Aisthesis

Firenze University Press
www.fupress.com/aisthesis

OPEN ACCESS

Citation: A. Borsari (2017) Human mimicry and Imitation: the case of Biomimetics. *Aisthesis* 1(1): 51-61. doi: 10.13128/Aisthesis-20903

Received: December 15, 2016

Accepted: April 15, 2017

Published: July 11, 2017

Data Availability Statement: All relevant data are within the paper and its Supporting Information files.

Competing Interests: The authors have declared that no competing interests exist.

Human mimicry and Imitation: the case of Biomimetics

Andrea Borsari
(Università di Bologna)
a.borsari@unibo.it

Abstract. Defining biomimetics (§ 1) as the imitation of models, systems and elements of nature for the purpose to solve human complex problems, the essay considers (§ 2) some examples of that activity, like display technologies, and nanoscientific innovations. According to the literature on the subject, the further section of the article (§ 3) examines the possibility of giving a conceptual framework for biomimetic processes, starting from the observation of its current insufficient development both on the logical level and on a wider philosophical one. The fourth section (§ 4) discusses the way through which an approach oriented to philosophical anthropology and recent perspectives on imitation can help us to understand this kind of phenomena at the intersection of human and (non-human) animal fields. In the final sections (§ 5), the text discusses the consequences of the biomimicry approach in the specific case of architecture and tries to draw some conclusions on the way an anthropology and an aesthetics of human mimicry and imitation can be re-shaped including biomimetics among their assumptions.

Key words. Biomimetics, mimicry, imitation, bioinspired design and architecture, aesthetics and philosophical anthropology.

1. INTRODUCTION: BIOMIMETICS, BIOMIMICRY, BIONICS

Recent works in natural sciences and technologies have obtained a wide range of results connected to the field of biomimetics or biomimicry, and produced an amount of artifacts such as bio-inspired devices, materials and, in general, ways to solve human problems. Defining biomimetics (§ 1) as the imitation of models, systems and elements of nature for the purpose to solve such complex problems, the following essay will consider (§ 2) some examples of that activity, like display technologies (ex. morpho butterfly and structural coloration), robotics (ex. geckos feet and their ability for adhesive reversal), and nanoscientific innovations (ex. nanowires, nanotubes and quantum dots). According to the literature on the subject, the further section of the article (§ 3) examines the possibility of giving a conceptual framework for biomimetic processes, starting from the observation of its currently insufficient development both on the logical level and on a wider philosophical one. The fourth section (§ 4) discusses the way through which an approach oriented to philosophical anthropology (especially Helmuth Plessner, Arnold Gehlen, and Roger Caillois) and recent perspectives on imitation (say Susan Hurley and Nick Chater) can help us to understand this kind of phenomena at the intersection of human and (non-human) animal fields. Comparing biomimetic phenomena with theoretical issues like model and copy, imitative representation, repetition and difference, *natura naturans* and *natura naturata*, nature and culture, imitation and creativity, the argument will focus on concepts like "mimicry", "likeness", "assimilation", "incorporation", "adaptation", "identification". In the final sections (§ 5), the text discusses the consequences of the biomimicry approach in the specific case of architecture and tries to draw some conclusions on the way an anthropology and an aesthetics of human mimicry and imitation can be re-shaped including biomimetics among their assumptions.

As Jeanine Benuys announced in her seminal work on biomimetics, the main goal of this new discipline is to explore all the new chances to solve human problems inspired by the ways evolution has found out to cope with problems similar to them. That is why, she opens her book explaining to the reader that:

In these pages, you'll meet men and women who are exploring nature's masterpieces – photosynthesis, self-assembly, natural selection, self-sustaining ecosystems, eyes and ears and skin and shells, talking neurons, natural medicine, and more – and then copying these designs and manufacturing processes to solve our own problems. I call their quest biomimicry – the conscious emulation of life's genius. Innovation inspired by nature. In a society accustomed to dominating or improving nature, this respectful imitation is a radically new approach, a revolution really. Unlike the Industrial Revolution, the Biomimicry Revolution introduces an era based not on what we can extract from nature, but on what we can learn from her (Benuys [2002]: 2).

Beyond the revolutionary emphasis of the co-founder of the Biomimicry Institute, the assumption that «life on earth presents elegant solutions to many of the challenges that designers and innovators face every day» has actually produced the data base «AskNature» where to find «biological strategies, inspired ideas, and resources» relative to cope one's innovation challenges, in order to «begin to emulate the time-tested forms, processes, and systems that already thrive in balance with Earth's complex systems»[1].

