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“Towards Genetic Posthuman Frontiers in Architecture & Design”

Alberto T. Estévez

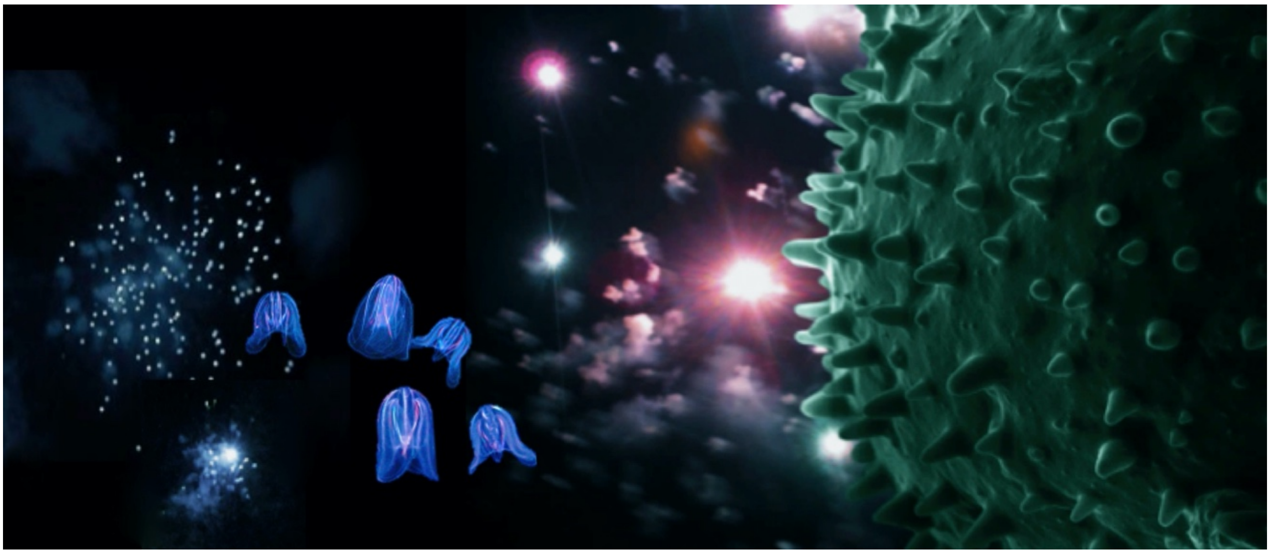

Figure 1. Alberto T. Estévez, *A Strange Alive Planet*: collage with scanning electron microscope photo of a *Malvaceae* pollen grain at 6000x, with photos of bioluminescent *Ctenophores* and fireworks (photos taken by the author).

Abstract

This paper includes a brief history about the beginning of the practical application of real genetics to architecture and design. Genetics introduces a privileged point-of-view for both biology and the digital realm, and these two are the main characters (the protagonists) in our posthuman society. With all of its positive and negative aspects, the study of genetics is becoming the cornerstone of our posthuman future precisely because it is at the intersection of both fields, nature and computation, and because it is a science that can command both of them from within—one practically and the other one theoretically. Meanwhile, through genetics and biodigital architecture and design, we are searching at the frontiers of knowledge for planetary benefit. In order to enlighten us about these issues, the hero image (Figure 1) has been created within the framework of scanning electron microscope (SEM) research on the genesic level, where masses of cells organize themselves into primigenic structures. Microscope study was carried out at the same time as the aforementioned genetic research in order to find structures and to learn typologies that could be of interest for architecture, here illustrated as an alternative landscape of the future. Behind this hero image is the laboratory’s first effort to begin the real application of genetics to architecture, thereby fighting for the sustainability of our entire planet and a better world.

Introduction

We know that the answer is in nature and that nature is the answer. The more that science advances, the more we know of what we call nature and the more we understand that nature is the answer. But, "if Nature is the answer, what was the question?" (Wagensberg 2007). We are exploring and interrogating "the question" through interdisciplinary endeavours involving fields such as material science, biology, genetics, art, architecture, civil engineering, design, computer graphics, and human-computer interaction. We are exploring posthuman frontiers. One such frontier can be explored at the intersection where genetics meets biology and the digital, and can be applied to architecture (and in other contexts, to art, civil engineering, and design). This is the intersection at which we find ourselves, and the one that this paper explores.

