Biomimetic Building skin: Living Envelope for Contemporary Architecture

Abstract

As a highly interdisciplinary field, many subjects of natural and social sciences are influencing architecture. While many subjects hold an indisputable effect on architecture, biological sciences are currently dominating the current era. It is totally comprehensible for architects to observe and imitate the natural phenomena on behalf of a better living. This article will present how to translate the lessons learned from the analysis and observation of the animal world to design experience. Skin is a complex and incredibly sophisticated organ that performs various functions, including protection, sensation, insulation and water regulation. The skin interfaces with the environment and is the first line of defense from external factors. Similarly, building envelopes serve multiple roles and they are the interface between the building inhabitants and environmental elements.

In architecture, the boundaries between materials and structures are blurred the same way as in nature. The study of biological systems might be useful for our purposes on how new materials can be designed. The new material is inspired by the study of how animals' skins perform and respond according to their different properties; they take into consideration various dynamic local environmental conditions, creating a more sustainable way of building hence living. The projects will be focused on specific functions that were unique to the selected animals' skins. The biology of an animal and the environment it lives in determine these functions. The processes by which each animal analysis will be carried out, will innovate in the design and conception of new materials. Which will, in turn, inform new synthetic designs based on biological systems that will describe new aspects and performance of the building envelope.

Key words: biomimetic, biological system, architecture, smart materials, environment factors

1. Introduction

Recently, a great number of individuals working in areas of material engineering, architecture and design have attempted to distill the generative logics of 'natural systems' into their works. Bio-inspired processes are now integrating in diverse design methods and practices. Specific fields of interest such as biomimetics which delve into understanding such natural mechanisms and the application of the extrapolated knowledge into constructing performative structures, have since been at the heart of contemporary architectural and engineering researches. Biology is a discipline that can influenence design in unexpected and interesting ways. Especially, how environmental and climatic conditions have influenced the evolution of behavioral and physiological traits of animals can inform and inspire fields such as design and architecture. Adaptation strategies are considered to be a key aspect for the design of building envelopes that can accommodate the environmental changes with less energy consumption. It is proposed that the implementation of successful adaptation strategies inspired from nature can result in adaptive building envelopes that "behave" as living systems that accommodate the dynamic environmental changes; in other words, the envelope should be able to regulate and manage, among others, air, water, light and temperature. To this end, successful strategies could be obtained from nature, which presents an immense source for adaptation strategies[1]. The challenge for architects, in this context, is to transform these adaptation strategies from nature into successful technological solutions for building envelope. In this specific research, eleven animals have been chosen as rolemodels to inspire new material design, following three main reasons ; 1.Their skins are highly performative, 2.Their skins represent a direct response or adaptation to their environment, and 3.Their skins are important to their survival. We propose a strategic methodology that provides an exploration and investigation platform for architects. It assists channelling the way from biology to design and technical challenges, through functional aspects and various strategies found in nature.

2. Nature role models: Animals' skins and their adaptation solutions in nature

Living organisms' factors have necessitated the evolution of unique adaptations in terms of physiology, morphology, and behaviour[2]; the physiological and morphological adaptations reflect functional features that help organisms to adapt to their environment, whereas behavioural adaptations relate to the actions done by organisms in order to survive. Adaptation is especially obvious in the organisms able to survive harsh and challenging environment conditions, which include: extremes of temperature, lack of water, solar radiation, and other environmental factors. The term 'skin' refers to any animal covering, including fur, feathers, scales, exosckeletons, and shells. Skin is understood as an interface, transcending its surface, giving the appearance of something that separate, but instead acts as a threshold boundary, allowing for interaction with the elements in multiple directions, scales and timeframes. Architectural envelopes furnish great opportunities to take into consideration dynamic local environmental conditions, creating the potential to use the conditions as resources to be enhanced and supported rather than simply elements to conceal or overcome. Rigorous and systematic analyses of the performative aspects of the animal skin are the initial steps of the proposed methodology. An animal's skin can be extraordinarily complex and interactive system due to adaptive and responsive physiology through their climate and habitat data. Skin comes in all kinds of textures and forms, the main objectives are to understand the structure of the skin, the basic functions of the skin in sensing stimuli, temperature control and mechanisms. We have chosen eleven animals, which their skins can remarkably adapt to the changes in their environments, habitat and help the animals to survive. In general terms the three main threats to survival are temperature, lack of water and lack of food. Outside of environmental threats, many animals also need to be able to defend themselves or escape from predators in order to survive, lists of role models as following;