The word "biomimetic" made its first appearance in Webster's Dictionary in 1974, as John M. Harkness remembers, which included the following definition:

The study of the formation, structure, or function of biologically produced substances and materials (as enzymes or silk) and biological mechanisms and processes (as protein synthesis or photosynthesis) especially for the purpose of synthesizing similar products by artificial mechanisms which mimic natural ones (Harkness 2002, see Vincent et al. 2006: 471).

Nevertheless, it happened to the polymath Otto Herbert Schmitt, who designed and built an electronic device to mimic the propagation of action potentials along nerve fibers for his doctoral research, to use the word in a title of a paper (1969) and, probably coining it, to prefer "biomimetics" (1963) to the former used "bionic", suggesting that «presumably our common interest is in examining biological phenomenology in the hope of gaining insight and inspiration for developing physical or composite bio-physical systems in the image of life» (Harkness 2002).

More than pertaining to a different meaning, the word "bionic" is mostly widespread in the lin-

[1] Homepage of the website https://asknature.org/; about the Biomimicry Institute see also https://biomimicry.org/what-is-biomimicry/ and, for a largest list of sites about biomimetics, «Sites web, projets et réseaux du biomimétisme» in Chapelle [2015]: 341-342.

guistic German world, as *Bionik*, although the current definition of the term sounds like this: «Bionics as a scientific discipline systematically deals with the technical implementation and application of constructions, procedures and development principles of biological systems. This also includes aspects of the interaction of living and non-living parts and systems, as well as the economic and technical application of biological organizational criteria» (Nachtigall [2013]: 3). It is a definition that seems to include a closer relationship with the field of engineering technology and more consistent with the approach that, in a military context, the expression had received since the sixties as «the science of systems which have some function copied from nature, or which represent characteristics of natural systems or their analogues» (Vincent *et al.* [2006]: 471). That the etymology of the word itself is disputed between a union of "bion" (unit of life) and the suffix "-ic" (like, in the manner of), hence "like life", and a portmanteau from "biology" and "electronics", stresses this inclination for technology and probably, along with the increased complexity of the term "mimesis," explains the greater propensity to use the expression "biomimetic" outside the German world and for all those areas that go beyond the strictly engineering field, such as art and architecture or the cooperation in ecosystems (see, for instance, Rovera and Michelangeli [2014], Myers [2012], Chapelle [2015]).

In current use today, you can still see a large area of overlap if not synonymy between terms such as "biomimetics", "biomimesis", "biomimicry", "bionics", "biognosis", "biologically inspired design" and similar words and phrases implying copying or adaptation or derivation from biology. All of them can describe a highly interdisciplinary field, which «involves the understanding of biological functions, structures and principles of various objects found in nature by biologists, physicists, chemists and material scientists, and the design and fabrication of various materials and devices of commercial interest by engineers, material scientists, chemists and others» (Bhushan [2009]: 1446).

2. BIOMIMETICS OR BIOINSPIRED TECHNOLOGIES

According to the idea that biomimetics means the understanding of the functions provided by objects and processes found in nature which can guide us to imitate and produce a biologically inspired design or adaptation or derivation from nature, we can summarize its main point in mimicking biology or nature. As Bharat Bhushan points out in his overview:

> *Biological materials are highly organized from the molecular to the nanoscale, microscale and macroscale, often in a hierarchical manner with intricate nanoarchitecture that ultimately makes up a myriad of different functional elements. Nature uses commonly found materials. Properties of the materials and surfaces result from a complex interplay between the surface structure and the morphology and physical and chemical properties. Many materials, surfaces and devices provide multifunctionality. Molecular-scale devices, superhydrophobicity, self-cleaning, drag reduction in fluid flow, energy conversion and conservation, high adhesion, reversible adhesion, aerodynamic lift, materials and fibres with high mechanical strength, biological self-assembly, antireflection, structural coloration, thermal insulation, self-healing and sensory-aid mechanisms are some of the examples found in nature that are of commercial interest (Bhushan [2009]: 1446, see also Nosonovsky and Bhushan [2008]).*

From the Chinese trying to make artificial silk 3000 years ago, through the many attempts to make airplane wings imitating bird wings and till the twentieth century's innovation based on the use of biology as a library of shapes for architects and designers, there is a long run prehistory and a long-term history of people who have looked to nature for inspiration, not excluding «apocryphal derivation», «urban myth», or «product of over-enthusiasm» (Vincent *et al.* [2006]: 471-474). In order to introduce a closer glance at the field, we can examine some examples on different levels of imitation: a basic one where a single product by nature is reproduced, a further step where we are mimicking more complex strategies adopted by nature, and a third level mimicking some aspect of the evolution's process itself[2].

