self-sufficiency, integrating bio-inspired form and function [2]. Each individual work in the series presents an interactive, urban renewable energy and agriculture prototype. As architectural engineers, Poletto and Pasquero utilize *H.O.R.T.U.S.* to propose a new consciousness "dictated by human rationality" as mankind approaches alternatives in "bio-artificial intelligence" [3]. I first encountered the *H.O.R.T.U.S.* series with *H.O.R.T.U.S. XL* in Tokyo, Japan, in 2019.

In this paper, I investigate the *H.O.R.T.U.S.* series by EcoLogicStudios and their use and representation of biomimetics and evolution through the collective exhibits. I argue that not only are *H.O.R.T.U.S.*, *Paris*, *Astana*, and *XL* as individual works bio-inspired, but also that the *H.O.R.T.U.S.* series as a whole is biomimetic in that it represents an evolution in materials, form, and function. I begin with a brief definition of biomimesis and biomimetic art. Then, I investigate each individual piece within my definition of biomimetic art. Next, I argue that the *H.O.R.T.U.S.* series as a whole is biomimetic in its embodiment of evolution. Lastly, I submit that the H.O.R.T.U.S. series also represents a call to action for humanity in reminding us of our bio-identity.

BIOMIMESIS

In order to articulate the functions of *H.O.R.T.U.S.*, *Paris*, *ZKM*, *Astana*, and *XL*, I now define the key terms art, biomimesis, and biomimetic art according to my own definitions. Art is defined as the creation of work to be perceived and admired by an audience. Biomimetics is defined hereafter as the practice of using mechanical means to mimic biological functions found in nature. The word 'biomimetics' comes from the Greek prefix 'bio,' meaning life, and the root word 'mimesis' meaning imitation. The field of biomimetics is emergent and is still considered "in its infancy" [4]. It is unique in its incorporation of multiple disciplines in its attempt to identify and apply the biological functions, structures, and principles of various objects found in nature [5]. In the 3.8 billion years it is estimated that life has existed on Earth, life has evolved to create highly-adapted organisms that efficiently perform their various functions [6]. By mimicking naturally occurring phenomena, practitioners can save time and resources while still accomplishing their goals and "integrat[ing] form, material, and structure into a single process" [7]. Biomimetics has the potential to inspire textiles or designs that are antifouling, self-assembled, respond to their surrounding environments--to name some potential uses. Some examples include buildings (inspired by plants) which absorb light to create energy and moving ceilings which self-adapt their structure depending on atmospheric conditions. Such structures integrate mechanisms which do not require any maintenance [8]. These buildings could potentially save the amount of manpower and cost that come with the upkeep/ wear and

conservation of a building. This extends to the appliance systems required to host its occupants.

While biomimetics can be applied to countless fields, this paper will focus on how it applies to art. Here, biomimetic art is the integration of biological form and function into a work of art. Traditional art often mimics the form of biological life, but biomimetic art introduces the function of it as well. Biomimetic art is not meant to be a literal representation of the form and function of nature. If the function desired for biomimetic purposes derives from the form of the natural entity, the art may take a similar form to its original inspiration.

INDIVIDUAL BIOMIMETIC WORKS

H.O.R.T.U.S., shown in Figure 1, mimics the symbiotic relationship between animals and plants. When humans breathe out CO_2, photosynthetic organisms use it as energy and release oxygen in the process. In the exhibit, spectators contribute their CO_2 by breathing through a tube that directly connects to the pouches of cyanobacteria. The cyanobacteria then photosynthesize and feed the inhabitants of the room with oxygen. The function of each pod is self-contained, creating its own biosphere and mimicking a unicellular organism. However, each individual bio-pod inhabits the same general space.

FIGURE 1: *H.O.R.T.U.S.*, Architectural Association London, London, United Kingdom.