01. Giraffa camelopardalis (Giraffe); *Survive the heat in Africa*
02. Hippopotamus amphibious (Hippos); *Survive in dry-tropical climate*
03. Crocodylus niloticus (Crocodile); *Survive to find food (pray) and suitable habitats*
04. Acomys kempi and Acomys percivali (African spiny mouse); *Survive from predators*
05. Cephalopoda (Inkfish); *Survive from defensing against predators*
06. Acrochordus granulatus (File snake); *Survive from humid-hot climate*
07. Moloch horridus (Thorny dragon); *Survive from lack of water in dry desert*
08. Barbourula kalimantanensis (Bornean flat-headed frog); *Survive from having no lungs*
09. Elysia chlorotica (Green sea slug); *Suvive without nutrition for long period*
10. Penguin feather; *Survive from extreme cold*
11. Physasterna cribripes (Namib desert beetle); *Survive from lack of water in dry desert*

The animals were chosen to reflect various types of skins from different climatic regimes. We focus on specific functions that were unique to the selected animals's skin. The biology of an animal and the environment it lives in determine these functions[3]. Investigating and analysing these strategies and their dominating principles are essential priors to the transfererability in design process.

2.1 Role model search, definition and paper references for scientific background

We start with the three main research areas ; science and technology as input, nature's principle as an abstraction for innovative design and architecture as an implementation. We developed a methodology and investigated the three areas and the role models through scientific papers. We create a data sheet for each animal to serve as working draft to present the underlying scientific information for the project and a system diagram to observe role models' phenomenas.

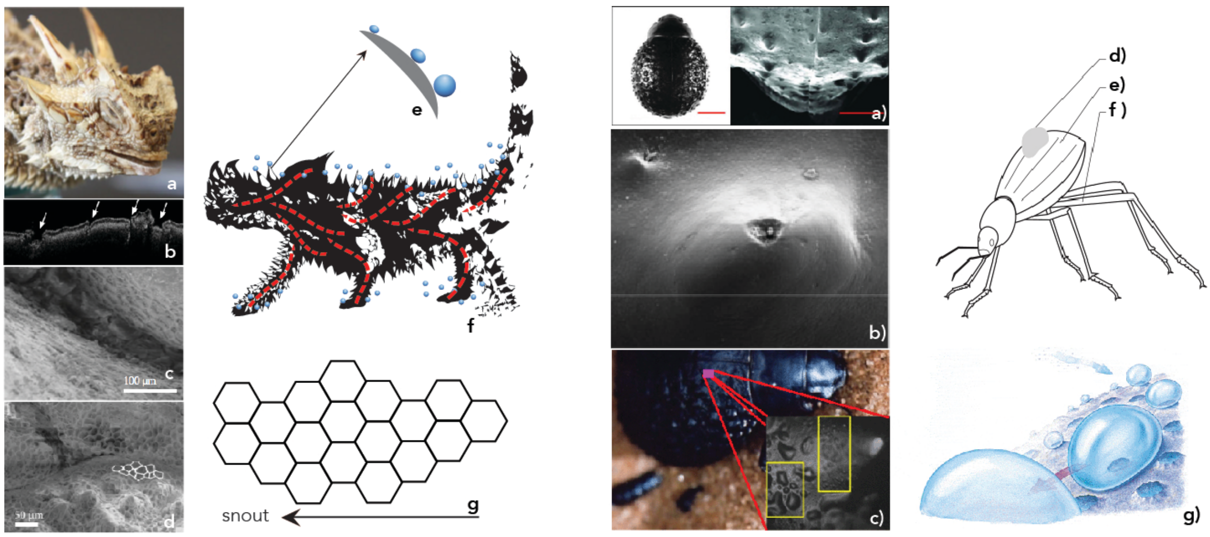

Figure 1. System diagram analysis. Left: a. Moloch horridus[4] (Thorny dragon), b. skin cross section from single OCT slide[5], c. SEM-image of capillary opening between the dorsal scales[6], d. The skin shows the honeycomb like micro ornamentation virtually all over all scales[7], e. Hygroscopic grooves between the spines of their skin, f. Water is conveyed to the thorny dragon's mouth by capillary action through a circulatory system on the suface of its skin, g. Diagram of hexagon structure. Right: a) Elytra structures of Physasterna cribripes (Namib desert beetle)[8], b) A bumb and surrounding valleys[9], c) Dew phenomena on the dorsal surface[10], d) Water dropet accumulmates on the dorsal, e) Exoskeleton ridges, f) Fog basking posture (23° from horizontal), exhibits a characteristic fog-basking head stand. This posture allows fog water collectd on the beetle's dorsel surface to trickle down to its mouth, g) Elytra (on dorsel) of all beetles were found to be completely hydrophobic, passively collect water from air[11].