At a *first* level, we can meet, for instance, the 'copying' of lotus. Lotus is a sacred plant in many oriental cultures. Why? Most people think that it is because its leaves stay clean even in a muddy pond. The reason is that drops of water on the leaf surface roll away and carry any dirt along with them (similar to what happens to mercury drops on a flat surface when we break our mercury thermometer).

It is the micro- and nano- structured surface of lotus leaves which minimizes the droplet's adhesion to the surface. The balance between adhesion and the droplet's surface tension (which tends to induce a spherical form) determines the shape of the droplet on the surface. If adhesion is minimal, the droplet is almost spherical – small contact angle – and rolls away collecting all the dirt on its path (the same always happens for mercury, because of its huge surface tension). If adhesion dominates, the contact angle is large.

Lotus bioinspired technology are subsequently self-cleaning surfaces obtained by structuring the surface or spraying micro- or nano-particles on the surface.

At the same level, we can quote devices inspired by geckos. Geckos can walk on smooth walls and upside-down across ceilings. They can stay attached as if they were glued, but they are not: they can attach and detach their toes for all their life. No glue, and also no suckers, which would not be easy to attach and detach. What is the trick? The fact is that their toes are covered by sub-micrometric setae and setulae, each of which is subject to a minuscule attractive force towards the surface. This force, that scientists call Van Der Waals interaction, is always present but typically negligible on the macroscopic scale. However in the case of geckos the net effect of the many many setulae is powerful and sufficient to hold the gecko's weight, and even more. What is important in order for the geckos to walk is that the grip is instantly lost when the direction of the setae is changed, with no need to exert a strong force.

Gecko bioinspired technology are special adhesives for some sort of Spiderman's gloves, or e.g. for sutures in surgery. The difficult part is finding the right materials to mimic the attach/detach trick. Early attempts by Andrej Geim (Nobel Prize 2010 for graphene) worked for a few cycles, then the setae attached with each other more than with the surface.

Another similar example of basic application concerns the amazing and vibrant blue color of Morpho butterflies, which is due to structural coloration rather than given by a pigmentation. Incident light waves are reflected at specific wavelengths to create vibrant colors due to multilayer interference, diffraction, thin film interference, and scattering properties. The scales of these butterflies consist of microstructures such as ridges, cross-ribs, ridge-lamellae, and microribs that have been shown to be responsible for coloration. They have a complex architecture on their wings – multiple layers of cuticle and air— to produce their striking blue colour by diffracting and scattering light. This structure is special: the same colour is reflected at almost all angles. The same principles behind the coloration of soap bubbles apply to butterfly wings. The color of butterfly wings is due to multiple instances of constructive interference from structures such as this. The photonic microstructure of butterfly wings can be replicated through biomorphic mineralization to yield similar properties.

Bioinspired technology connected with Morpho's wing coloration are artificial systems where color is also produced by structure rather than pigments based on toxic metals (e.g. Pb): photonic crystals.

At a further level, the idea consists of mimicking more complex strategies adopted by nature. Nature is fault tolerant. Think of our brain. If I bang on my head, some connection may break but my brain will still work … more or less. It is

[2] In the following paragraphs a series of examples will be summarized; see detailed illustrations and bibliography in Jabbari *et al.* (2014) and in *Le biomimétisme, source d'inspiration* (Chapelle [2015]: 149-282

redundancy that saves us. It is much less expensive to make many imperfect connections and use redundancy, rather than aiming at fault-less systems.

The same strategy may work in future electronics. As devices shrink down to the nanoscale where the cost of lithographic processing can become prohibitive, it may become convenient to give up on control and use cheap and less accurate processes plus redundancy. According to Moore's law, we can ascertain the empirical observation that, over the history of computing hardware, the number of transistors in a dense integrated circuit has doubled approximately every two years (Moore was the chief executive officer of Intel).

A third step in this progression can be the idea of mimicking evolution. Suppose I want to select an optimal molecule for a certain function: I can try to design the molecule as accurately as possible … but I have to know the system and the principles! Sometimes I do not know much about my system. An alternative strategy is to prepare many many molecules, just at random. Then try them, and keep the ones which work best. Then introduce random mutations on the selected ones, and try the next generation. Keep the ones which work best, and so on until you obtain the desired performance. This is how evolution works. Evolutionary strategies can be the only solution when we need to optimize without knowing much of the system at the beginning. Often the result of the evolution allows us to learn a lot about the system a posteriori.