H.O.R.T.U.S. Paris (Figure 2) mimics both the form and function of a tree. Nutrients flow up from the "roots", through the "trunk", and to the "leaves". The "leaves" contain chloroplasts which in turn engage in photosynthesis, producing oxygen and fuel for the organism. *Paris* mimics this by placing nutrient fortified water in receptacles at the base of the "tree", then pumping the liquid reserves through thin tubes into the pods holding cyanobacteria. The cyanobacteria use the nutrients and the CO_2 provided by spectators to photosynthesize and emit oxygen into the room for its occupants. *Paris* is a network of interconnected pipes and pods, representing a multicellular organism.

FIGURE 2: *H.O.R.T.U.S. Paris,* Espace Fondation EDF, Paris, France

H.O.R.T.U.S. ZKM (Figure 3) shares the same tree structure with *Paris*. However, it has evolved to include an overhanging, cloud-like network for algae circulation which acts as a stabilizing structure for the pipes. It mimics the nutrient circulation within a tree's branch system.

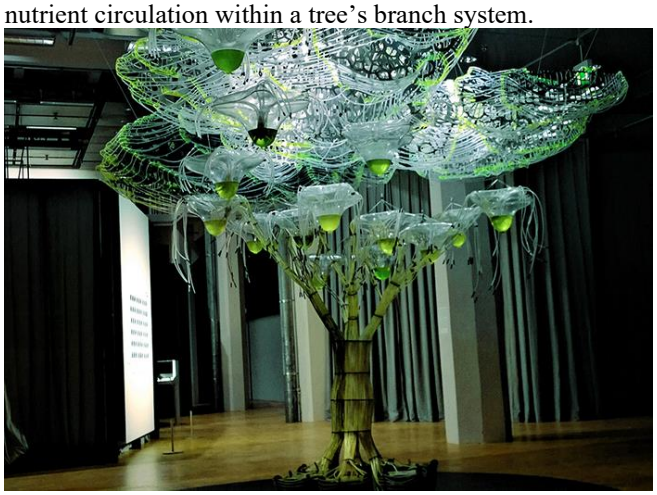

FIGURE 3: *H.O.R.T.U.S. ZKM,* ZKM museum, Karlsruhe, Germany.

The exhibit *H.O.R.T.U.S. Astana* (Figure 4) mimics the phototropism of plants. Plants respond to the surrounding environment by growing towards the direction of sunlight for maximum exposure. In this exhibit, *H.O.R.T.U.S. Astana* was configured using digital computation which allowed the artists to assess the highest energy points in the room. This enabled them to maximize the display's exposure to sunlight. This augmented feature, incorporated with the CO_2 provided by spectators through hand pumps, ensures that the cyanobacteria are able to photosynthesize with utmost efficiency.

FIGURE 4: *H.O.R.T.U.S. Astana,* Astana EXPO 2017, Nur-Sultan, Kazakhstan.

H.O.R.T.U.S. XL (Figure 5) simulates the growth of substratum in coral morphology [13]. In nature, coral is a host to cyanobacteria colonies which photosynthesize and release oxygen. In *XL*, cyanobacteria are inserted into the structure, providing maximum exposure to sunlight due to the structure's design. The cyanobacteria then photosynthesize, releasing oxygen for surrounding organisms.

FIGURE 5: *H.O.R.T.U.S. XL,* Centre Pompidou, Paris, France.

A BIOMIMETIC SERIES

Having demonstrated the biomimetic qualities of each work, I now argue that the series as a whole is biomimetic. While each individual exhibit itself is inspired and mimics organic mechanisms found in nature, the *H.O.R.T.U.S.* series as an entire whole is biomimetic in its evolution of form, materials, and the methods by which it performs its function. This biomimetic evolution is shown in FIGURE 6.