3. Building Envelope and Environment factors

Our research tackles the main question of how to generate design concepts for building envelopes that regulate environmental aspects, based on adaptation strategies from nature. Adaptation strategies are considered to be a key aspect for the design of building envelopes that can accommodate the environmental changes with less energy consumption. The successful strategies could be obtained from nature, which presents an immense source for adaptation strategies. The challenge for architects, in this context, is to transform these adaptation strategies from nature into successful technological solutions for building envelope adaptation.
Materials have a great influence on the performance of systems due to their molecular structure. The integration of advanced and responsive materials in building envelopes can enhance the adaptation in real-time for a better performance. A wide range of smart materials has been emerging throughout the last years, where it has a high potential in the construction field[12]. For example, phase change materials applied in buildings for energy conservation purposes improve thermal distribution and cost and space effectiveness. A new class of materials is being developed for potential use in buildings, e.g. the investigation of the use of shape memory alloys (SMA) and

shape memory polymers (SMP) to realize a shape adaptable architecture for various purposes[13], specially these smart materials can performatively behave like biological system.

4. Biomimetic Approach and Design Methodology

A major challenge of using biomimetics as a design tool is the filtering of the wide possibilities that nature provides, especially for architects who have limited biophysical background. The design generating tools should support the transitions between the domains, especially the identification of biological analogies and their abstraction. Biomimetics in architecture is an emerging field that develops further the interest of architects in role models from nature to a new discipline. The strategic approach differentiates biomimetics from mere inspiration from nature that has always existed in architecture. Bioinspiration transfers merely aesthetic and morphological aspects. Whereas in biomimetics, functional aspects play a key role. In general, materials, structures and processes from nature can find biomimetic transfers to new technical solutions.[14]

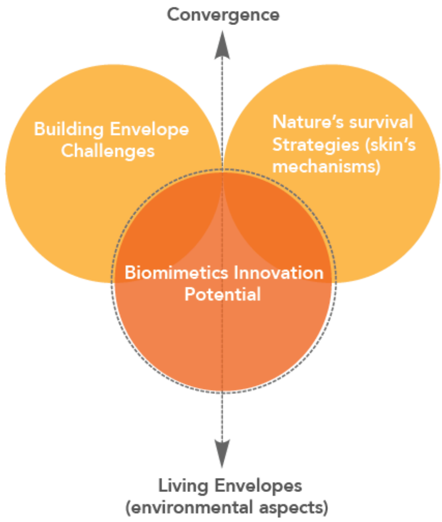

Figure 2. Scheme of the approach towards the living envelope: convergence of the building envelope's challenges with nature's survival strategies (animals' skins) through biomimetics.

Although, nature provides a large database of adaptation strategies that can be implemented in biomimetic designs. Additionally, successful concept designs are limited, likely due to a number of factors beyond the ability to emulate nature's strategies to meet corresponding functional needs. Challenges in implementing biomimetic designs likely include: 1. the search for, and the selection of, an appropriate strategy or multiple strategies from the large database provided by nature, 2. scaling difficulties; strategies that work at one scale (e.g. nano) might not work at another (e.g. micro), and 3. built-ability in design phase. The selection of role models from nature is a common challenge facing architects. Processes, morphologies, and systems are all strategies available for mimicking, which can be implemented at various scales of results, e.g. material, element, building, and urban. From the literature[15], two main approaches with various terminologies (B3.8[16], BioT[17], Shu[18], Goel[19], Gruber[20]) are noticed in biomimetics: 1. Biology to Design or 'solution-based', are inspired by an observation in nature which leads to a technological design, 2. Challenge to biology or 'problem-based', seek a solution from nature for a particular engineering problem. This project follows the first approach, where an observation in nature lead to a technological design innovation to solve particular problems, e.g. thermoregulation and water management in arid areas. This approach is taken to address the myriad challenges associated with adaptive building envelopes.