In order to pursue this line of inquiry, the Genetic Architectures Research Group & Office and the Biodigital Architecture Master Program was founded at the ESARQ, the School of Architecture of UIC Barcelona (Universitat Internacional de Catalunya). This is where we work to create architecture and design, with geneticists focused on architectural objectives, and architects researching the fusion of biological and digital techniques.

A bit of (genetic) history

It might now make a little sense to give a little history on the subject. Between December 1999 and January 2000, a snippet of information went viral, with the media publishing increasingly more information on it and constantly "infecting" each other. In this case, it was a story about genetics: press, radio, and television were very quickly inundated by news reports on this subject.

Then, watching how genetics offered such a huge field in the world of health and nutrition, I wondered about the application of genetics to architecture and design. For that reason, in 2000 we created the aforementioned research group and Master's degree program, and also connected it to a PhD program.

At the same time, without us knowing about it yet, Eduardo Kac was working on *Alba*, a transgenic artwork that attempted to create bioluminescence in a rabbit through the use of green fluorescent protein (GFP). As is it known, the GFP gene is widely used in genetics as a marker; an indicator that allows for easy verification of genetic transformation success. And though it is now supplied to genetic laboratories without problem, the natural source of this gene was originally a jellyfish called *Aequorea victoria*, from the Northeast Pacific, in which GFP glows in the dark. After the transformation of the cells that have been required for each case, the gene synthesizes the protein, which allows the cells to emit a bright green color when exposed to blue or black light. However, GFP is also present in hundreds of sea species, with green, orange, and red colors, as in sharks, eels, seahorses, fish, coral, etc. This discovery has recently given rise to fluo diving, night diving in fluorescent underwater marine life, as if one were floating in the Avatar movie.

One day in January of 2003, while talking with the geneticists in our group about the use of GFP in research, Dr. Miquel-Àngel Serra asked “what else can the GFP be used for other than being an indicator?” As an architect it was clear to me: “for illuminating architectural spaces!” At that moment we began research for getting trees to work as “lamps” illuminating streets, plants illuminating homes, vegetation illuminating the roadsides without electricity: the creation of plants with natural light by genetic transformation for urban and domestic use had emerged.

So, in October of 2005, thanks to our geneticist Dr. Agustí Fontarnau along with Dr. Leandro Peña, we successfully obtained the first seven lemon trees with luminescent leaves (Figure 2) provided by GFP. These modified lemon trees get their green fluorescent protein through the expression of the GFP gene. That gene was transferred to the lemon tree cells through an in vitro culture experiment using a DNA vector containing GFP genes (the DNA containing the GFP gene was not spliced; it was inserted into the lemon tree genome and kept intact inside of it). Some of the transformed cells regenerated a new plant, with cells expressing GFP, knowing that the glowing properties can be seen by microscope from the beginning of its cellular transformation. In two months, the trees were approximately 30 cm high, so that we were able to directly see the bioluminescent properties with our own eyes. We then took photos with blue light and a conventional reflex camera, or along with Dr. Josep Clotet, also from our University, taking photos with our special UV camera.

Figure 2. Alberto T. Estévez, *Genetic Barcelona Project*: The magic light of the GFP lemon trees. Center, image of a possible world (image of Casa Milà by Antoni Gaudí). Right, real comparison between a lemon tree leaf with GFP and another without GFP from the same tree type: above photo taken with conventional reflex camera, and below photo taken with special UV camera (author’s images and photos).

We started with GFP, since it is one of the most studied genes, as geneticists use it as a common cellular marker. The functionality of our project was clear: the trees in this project were made with the objective of being of architectonic and urban use. It was the first time in architectural history that geneticists had worked for an architect. In 2005, we also presented this research under the name of the *Genetic Barcelona Project* to the mayor of Barcelona. Regarding durability, the results were good: today, more than 10 years later, the leaves have the same luminescence, and the initial little lemon trees continue to grow depending on soil availability. They can also be also multiplied by planting their branches, becoming non-manufactured "lamps", for free! But from the beginning, the lightning efficiency was very poor and needed special light inputs in order to achieve enough brightness.