3. A CONCEPTUAL FRAMEWORK FOR BIOMIMETICS?

If we consider the theory and practice of biomimetics, we can conclude, as Vincent does, that no general approach has been developed for biomimetics, although «a number of people are currently developing methods for searching biological literature for functional analogies to implement»:

> *We think that this is only part of the required framework. Although it is well known that design and engineering are rendered much easier with use of theory, in biomimetics, every time we need to design a new technical system we have to start afresh, trying and testing various biological systems as potential prototypes and striving to make some adapted engineered version of the biomimetic device which we are trying to create. Additionally, the transfer of a concept or mechanism from living to nonliving systems is not trivial. A simple and direct replica of the biological prototype is rarely successful, even if it is possible with current technology. Some form or procedure of interpretation or translation from biology to technology is required. More often than not, the technical abstraction is possible only because a biologist has pointed out an interesting or unusual phenomenon and has uncovered the general principles behind its functioning (e.g. the self-cleaning lotus effect). Only then does the biological principle become available outside biology for biomimetic use. The result is often unexpected (e.g. self-cleaning buildings) and the final product—in this instance, a paint containing particles— seldom resembles the biological prototype (Vincent et al. [2006]: 474).*

This situation hints the author to conclude that biomimetics is currently «empirical in its approach», and not a new way of adapting ideas from biology: «if it is to build on current successes, and to be able to serve our technological society, then it needs some sort of regularizing, best introduced as a set of common principles» (Vincent et al. [2006]: 481). The Vincent and others' proposal, assuming the practice of biomimetics as something operating across the border between living and non-living systems, whose reason for looking to nature for solutions is to enhance technical functions, leads them to seek for a logical kind of solution (Vincent et al. [2006]: 475). In this case, that means to present a logical framework that could expose some important underlying patterns, i.e. the TRIZ (the acronym of Teorija Reshenija Izobretatel'skih Zadach, loosely translated as «Theory of Inventive Problem Solving»)[3].

On the other hand, Jeanine M. Benuys, in her defense of innovation inspired by nature, defines the sphere of biomimetics as a new science («Bio-

[3] For more detail, see Vincent et al. [2006]: 474-481.

mimicry») that studies nature as a model, as a measure and as mentor. It imitates or takes inspiration from nature's models, designs and processes to solve human problems and uses an ecological standard to judge the «"rightness" of our innovation», learning from evolution what works, is appropriate and lasts. However, it should be noted, at this point, how this setting is subject to a non-obvious equivalence between human and animal processes of mimicry. By this way Benuys puts on the same level imitation by human being and mimicry (ex. viceroy butterfly that resembles the poisonous monarch butterfly) and suggests that Biomimicry «helps animals and plants blend into their surroundings, or, in the case of the viceroy and monarch, to take on the traits of a species that is better adapted to its environment». And adds: «By mimicking nature's best and brightest, we, too, have a chance to blend in and become more like what we admire» (Benuys [2002]: 295-296). But this is completely wrong, if we seek a theoretical framework for biomimetic processes, and not simply a logical operational tool, we have to turn rather to a more broadly philosophical context.

4. BIOMIMETICS AND SOME PERSPECTIVES ON MIMICRY AND IMITATION

Actually, even if we use the same word «mimicry» (or mimetics) which refers to unconscious processes of bodies' tropology working below the level of consciousness, we are facing here – on the contrary – an entirely intentional process of imitation. Mimicry can also be interpreted as applying to human being a sort of unconscious adaptation to the model mimic/model/dupe, like in the paradigm of «Human mimicry», or as luxury and uselessness, like in Roger Caillois, but it can never be understood as an intentional behavior at an animal level. When we speak – for instance – about blend in for military purposes, like in the case of camouflage, we are actually speaking of an intentional behavior, i. e. a kind of biomimetics. In fact, the two perspectives, mimicry and biomimetics, represent – by this point of view – a sort of polarity, in which they are located on opposite ends of the process of imitation.