4.1 Analysis and evaluation matrix of role models aspects

The evaluation matrix was created as a knowledgebase and a selection tool, with the criteria delivering comprehensive information on the characteristic, performance and transferability of the chosen biological phenomena. Below the list of criteria used in the evaluation is presented. For most of the selected criteria quantitative data is not available. However, a qualitative statement estimating the importance of the criterion for the respective role model can be made. A simple differentiation between six qualities was used, from irrelevant-0, to very high-6. All role models were evaluated using the presented list of criteria.

Architectural and Skin Properties Table	Species										
	Giraffa Camelopardalis (Giraffe)	Hippopotamus Amphibious (Hippopotamus)	Crocodylus Nioticus (Crocodile)	Acomys Kempi and Acomys Percivali (African Spiny Mouse)	Cephalopodae (Inkfish)	Achrocordus Granulatus (File Snake)	Moloch Horridus (Australian Lizard)	Barbourula Kalimantanensis (Indonesian Frog)	Elysia Chlorotica (Green Sea Slug)	Penguin Feather	Physasterna cribripes (Namib desert beetle)
Air regulation	3	3	0	0	0	0	3	4	0	5	3
Water							■				■
Hygroscopic	0	2	2	0	0	5	5	2	0	0	5
Hydrophobic	0	5	3	0	4	5	3	3	1	5	4
Hydrophilic	4	0	4	0	4	0	0	3	1	2	4
Temperature	■	■				■				■	
Thermal regulation	5	4	4	0	2	5	3	3	2	5	3
Insulation	5	3	3	0	0	3	2	0	0	5	1
Energy									■		
Passive	4	3	3	0	4	5	5	3	4	4	5
Active	5	5	5	5	5	3	3	5	5	2	3
Structure	■						■			■	■
Efficiency	4	3	4	5	4	3	4	4	3	5	4
Performance	4	5	4	5	5	4	5	5	5	5	4
Dimension											
Speed/time	3	3	5	5	5	3	4	3	3	3	4
Scale	2	4	4	5	4	2	3	1	1	4	2
Scalability							■			■	■
Geometry	4	2	3	2	1	4	5	2	1	4	3
Function	4	1	2	1	2	3	3	1	1	2	2
Material		■		■	■	■		■	■		
Chemistry	1	5	3	5	5	5	4	5	5	1	3
Texture	1	4	4	5	5	5	4	4	1	1	4
structure	1	4	4	5	5	4	4	4	1	3	4
Form	■						■			■	■
Function	5	3	3	3	3	3	5	4	2	5	4
Pattern	5	0	5	0	4	3	4	3	4	5	4
Hierachy	4	5	3	4	3	2	4	3	3	5	3
Communication			■		■				■		
Sensor	0	3	5	0	4	0	0	0	3	0	0
Networks	4	0	5	4	5	4	4	0	3	1	3
Interaction	3	3	5	4	5	2	3	2	4	1	3
Responsiveness			■		■			■			
Self-organization	3	0	0	5	4	0	5	2	3	4	0
Environmental Impact	5	5	4	0	4	5	4	5	2	4	5
Motion	4	0	5	3	4	5	4	4	2	3	4
Input/Output	4	4	5	0	4	2	3	4	4	2	4
Availabilty of information	2	3	4	3	4	1	5	1	1	3	5
Innovative potential	4	4	4	3	3	3	5	2	2	4	4
Transferability	■		■				■			■	■
Design phase	3	1	3	1	1	2	4	1	1	3	4
Technological transfer	4	4	5	3	4	4	5	1	1	4	5

Evaluation	
5	Very high
4	High
3	Medium
2	Low
1	Very low
0	None

■ Optimal performance

Figure 3. Evaluation sheet: Intersection of the properties of animals' skins and architectural design.

We first developed an understanding of the climatic characteristics of the environment in which the animal lives, followed by a study of the morphological and physiological strategies the animal uses to survive in its particular environment. After having an overview to each animal's adaptation we focus on animal's skin; the different layers, primary functions, how other physiological systems interact with the skin and how skin interacts with the environment. The analysis resulting of metrix evalution sheet aide in defining the stratification and functioning of the skin. Through this detailed analysis, a design lesson emerged, highlighting the fundamental elements of the skin and inspiration for the design of the living envelope.