Through a second phase of this project, to make more efficient and useful bioluminescent vegetation, we arrived at "Biolamps" (Figure 3). In 2007, we started to research bacterial bioluminescence for urban and domestic use. We were also involved with research into how to achieve bioluminescent plants with a bacterial gene group responsible for bioluminescence at the same time.

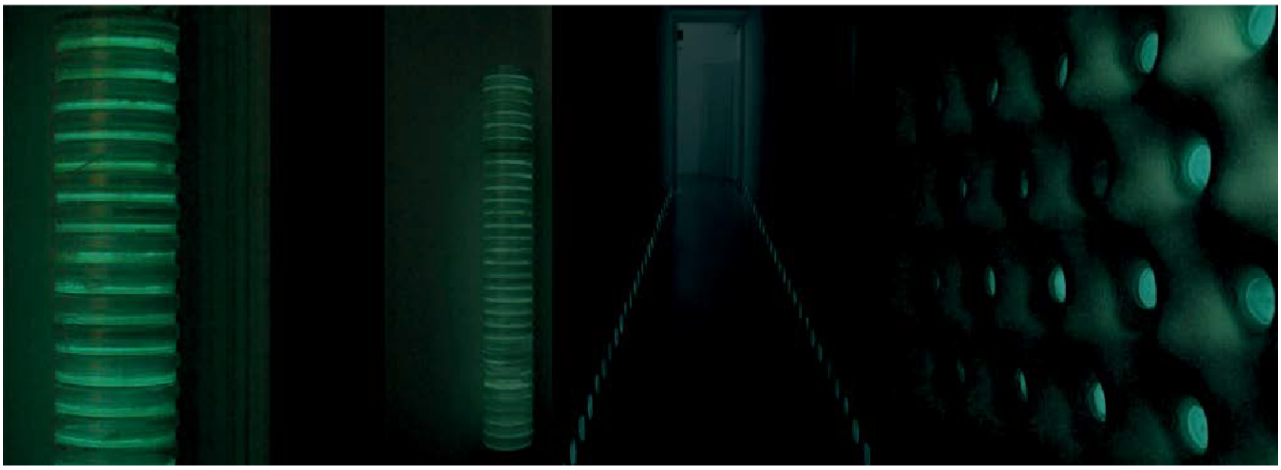

Figure 3. Alberto T. Estévez, "Biolamps": the first systematically fully illuminated apartment with living light (human eye view: photos by the author, taken with a conventional reflex camera).

In this phase, in 2008 we began to create "Biolamps," a kind of "battery" with bioluminescent bacteria that are originally found in abyssal fish. With them, we created the first fully illuminated living light apartment without electricity. For the first time in architectural history, a whole home was illuminated using bioluminescence, without any electrical installation.

Figure 4. Alberto T. Estévez - GenArqOffice, *Biodigital Lamps Series*, used as "Biolamps" digitally 3D printed.

The digital design and manufacturing of the *Biodigital Lamps Series*, and its use as "Biolamps" had also begun (Figure 4). These lamps are based on an analysis of radiolarian structures and pollen. This analysis was applied to the digital development of architecture and design, first by using an SEM, which we have used from 2008 to now. This continues along the lines established through the idea of “bio-learning,” which offers the benefits of the structural, formal, and processual efficiency that we can learn from nature. Using CAD-CAM technology, once we believe that the drawings have reached the desired result, will proceed to its digital manufacturing, directly on a scale of 1:1. In this case, we can take advantage of different parts or levels where this technology allows for interscalarity. This allows us to easily change the scale of the jewelry and lamps to that of the pavilion. Research starts by choosing a system, and a structural, architectonic, and design idea using geometry in order to draw it. Finally, in order to manufacture this, research with digital machines need to be carried out with the confidence that “what can be drawn can be built” (Figure 5 and Figure 9).