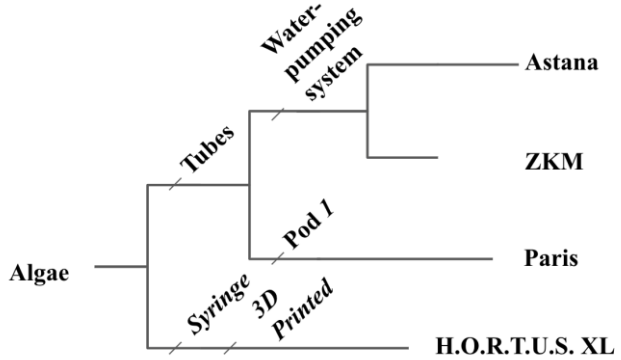

FIGURE 6: Cladogram demonstrating the evolution of the H.O.R.T.U.S.

The first stage of the *H.O.R.T.U.S.* series, *H.O.R.T.U.S.*, is an exhibit showcasing two variations of clear plastic pouches suspended individually from the ceiling. The first variation of plastic bag is similar to an IV bag, while the second is concave and shaped like an upright bellflower. These suspended bio-pods are filled with a mixture of minute algae particles in water--which give it a green or rustic hue. The pouches are hung at different heights throughout the room which allows them to "inhabit" the same space, yet each pod represents its own biosphere. In this sense, the room itself embodies the individual alga coexisting in each of the liquid pouches. Below these hanging clusters, the floor is lined with green carpet. Large rolls of the same carpet are placed throughout the room along which occupants can prop themselves against. This provides an area where visitors can lounge and congregate.

H.O.R.T.U.S. is made up of a wide range of plastic materials for different functions. This includes two types of plastic bags, thin flexible tubes, and plastic strings to suspend individual bags from the ceiling. At first, the use of plastic seems contradictory: plastic is one of the largest contributors to environmental damage. This could be an artistic statement, although the artists' intentions are not known. EcoLogicStudio collected different types of algae from lakes and ponds within Central London, establishing biological diversity within the exhibit [3]. The work also includes a digital interface for the audience to interact with.

H.O.R.T.U.S. allows for visitors to contribute their CO_2 by blowing through the thin plastic tubes and into the plastic bags [photo-bioreactors] containing cyanobacteria. Throughout the week, visitors engage daily with *H.O.R.T.U.S.*. This creates a consistent and fluctuating nutrient dosage for the algae. The cyanobacteria then photosynthesize and produce oxygen, essentially enabling a symbiotic loop with the visitors in the room. The spectators further interact with H.O.R.T.U.S. utilizing Twitter. Information in the form of tweets creates an interactive platform so individuals near and even far away can contribute to feeding the virtual pods via tweets. Its virtual plots are

nurtured by the flow of tweets posted by each visitor both locally and globally, creating new "cyber gardening practices" [15].

In *H.O.R.T.U.S. Paris*, the second stage of the *H.O.R.T.U.S.* series, several bio-pods are hung from a tree-like structure. Flexible tubes are assembled to form the roots and trunk of the tree using black plastic stabilizers to hold them together. Bellflower shaped bio-pods represent both the fruit and the leaves of the tree.

H.O.R.T.U.S. Paris retains the original prototype of hanging algae/water solution in plastic receptacles. Clear, pliable tubing suctions liquid from water tanks on the ground which lead upward and culminate into a large "tree trunk," and further out to the pods. These clear plastic receptacles-- in this instance, upturned bell-shaped pods-- are given the illusion of resting upon the upper "branches."

Materially, Paris uses only one of the two types of plastic bags previously used in *H.O.R.T.U.S.*. Unlike *H.O.R.T.U.S.*, the majority of *H.O.R.T.U.S. Paris* consists of thin, plastic tubes and aluminum which makes up the frame of the overhanging network. Smaller parts include green and black plastic segments to hold the thin tubes together. The exhibit also utilizes a pumping system and four water buckets for the flow of nutrients and algae. The cyanobacteria remain in liquid form. Furthermore, there is no longer a digital interface.