4.2 Design Methodology

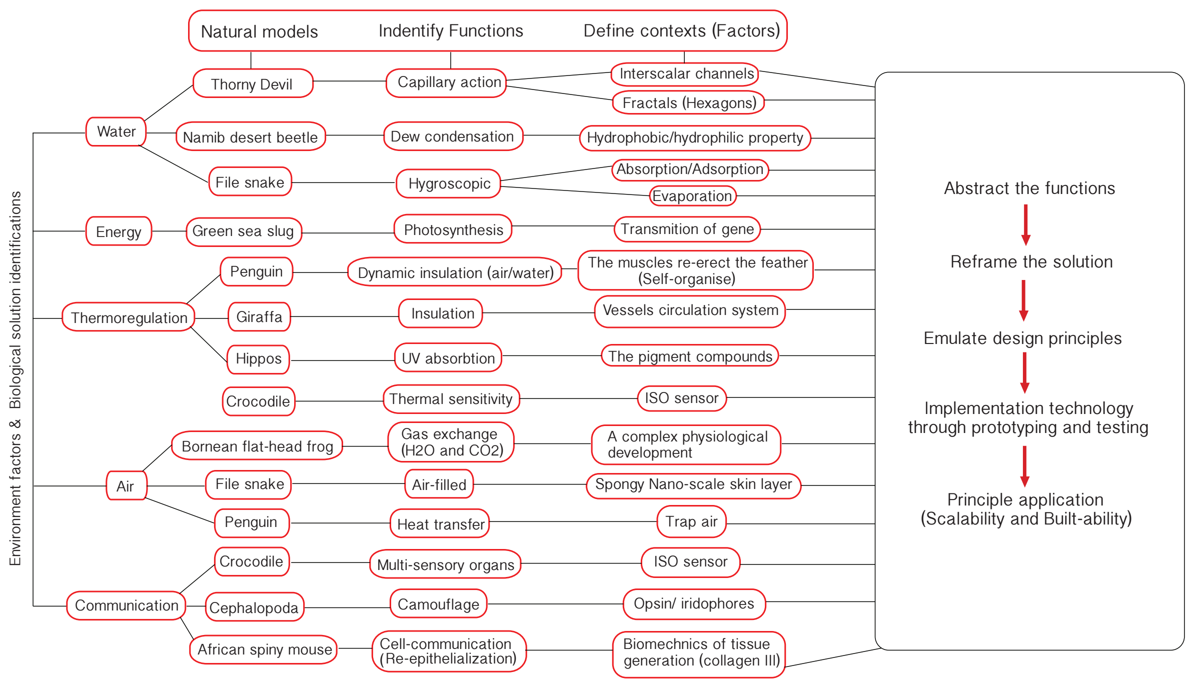

Figure 4. The unique flow chart methodology leading to a concept design of the living envelope.

The design methodology selects dominant strategies that function simultaneously in nature. The proposed strategy consists of several phases and sub-phases, which are presented in unique flow charts that provide a selective user-friendly tool, which leads to a concept design of the living envelope. The new methodology provides a path for drawing design inspiration from nature. It considers architecture beyond the aesthetics or functional, and begins to explore the conceptually strategic. For architects and designers, it provides biological inspiration for further flexible and dynamic design, and templates for them to derive other species examples, an acts as a springboard for exploring broader applications beyond envelopes to applying whole ecosystems to entire building and communities. Five main considerations for living envelope concerning environment factors are; water, energy, thermoregulation, air, communication. The proposed methodology has to be selective in order to enable managing the large sample size nature provides. Thus, the methodology requires investigating adaptation strategies and mechanisms found in nature, and distinguishing various functional aspects relevant for adaptation, which are classified in an exploration model and selective design tools leading to the generation of design concepts for building envelopes. The flow chart tools increase the efficiency of the design process, and they are capable to generate design concepts with a specified initial challenge set by the user. Moreover, the design cases opened new perspectives for new possible technical solutions for building envelopes, and the potential to realize a new class of innovation and lay a functional foundation in architecture: a bio-inspired, climatically oriented, and environmentally conscious.