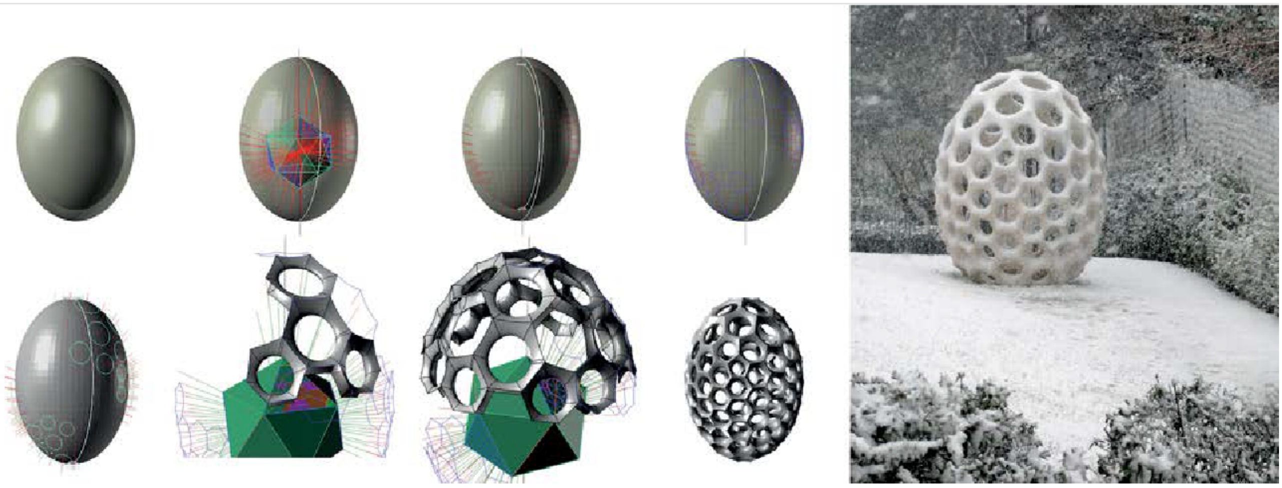

Figure 5. Alberto T. Estévez, *Biodigital Barcelona Pavilion*. Some images of the drawing process, and digitally manufactured pavilion (left: drawings with the collaboration of Daniel Wunsch; right: author’s photo of the *Biodigital Barcelona Pavilion*).

Paradoxically, unlike the GFP lemon trees, the second phase of this bioluminescence research was very effective for lighting, but problematic in terms of durability: every 10 days, the “bio-batteries” needed to be changed. The other option was fabricating a lamp that could guarantee the required air-tightness, oxygen, and food. However, it was determined that the lamp was too complicated to manufacture compared with a simple bioluminescent plant or tree.

We are now in the third phase, trying to introduce the genes responsible for bioluminescence in ornamental plants. First, we obtained two stable lines using bioballistics, with the plasmid pLDLux integrated into the genome of the *Nicotiana tabacum* W38 chloroplast, and we can assert that the expression of the bacterial operon luxCDABE is correct and stable. We have also done the same using bioballistics with different species of ornamental flowers, such as *Begonia semperflorens*, *Codariocalyx motorious*, *Mathiola incana*, and *Dianthus caryophyllus* (Figure 6). However, due to the low bioluminescence provided by the pLDLux vector (probably due to a lack of a LuxG gene whose mission is to participate in the turn-over of FMN, flavin mononucleotide), our efforts are now being focused on finalizing a vector of chloroplast transformation possessing LuxCDABEG genes. A work in progress!

Figure 6. Author's photos of the current research with different species of ornamental flowers already genetically transformed, but with too low bioluminescence.

After its presentation at various congresses and publications in 2005, 2006, 2007, etc., we can say that the diffusion of this research has been a success (Estévez 2005; Estévez 2006; Dollens and Estévez 2007). In 2010, the American "Bioglow" company took our idea for producing plants which can illuminate human spaces. Soon thereafter, in 2012, the "Glowing Plant Project" began to search for the same genes (but not without controversy). "Bioglow," led by a geneticist, has also seen this as a potentially powerful niche. Its second project, the "Glowing Plant Project," was led by a businessman who also saw this as a great business opportunity. Since then, there have even been different cases when the forgetful mass media has occasionally come out with the "amazing" news about the "novel" idea of illuminating trees illustrated using Photoshop (i.e.: Swain 2010; Rincon 2013; Brooks 2014).

Genetic posthuman frontiers

We can see the enormous potential that nature offers us in order to assure a better future for our planet. This is the path towards genetic posthuman frontiers. After fifteen years of work, a big difference remains between what we can imagine and what we can achieve, because everything depends on getting money for research.