It was Kyung-Ho Cha who reconstructed the paradigm and fortunes between Nineteenth and Twentieth Century of the «human mimicry» (*Humanmimikry*) which gives human beings a mimetic capacity similar to that of animals, especially insects[4]. By «human mimicry», he refers to a process of adaptation, with which a similarity is established with a model or with the environment and where the views on resemblance depend on the interest of the observer, for which the adaptation can be of physical or psychic type. Consequently, a human being can exert on another human being an effect similar to that of the environment on an insect (Cha [2010]: 14). On this basis, the phenomenon in which there is an assimilation between a human being and the social environment that surrounds him/her – so that he/she moves, speaks, writes, thinks and feels like his/her social environment, and finally, becomes physically alike to the people around him/her – is made equivalent to the assimilation to the natural environment of an animal. This way, the man of mimicry (*Mimikrymensch*) becomes a *homo adaptivius* par excellence. Cha's criticism focuses on this paradigm and considers it a mythology or poetic evolution and, more importantly, identifies it with a fallacy, a false inference that wrongly recognized (intentional) mimesis with mimicry. The structure of this idiosyncratic scientistic myth is revealed in two considerable aspects. The first is the assumption that the human mimicry evolves from that of insects and represents their human counterpart. Such anthropogenic representation is based on the inference that «it must necessarily be given a mimicry of human beings, since there is one of the insects». The second structural aspect consists of «a naturalistic fallacy, which leads to misunderstand (intentional) mimesis for mimetics (Cha [2010]: 16).

If the distinction between intentional imitation and mimicry is undoubtedly a gain of this criticism, however, in this perspective, the problem

[4] See Cha (2010).

of giving account to what stays below the level of consciousness in many mimetic human phenomena still remains open. The work of Roger Caillois has led the attention precisely on that, at his time, with his anti-utilitaristic «instinct of letting go» as an antidote (Caillois [2003]: 91-103)[5], albeit rightly criticized by Cha ([2010]: 83-90).

As we will also see about the biomimicry, in fact, to detect the intentional imitation, as distinguished from the animal level, does not necessarily mean to exclude a dimension of mimetic phenomena that have no direct access to the conscious level.

Anyway, coming back to biomimetics, we can observe that we are in presence here of what Helmuth Plessner calls «intentional re-making» (*Nachmachen*) which proceeds starting from an «act of distancing» (*Distanzierung*) rather than from an «act of identification», as in the other case (Plessner [1982]: 451). Although – again in plessnerian terms – we are faced with an imitation intended as «reproduction in a technical sense», in the case of bioinspired technologies, «original» and «copy» do not need to exchange, and although the process is bound to the existing model, just because they use – as we have seen – the development of biological methods, the results can differ a lot from the biological starting point. It seems so to open spaces of originality and creativity in the reproductive process, where the repetition tends to introduce a difference. In the long run of totemistic and material continuity between humans and animals, we can refer the imitation in biomimetics to the imitative representation evoked by Arnold Gehlen, as main anthropogenetic factor which objectifies terrifying elements and risks of the environment reproducing them, and making them available for the human action (Gehlen [1985])[6].

According to Plessner again, zoomorphism, the identification of humans with animals worshiped as gods, and the subsequent anthropomorphism represent the «basic stem» of the specific powers of representation, understood as the reproduction or presentation (*Darstellung*), which has developed both as a representation of the self, the «drama» (*Schauspielerei*) linked originally to the priestly function during certain ceremonies and festivities, and as a representation of something external, other and alien, through sculpture and painting. «Imitation – concludes the point Plessner – is therefore anchored in the fundamental human constitution [*menschliche Grundverfassung*]» (Plessner [1983] 199). The current recovery of the concept of totemism has reached not dissimilar findings. Beyond the interdict of the previous season, and its reduction to an «illusion», some works have examined the possibility of doing of totemism an «ontology» and a «theoretical model» which «underlines the material and moral continuity between human and non-human» (Descola [2005]). And, on the other hand, some other attempts have worked to the construction of a «zooanthropology» which considers human culture as an hybrid space not directly descended from the man's phylogenetic characteristics, but also due to their extension through the mimetic inclusion of non-human, the relationship with the animal, exemplified by the dual nature of the totem (Marchesini [2007]).

If we look at the two volumes, which collected the most important works on imitation in the former decade, the *Perspectives of Imitation* edited by Susan Hurley and Nick Chater twelve years ago, we can observe that they do not mention biomimetics as a distinctive subject. Nevertheless, Nick Chater, in his contribution, tracing the difference between the emergence of biological complexity in Darwinian sense and the cultural transmission, notices that in the first case variation is random, not directed, and that selective forces operate by means of the reproductive success of the whole organism, not directly at the level of the individual genes. In the second case: «We often create deliberate variation and imitate creatively, guided by our goals; we intentionally select particular aspects of models to imitate and decide not to imitate oth-

[5] For a reconstruction of Caillois' «dark side of mimesis» and «mimetic temptation», see Borsari (2003).