In *H.O.R.T.U.S. Paris*, visitors are still able to blow into the tubes connected to each bag to feed the cyanobacteria inside. However, this time the exhibit has changed in the method by which it achieves its outcome, which is oxygen production. In this case, the structure includes a pumping system at the base. Compared to *H.O.R.T.U.S*, *H.O.R.T.U.S Paris* is a network that integrates the tubing, cyanobacteria, and pods to mimic the shape and also function of a tree. The photo-bioreactor pumps nutrients upward to the rest of the structure, much as a root system does. *H.O.R.T.U.S.* has evolved so that the individual plastic bags [cells] come together to create a structure, and as a garden, it is now easier to distribute nutrients and CO_2 to the cyanobacteria. I submit here that this is an example of reconciling technology with nature's already acquired evolutionary wisdom.

In *H.O.R.T.U.S.* ZKM, the structure retains the tree-like base from Paris, but the form has evolved to include an overhanging structure in the shape of a cloud. The cloud is green in color-- depending on the circulation of algae--and consists of an aluminum base that is covered with a network of tubes. The overhanging cloud-like network of pipes represents the branches of the tree-- circulating nutrients.

The newest component of the *H.O.R.T.U.S.* series is suspended above the tree and the pods in ZKM: an aluminum lattice enveloped in a webbing of the same plastic piping, forming a cloud-like biomass. The plastic piping is held in place with plastic, neon-green stabilizers.

Though the method of achieving function remains the same as Paris, it is executed more efficiently by circulating the flow of algae in the overhanging structure.

The fourth exhibit in the series, *H.O.R.T.U.S. Astana*, reveals a version of the system that is an unspecified shape. Constructed of large flat sheets of laser-cut aluminum, each unique cutout is suspended within close proximity to the next layer. In effect, this creates a 3-dimensional biomass which takes on the appearance of a cloud. It has incorporated the concept of an overhanging cloud-like network from *H.O.R.T.U.S. ZKM*. However, the presentation is cleaner, and the breathing apparatus has been replaced by a black, ovoid hand pump with four fins adorning the bottom. Each pump hangs from a single, transparent tube. This gives the illusion of standing within a cavern or cave. The cyanobacteria are again mobilized through clear transparent tubes that line the edges of each horizontal aluminum plate. The cyanobacteria emit a green hue which highlights the structure's shape.

In contrast with *H.O.R.T.U.S. ZKM*, in *H.O.R.T.U.S. Astana*, the artists have eliminated the use of plastic bags. Instead of thin pipes, they utilize hand pumps hanging from the suspended structure. They have, however, kept the water pumping system. A small pump for fluid circulation, a glass container for the microalgae, and wide-spectrum lights are also integrated [16]. The structure now consists of laser-cut aluminum leaf-like sheets that are stacked to form a cloud. Each layer is lined with clear piping to create a network that carries the flow of cyanobacteria.

H.O.R.T.U.S. Astana was built by first digitally mapping the space to visualize the intensive field of energy[light sources] [16]. The cyanobacteria were then arranged along surfaces, allowing optimal incoming radiation. A network connects the pathways of tubes which carry nutrients and CO_2 to the nodes housing photosynthetic cyanobacteria. In the form of a cloud, the structure is divided into four clusters which operate as an integral unit [16]. The degree of connectedness depends on physical light. Astana again engages with the audience, this time allowing them to contribute via a hand pump.

H.O.R.T.U.S. XL, the final exhibit in the series, shows a significant transformation in form. Now, it takes the shape of a free-standing structure that is opaque and appears to resemble a coral formation. The coral-like structure is porous, 3D-printed, and composed of triangular units that make up larger hexagons for strength and support. It is much lighter but also denser in space and minimalistic compared to the previous exhibits. The 3D-printed structure, which is opaque in color, juxtaposes with the green cyanobacteria.