For example, we have already explored three ways of using bioluminescence in order to drastically reduce energy consumption for night lighting and the pollution it produces. We are now at the threshold of a fourth method, which might be more effective, using bioluminescent fungi. We are preparing the identification of the responsible genes for bioluminescence of *Mycena*, *Gerronema* and *Armillaria*. A fifth possibility is researching bioluminescent yeast, which is more experimental and perhaps more spectacular.

This is thereby the beginning of a revolutionary change in the cultural posthuman understanding of light, city and architecture. This is also applicable to heat and habitat. What is at the end of the road? The satisfaction of meeting three of the most basic humans needs solved in the most natural and sustainable way: natural light, heat, and habitat, and living without consuming energy and producing pollution, fueled by the power offered by natural processes. Trees and plants offer biolight and bioheat naturally in streets and homes; there are even vegetable genes responsible for providing warmth. Imagine living biohouses consisting of trees or mushrooms with inhabitable conditions that can be purchased in malls; seeds which can be planted in the ground and grow alone; this all opens up an infinite unexplored posthuman horizon.

How can we visualize posthuman cities and future houses? As “soft and furry (hairy)” architecture, living cities, and houses (Figure 7). The city of the future will be 50% biological technology and 50% digital technology (100% biodigital). Living houses that grow alone, trees that give light at night, plants that provide warmth in the winter: a city that is more like a forest than a landscape of shipping containers on the port. After all, where do we prefer to live, in boxes or in trees? Our cities are destroying nature wherever they grow. We need to assure that every human footprint becomes a creator of life. We need to change our reality with life!

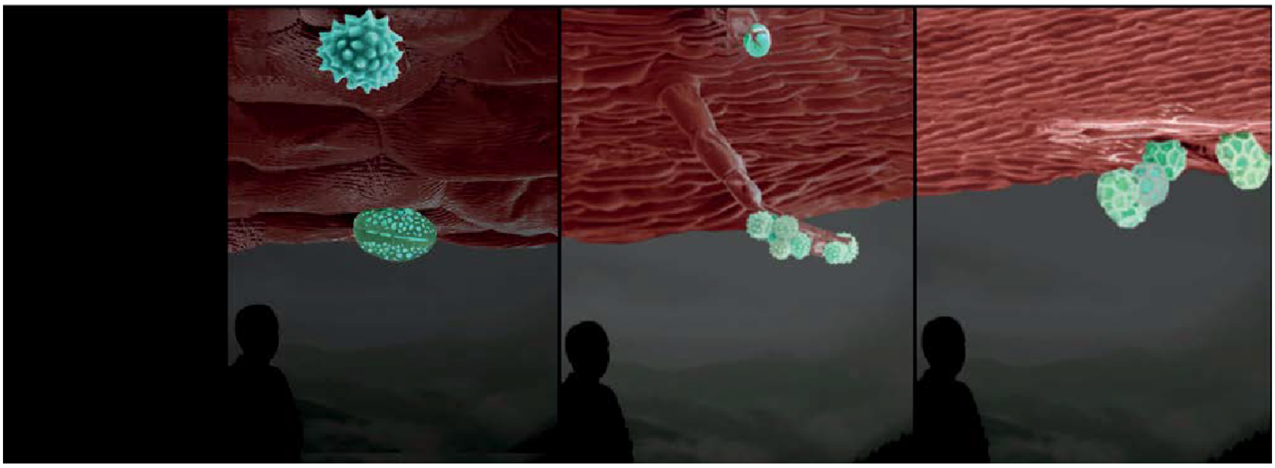

Figure 7. Author’s images of biolamps and bioceilings based on research with SEM.

(Gen)ethics

Genetic research for architecture also requires precautions, like avoiding accidents and contamination, as in conventional medical research, or in simple heart surgery. Science requires responsibility and we are establishing strict procedures for testing in hermetic environments, breeding plants without pollen, or by acting in chloroplast to avoid pollination problems. Our team includes philosophers dealing with bioethical matters, like Dr. Josep Corcó and Dr. Xavier Escribano. We hyphenate the word “gen-etics” (meaning “ethics”) in our research when the need for planetary sustainability justifies our work.