[6] About Plessner and Gehlen on imitation and mimesis, see Borsari (2007).

er aspects. Cultural complexity,» – and we could add here: «technological complexity as part of culture» – «unlike biological complexity, is largely produced by design; by sighted, not blind, watchmakers» (Hurley and Chater [2005]: II.47). Finally, Chater argued that the analogy between biological and cultural evolution is only partial:

Darwin's deep insight that the natural selection may act as a blind watchmaker, creating complex designs from the slow and grindings operation of blind processes of variation and selection, does not carry over to the cultural case. Cultural complexity works rapidly and flexibly because it is produced by design through the cumulative and deliberate operation of human intelligence (Chater [2005]: 362).

In her commentary to Chater's paper, Susan Blackmore discusses his conclusion about the relationship between processes of selection and human goals, referring to the modern case of massive design (Internet) where the human goals are «just one factor in selection» (Blackmore [2005]: 411). Without entering into the discussion on the memetic applied to human culture at stake here, what seems important in this criticism is the ability to distinguish between the different levels of the conscious intention in human intervention, on one side, and the set of interactions that plurality and partiality of such interventions produce, on the other side. From the specific point of view of the argument on biomimetics this distinction could open countless cognitive and ethical problems.

5. BEYOND BIOMIMICRY? THE EXAMPLE OF ARCHITECTURE AND SOME ANTHROPOLOGICAL-AESTHETICAL POINTS

When we consider the specific domain of architecture and the way bioinspired design has changed its perspective recently, we can find a confirmation of this tendency to go over biomimicry and an example of the idea that the mere «copying nature is completely pointless». As Patricia Pérez noticed in her *Introduction* to «the building/biology connection», «the use of animal forms in contemporary architecture – whether to endow a project of a symbolism, seek functional solutions, or simply for esthetic reason – has become a recognized, indeed a commonplace, practice». And, she adds, «architects of the stature of Renzo Piano, Norman Foster and Frank Gehry, have all opted to use animal forms in some of their recent buildings». Her choice is to avoid a checklist of zoomorphism in contemporary architecture and to focus on «specific analogies with animal strategies to protect the body from toxic substances, radiations, vibrations, impacts, humidity, and all other types of negative external influence, without blocking contact between the exterior and the interior» (Bahamón and Pérez [2009]: 4).

This kind of analysis refers to anatomical structures, incorporated into the animal itself, to constructive structures artificially created by animals, and to preexisting structures that are appropriated by certain animals. But the attempt to «naturalize architecture» can also intersect the «sources of molecular biology, down to the processes of replication, transcription, or translation of genetic material», under the sign of «hybridization»:

Architects can generate complex models resting on self-generation processes of matter and integrating computational, social, material or environmental variables. [… Architects] implement specific strategies to transcend the distinction between nature and artificiality. Mastery of the formation and growth principles that are specific to living organisms has inaugurated a genuine meta-ecology (Brayer and Migayrou [2013]: 10-11).

It keeps closer to the original setting of biomimetics, the search for solutions in architecture to achieve increases in resource efficiency, to shift from a fossil-fuel economy to a solar economy and to transform from a linear, wasting and polluting way of using resources to a closed-loop model. This approach also stresses, from an architectural perspective, the distinction between biomorphism and biomimicry, opting definitely for the latter one, as a «functional revolution» (Pawlyn [2012]: 1-6).

As highlighted by different texts, nature cannot be copied, but architects and civil engineers find in the living world a lot of analogies and suggestions for their own creative design. The pioneer of bionic/biomimetics in Germany, Werner Nachtigall stated that the task

> *is not to copy the forms, but to make an analogy of functions. Thus abstraction of general principles from the biological field and their technically adequate implementation. You often read, you just have to do everything like nature, and then everything is all right. This is the biggest nonsense. Copying is completely pointless. One has to abstract the stimuli from nature and install them where it is useful and practicable.*

Nature has its own forms and it is up to the architect to determine whether to use them or not, whether he/she imitates them or not (Schultz [2011]: 14-16).[7]

Furthermore, William Myers has clearly pronounced in favor of a development of the bioinspired design that goes beyond the biomimicry. Rejecting a «form driven» design approach which offers «only a superficial likeness to the natural world for decorative, symbolic, or metaphorical effect», he chooses a design that «sets out to deliberately achieve the qualities that actually generates these forms – adaptability, efficiency, and interdependence», which is «infinitely more complex, demanding the observation tools and experimental methods of the life sciences» (Myers [2012]: 11).