H.O.R.T.U.S. XL changes from Astana by replacing the plastic tubes, hand pumps, pumping system, and aluminum frame with 3-D printed plastic materials. *H.O.R.T.U.S.* no longer uses pipes or aluminum; rather, it creates a net using only one material built layer by layer. In contrast to *H.O.R.T.U.S. Astana's* liquid cyanobacteria, *H.O.R.T.U.S. XL* uses cyanobacteria in the form of a gel.

H.O.R.T.U.S. XL is a structure that simulates the growth of substratum inspired by collective coral morphologies using a digital algorithm [13]. The piece is algorithmically designed and produced using large-scale, high-resolution 3D printing technology. In order to optimally arrange the photosynthetic organisms along iso-surfaces of increased incoming radiation, the density-value of each "bio-pixel" is also digitally computed [13]. Apart from its technical makeup, the structure itself functions completely differently. Visitors can no longer pump or blow CO_2 into the structure's components. The structure is mostly hands-free, because the gel has already been inserted in each "bio-pixel." The cyanobacteria get CO_2 from the surrounding inhabitants and environment through the porous structure and, because they are in a gel form, have no need to be circulated. Instead, the cyanobacteria are inserted into the triangular units manually.

The structure simulates the growth of substratum inspired by coral morphology which gives it an organic feel, as coral reefs are home to an abundant amount of marine life. This supports the idea of future forms of spatial intelligence that will be able to function and support themselves. Like the coral it was inspired by, *H.O.R.T.U.S. XL* provides a sturdy structure that can be incorporated into various living spaces.

Together, all of these small material changes [microevolution] show a greater change [macroevolution] through the *H.O.R.T.U.S.* series. In contrast to *H.O.R.T.U.S.*, which featured three types of plastic materials and cyanobacteria in liquid form, *H.O.R.T.U.S. XL* has evolved to consist uniformly of one plastic material and a cyanobacteria gel. *H.O.R.T.U.S. XL* eliminates plastic bags, aluminum, pipes, water tanks, hand pumps; plastic tubes, and water pumping systems. The series has evolved so that the work can be built layer-by-layer to create a complex, high-performance structure using limited materials efficiently.

CONCLUSION

In this paper, I have demonstrated that though each individual work in EcoLogicStudio's *H.O.R.T.U.S.* series is biomimetic, the series itself embodies biomimicry in its evolution in form, materials, and function from piece-to-piece and overall. The *H.O.R.T.U.S.* series proposes a future of "new novel material practices"[3], emergence and practice of new fields, and the "collaborative" relationship between the natural biosphere and the artificial urbansphere [16].

Biomimietic art and architecture effectively joins different fields, new practices, and art, showing promising conceptions of future works responsive to urban stimuli. Furthermore, the emerging symbiotic relationship between the artificial and natural worlds could massively influence the future of humanity. The field of biomimetics has great potential for solutions to the global crises of the 21st century: climate change (caused by the emission of greenhouse gases), environmental pollution, sustaining growing populations, and managing earth's natural resources.

The agricultural revolutions of the past occurred through scientific and technological innovation. However, the byproduct of rapid growth is a looming concern. Farming and agriculture have used and continue to use Earth's resources too liberally. Fortunately, with the current awareness of the impact we have on our environment, organizations and individuals are making efforts to steer us from this trajectory and take advantage of this probationary moment to conserve resources and diminish the effects of climate change. Moreover, H.O.R.T.U.S. ultimately is not only a literal demonstration but an art piece, meant to inspire and help us reconsider old ways of thinking while nudging us in a hopeful direction to see the possibilities of these integrated disciplines.

H.O.R.T.U.S. XL features a vertical gardening prototype, conserving space and energy, while *H.O.R.T.U.S. Paris* and *ZKM* are fundamentally-modified hydroponic systems, and novel approaches toward sustainability. The H.O.R.T.U.S. series reminds mankind of its place in this delicate and complex biosphere. Biomimicry is a template for humanity to become more involved with the symbiotic relationship we have with the environment. We're approaching a new space where technology becomes more synthesized with biology, and humans become consolidated into the complex functions of nature.

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