Nonetheless, from an objective point of view, there is no ethical difference between acting on “the surface of things” and acting at the intramolecular level. Once we accept the organic and fluid configuration of nature, there is, ethically speaking, not much difference between the production of a Japanese bonsai and a fluorescent rabbit. Bonsais are socially accepted even though they are the result of “tormented” living matter, while a fluorescent rabbit is not less happy than a black or white one.

What's more, the most extreme action would be eating a living being because we simply don't kill it but instead we make it disappear into our own cells. However, nobody is put in jail for eating a chicken sandwich. Since this applies to even the most extreme action—eating—it automatically follows that any other less drastic action is permissible, excluding ill treatment.

But of course, if we work with genetic material, we must accept our responsibility as illustrated by the "domino effect" that takes place in time and space, and that has been explained using the example of a butterfly. In spatial terms, there is the "butterfly effect," where the beating of a butterfly's wings in China is said to be able to trigger a storm in US. In terms of time, we can refer the dramatic book *A Sound of Thunder* (Bradbury 1953), where a prehistoric butterfly is accidentally killed by a traveller from the future thereby changing life millions of years later.

Precisely, it's not only our actions on genetic material, but all of our actions that have a corresponding domino effect millions of years later. At least everything is part of nature, but with genetics, "a new and vast territory is removed from the realm of randomness and enters into the realm of morality. We are captives of our own competence, of our own capabilities, by which we recreate what we only wanted to represent, or we transgress the natural order that we only pretended to repair" (Rubert De Ventós 2015).

Kac's affair

Furthermore, the way Eduardo Kac explains his work should be approached in terms of ethics. He defined Transgenic art as "a new art form based on the use of genetic engineering techniques to transfer synthetic genes to an organism or to transfer natural genetic material from one species into another, to create unique living beings" (Kac 1998). The only wrong and confusing aspect of this definition is the word "unique," like when he claims to be some kind of God-Creator and oversteps the definitions that humans have agreed on. This transgression does not do science any favours. The account that he likes to offer in public (like the following excerpt from an interview) does more harm than good:

Kac: "it took—seven years!—of work on the Edunia petunia before I managed to introduce my own DNA into it. [...] I put my DNA into its 'veins,' and now it is producing my human proteins. The green phosphorescent rabbit and the "plantimal" aren't nature... I created them! [...] With Alba (2000) and the plantimal Edunia (2003), I also relieve God of his status as a creator-myth and turn him into a lab worker, a technician working in a transgenic workshop."

Amiguet: "You don't seem very humble."

Kac: "I don't copy reality: I create it" (Amiguet and Kac 2012).

It has a negative effect that somebody with a strong presence in the media speaks without any scientific accuracy, and demonstrates terminological and ideological confusion. In addition, the necessary clarifications and criticisms below are not arguments taken from the authors' subjective point of view, because they have a background that is substantiated by the previously mentioned scientists, geneticists, and philosophers in our research group:

It is not true that he spent seven years on this project, it simply took seven years to happen.

It is not true that he inserted his DNA into the plant, it was more like having a "microbrick" inserted into an enormous set of many thousands of "microbricks." In any case, this "microbrick" is identical to the ones that we all have and it is not in any sense specifically or uniquely "his."

It is not true that the resulting plant produces "his" human proteins. Rather, it produces human proteins that are chemically identical to those of any human.

It is not true that by inserting a gene taken from an animal into a plant, it becomes a "plantimal." Just like a virus can mutate our cell's DNA and cause a tumour, this does not make us a "humanirus."

It is not true that the rabbit and the plant in question "are not nature."

It is not true that he created this rabbit and this plant.

It is not true that he relieves God of his status as a creator-myth and turns him into a lab worker, a technician in a transgenic workshop, because the definition of "God" includes he who "creates from nothingness." Genetic manipulation simply involves repositioning existing "microbricks."

It is not true that he "creates reality," because the gene that he integrates into an enormous pre-existing genetic structure already existed before. Therefore, he doesn't create a single gene, he simply changes its position.

Basically, by inserting a gene from another being into the rabbit and the plant, these did not cease to be "natural," nor did they cease to be nature. This gene "repositioning" has been carried out anonymously by the pharmaceutical and agricultural food industries long before Kac's projects, with more complexity and implications, and on a large scale.