In order to precise in philosophical, anthropological and aesthetic terms this demand for creativity connected to natural processes rather than to the products of nature, it could be useful to introduce a reference to the thick tradition of reflection about mimesis. In particular, explaining Aristotle's theory of artistic production in its relationship with nature, Gunter Gebauer and Christoph Wulf remind that poetry, painting, and music «must create their works as *nature* creates».

> *What is intended here is not an imitation of nature, such that a work should be fashioned as the equivalent of nature. The goal is rather to achieve similarity in the processes of creation. Painters, musicians and poets should produce by means of the same force as nature. Like nature, they are capable of creating matter and form. The creative force in nature lies in nature itself; in art, artists fashion material in terms of a function they have themselves contrived. This process through which a work comes to exit in the world is what defines art, poetry and music[8] (Gebauer and Wulf [1995]: 55-56).*

The characteristic that defines the aesthetic domain thus becomes «the ability of the artist, painter or poet to create as nature does» and the specificity of such forms of artistic expression lies in the «processing of different elements into a consistent work of art»: «Mimesis creates art. Its objects, devices and representational forms serve goals conceived by the artist, rather than things existing external to artistic intention» (Gebauer and Wulf [1995]: 56).

It is something interwoven with a concept that a later modernity (Bruno, Spinoza) would have called «natura naturans», as a perpetual-generating activity or the capacity of nature to produce its own reality, considered as opposed to «natura naturata», or the complex of produced/created beings. Commenting Adorno's aesthetic theory further, Gebauer and Wulf observe that «the work of the artist includes not merely the imitation of the objective world, but aims at bring object to speech»:

> *Similarity with the products of nature is not the aim of art; rather, it is similarity with the natural force that brings them into existence. When Adorno emphasizes the similarity between nature, the artist and art, he has in mind, not natura naturata, but natura naturans. If artworks, freed from the obligation to posit identity, are equivalent to themselves, then this self-equivalence can only be grasped mimetically (Gebauer and Wulf [1995]: 289).*

Since mimesis in this context cannot denote «the imitation of something that preexisted the

[7] See also Nachtigall and Pohl (2003). For a further discussion of biomimetics in design and architecture, see also *Biomimétisme* (2017).

[8] See Aristotle [1986]: 35 ff.

work», they can conclude: «mimesis is similar to the self-referential creative of the *natura naturans*, the nonobjective aspect of nature» (Gebauer and Wulf [1995]: 290).

Finally, the question about how the anthropology and the aesthetics of human mimicry and imitation can be re-shaped including biomimetics among their assumptions still remains open. Converge toward its solution, however, a number of elements that we have so far collected by comparing the different phenomena of biomimetics: intentionality, the intentional character of the imitation involved in technical processes; its connection with the main factors of human development (imitative representation etc.); the embodiment of bioinspired functions in artifacts through distance and not through identification; difference in repetition and creativity in reproduction; the moral and material continuity between human and animals; in general, the prevailing imitation of the productive capacity of the nature as including the imitation of its products: natura naturans over natura naturata[9].

BIBLIOGRAPHY

Aristotle, 1986: *The Poetics of Aristotle. Translation and Commentary*, ed. by S. Halliwell, The University of North Carolina Press, Chapel Hill.

Bahamón, A., P. Pérez, 2009: *Inspired by nature. Animals: the building/biology connection,* W.W. Norton, New York.

Benuys, J.M., 2002: *Biomimicry: Innovation inspired by nature*, Perennial, New York.

Bhushan, B., 2009: *Biomimetics: lessons from nature. An overview*, "Philosophical Transactions of the Royal Society A", 367, pp. 1445-1486.

Biomimétisme. Science, design et architecture (2017), ed. by M. Antonioli, in collaboration with J.-M. Chomaz, L. Karst, Loco, Paris.

Biomimicry Institute: https://biomimicry.org/what-is-biomimicry/

Bionik Stiftung: http://www.bionikzentrum.de/new-page/

Blackmore, S., 2005: *Can Memes meet the Challenge? Susan Blackmore on Greenberg and on Chater*, in S. Hurley, N. Chater (eds.), 2005a*: Perspectives on Imitation. From Neurosciences to Social Sciences*, vol. 2, *Imitation, Human Development, and Culture*, MIT Press, Cambridge (MA).

Borsari, A., 2003: *Il lato oscuro della mimesis. La tentazione mimetica di Roger Caillois*, in A. Borsari (ed.), *Politiche della mimesis. Antropologia, rappresentazione, performatività*, Milano: Mimesis, pp. 223-284.