Deconstructing nature

However, this emergent character of life is what humanity has to take advantage of, and this is why we are interested in investigating how genetics can be applied to architecture. The idea is to take advantage of nature's capacity for self-organization, growth, and reproducibility "for free." Therefore, we look for plants that emit light or heat and will help find the energy-saving mechanisms that our world needs, and that will be usable as construction materials and even as entire habitats. We can begin to imagine, in a not so distant reality, "streetlights," "heaters," and even entire houses that grow on their own.

Given that this research also focuses on the use of genetics, we can also consider possible architectural uses at the level at which undefined cellular masses emerge and self-organise, as the first structural step. We can study this with an SEM, which has an extremely high resolution, allowing to us see images magnified thousands of times. This opens up a little-known dimension of reality, which, depending on how the images are read or interpreted, can lead to a fascinating level of surreality (Figure 8). As a result of research carried out in this framework, it was possible to create strange and surprising new images: "altered" photographs of natural structures at their most Genesis-like and primitive level. Artistic works and architectural plans based on biotechnological work that have an enigmatic evocative power.

Figure 8. Alberto T. Estévez, *Living city*: the enigmatic evocative power of SEM images.

Conclusion

To conclude, describing the future development of our work and providing a reasonable projection of the research into future applications, it can be said that the equilibrium of our planet—for our own survival—needs several things: accurate and precise reset of our behaviour, education, basic habits, food, ability to manage waste, and consumer goods. For example, we have to get used to the idea that we don't need so much light at night (our eyes have a wide range capacity that we don't use), just as we put on a sweater if it is cold.

Consumption of energy must be radically reduced: a middle-sized European city of only 100 km2 spends 10 million Euros annually just on the maintenance of its street lights (new lamps, repairs, repainting), in addition to electricity consumption. If multiplied by all the cities on the five continents, the figure is absolutely astronomical. Therefore, bioluminescence will substitute artificial lighting, at some levels—there is no doubt about that. Nature is always teaching us, in this case with in many bioluminescent ways, from bacteria and plankton to algae, fungi, insects, etc. It would be like suicide for the next generations if we didn't learn about it.

And this is only a fraction of the possible scope of the application of genetics for architecture and design. When architects stop needing conventional construction industries and start working with geneticists, who are the bricklayers of the posthuman future, we may begin moving towards science, architecture, and design collaborations where genetics becomes integral to architectural research and production, with infinite possibilities.

The research into the architectural application of cutting edge biological and digital techniques—with the benefits that come from the inclusion of genetics, like efficiency, economy, renew- able use, and self-replication—is crucial, relevant, and urgent: it must be pursued before it is too late for our planet, which has reached the limits of its sustainability. “We have, because human, an inalienable prerogative of responsibility which we cannot devolve.” (Sherrington 1940).