Borsari, A., 2007: *El totem y el oso espadachín. Antropológia filosófica de la imitación: Plessner y Gehlen*, Universitas, Córdoba.

Brayer, M.-A., F., Migayrou (eds.), 2013: *Naturaliser l'architecture*, HYX, Orléans.

Caillois, R., 2003: *The Edge of Surrealism. A Roger Caillois Reader*, ed. by C. Frank, Durham, Duke University Press, London.

Cha, K.-H., 2010: *Humanmimikry. Poetik der Evolution*, Fink, München.

Chapelle, G., M., Decoust, 2015: *Le vivant comme modèle*, Albin Michel, Paris.

Chater, N., 2005: *Mendelian and Darwinian Views of Memes and Cultural Change*, in S. Hurley, N. Chater (eds.), 2005a*: Perspectives on Imitation. From Neurosciences to Social Sciences*, vol. 2, *Imitation, Human Development, and Culture*, MIT Press, Cambridge (MA).

Descola, P., 2005: *Par-delà nature et culture*, Gallimard, Paris.

Gebauer, G., C., Wulf, 1995: *Mimesis. Culture, Art, Society*, University of California Press, Berkley.

Gehlen, A., 1985: *Urmensch und Spätkultur. Philosophische Ergebnisse und Aussagen* (1956), Aula, Wiesbaden.

Harkness, J.M., 2002: *A lifetime of connections. Otto Herbert Schmitt, 1913–1998*, "Physics in Perspective", 4, p. 456.

[9] Many thanks to Fabrizio Desideri for the invitation to the Conference, to Christoph Wulf for his comments to the talk and to Elisa Molinari for her generous willingness to provide information and considerations in the long run on some aspects of the research in physics, nanosciences and bioinspired innovation.

Hurley, S., N. Chater, (eds.), 2005a: *Perspectives on Imitation. From Neurosciences to Social Sciences*, 2 voll., vol. 1. *Mechanisms of Imitation and Imitation in Animals*, vol. 2, *Imitation, Human Development, and Culture*, MIT Press, Cambridge (MA).

Jabbari, E. et al. (eds.), 2014: *Handbook of Biomimetics and Bioinspiration*, World scientific, Singapore.

Marchesini, R., 2007: *Principi e strumenti della zooantropologia*, in Id., S. Tonutti (eds.), *Manuale di zooantropologia*, Meltemi, Roma.

Myers, W., 2012: *Biodesign: Nature, science, creativity*, with a Foreword by P. Antonelli, Thames and Hudson, London.

Nachtigall, W., 2008: *Bionik: Lernen von der Natur*, C.H.Beck, München.

Nachtigall, W., 2013: *Bionik: Grundlagen und Beispiele für Ingenieure und Naturwissenschaftler*, Springer, Berlin, Heidelberg.

Nachtigall, W., G., Pohl, 2003: *Bau-Bionik: Natur - Analogien – Technik*, Springer-Vieweg-Verlag, Berlin, Heidelberg.

Nosonovsky, M., B., Bhushan, 2008: *Multiscale dissipative mechanisms and hierarchical surfaces: friction, superhydrophobicity, and biomimetics*, Springer, Berlin.

Pawlyn, M., 2012: *Biomimicry in Architecture*, RIBA, London.

Plessner, H., 1982: *Der imitatorische Akt* (1961), in *Gesammelte Schriften*, edited by Dux, G., O. Marquard, E. Ströker, vol. 7, *Ausdruck und menschliche Natur*, Surhkamp, Frankfurt am Main.

Plessner, H., 1983: *Die Frage nach der Conditio humana* (1961), in *Gesammelte Schriften*, edited by Dux, G., O. Marquard, E. Ströker, vol. 8, *Conditio humana*, Surhkamp, Frankfurt am Main.

Rovera, O., L., Michelangeli (eds.), 2014: *Mimesis art. La biomimetica nell'arte*, Albertina Press, Torino.

Schultz, B. (ed.), 2011: *Die Natur zu kopieren ist völlig sinnlos. Interview mit Werner Nachtigall und Göran Pohl*, "Bauwelt", 31, pp. 14-17.

Vincent, J.F.V., O.-A., Bogatyreva, N.R., Bogatyrev, A., Bowyer, A.-K., Pahl, 2006: *Biomimetics: its practice and theory*, "Journal of the Royal Society Interface", 3, pp. 471-482.