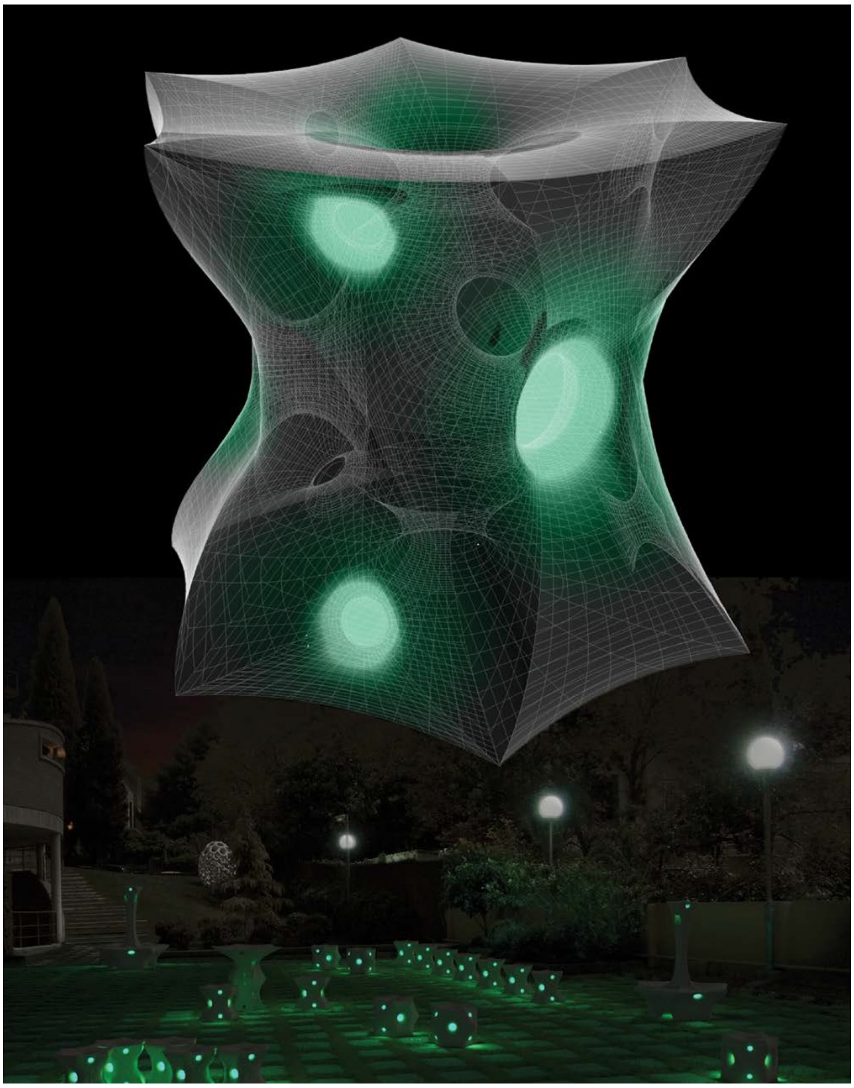

Figure 9. Alberto T. Estévez, *Biodigital Furniture Series*, with the application of “Biolamps”, digitally designed for digital manufacturing.

Acknowledgements

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References

Amiguet, Lluís and Eduardo Kac. 2012. "Eduardo Kac, creador del conejo fosforescente." *La Vanguardia*, February 4. 64 (obc). Also at http://www. lavanguardia.com/lacontra/20120204/54248805338/eduardo-kac-el- perro-es-una-tecnologia.html

Bradbury, Ray. 1953. "A Sound of Thunder." In *The Golden Apples of the Sun*, Ray Bradbury. New York: Doubleday & Company.

Brooks, Katherine. 2014. "In The Not So Distant Future, Glow-In-The- Dark Trees Could Replace Street Lights." *Huffington Post*, March 30. http:// www.huffingtonpost.com/2014/03/30/daan-roosegaarde_n_5044578. html

Estévez, Alberto T. 2005. "Genetic Barcelona Project." *Metalocus* 17: 162–165.

———. 2006. "Genetic Barcelona Project: Cultural and lighting implications". In *Urban Nightscape 2006, Proceedings of the International Commission on Illumination*. Athens: CIE. 86–88.

———. 2007. "The Genetic Creation of Bioluminescent Plants for Urban and Domestic Use." Translated by Dennis Dollens. *Leonardo* 40 (1): 18, 46.

Kac, Eduardo. December 1998. "Transgenic Art." Originally published in *Leonardo Electronic Almanac*, 6 (11). Cambridge, MA: MIT Press. Also at http://www.ekac.org/transgenic.html

Rincon, Paul. 2013. "The Light Fantastic: Harnessing Nature's Glow." *BBC News*, January 24. http://www.bbc.com/news/ science-environment-21144766

Rubert De Ventós, Xavier. 2015. In *¿Humanos o posthumanos?: Singularidad tecnológica y mejoramiento humano*, edited by Albert Cortina and Miquel-Àngel Serra. Barcelona: Fragmenta. 257–261, 161–165.

Sherrington, Charles. 1940. *Man on his Nature*. Cambridge: Cambridge University Press.

Swain, Frank. 2010. "Glowing Trees Could Light Up City Streets." *New Scientist*, November 24. https://www.newscientist.com/article/ mg20827885.000-glowing-trees-could-light-up-city-streets/

Wagensberg, Jorge. 2008 (2002). *Si la naturaleza es la respuesta, ¿cuál era la pregunta?* Barcelona: Tusquets.