5. Material Design

We realise that nowadays, water shortage is a severe issue all over the world, especially in some arid and undeveloped areas. Interestingly, from a variety of animals' skins selected can collect water from fog, which can provide a source of inspiration to develop novel and functional water-collecting materials. The theoretical basis related to the phenomenon of water collection containing wetting behaviors and water droplet transportations is described in desert animals in the initial biological observation, ie**.**, the thorny devil's skin has funtional system with Hygroscopic grooves (absorbing moisture from air) and the ability to passively transport water through capillary system to its mouth. The namib desert beetle's skin collects water from fog by condensation on the elytra (fog-basking behaviour), also a special arrangement of hydrophilic and hydrophobic areas on the elytra results in attracting water droplets and transporting it to the mouth. Then, the water collection mechanisms of the desert animals are discussed and their corresponding bioinspired materials are simultaneously detailed. Finally, conclusions and outlook concerning the future development of bioinspired fog-collecting materials are presented.

5.1 'Hygro-NET' fog-harvesting material design

'Hygro-NET', is a bio-inspired fog-harvesting material design that abstracts the strategic methods from the desert animals, Thorny dragon and Namib desert beetle, how their skins perform to collect and supply water in arid climate. We transfer this process of passive water transport system and dew condensation to improve the efficiency of the fog-harvesting material design.

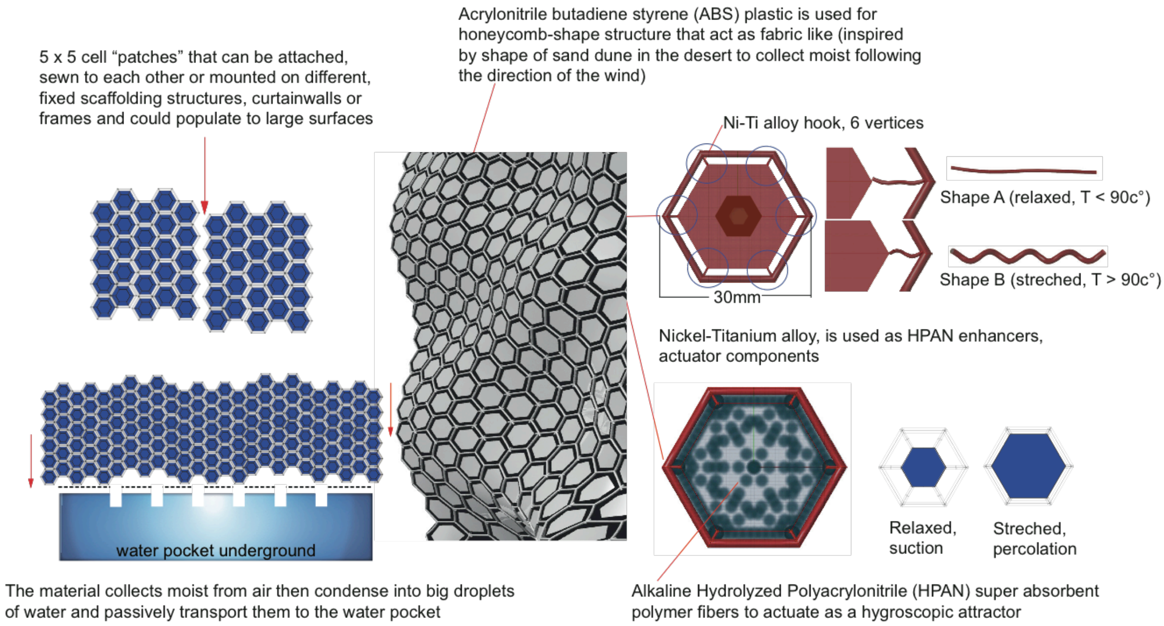

Figure 5. Hygro-NET system diagram, fog-harvesting material that behaves as functional living system.

The suggested component materials were the following;

1) Acrylonitrile butadiene styrene (ABS) plastic, to be used as structural, cohesive framework providing stability and integrity and also serve as condensed water drivers aided by gravity, mimicking "capillary action", these should be fabricated using a 3D printer.
2) Alkaline Hydrolyzed Polyacrylonitrile (HPAN) super absorbent polymer fibers to actuate as a hygroscopic attractor, as defined and fabricated by Xiaoyu Hu and Changfa Xiao[21] and investigated by Mark González[22].
3) Nickel-Titanium alloy (Flexinol Muscle wire brand sold by robotshop and manufactured by DYNALLOY) to be used as HPAN enhancers, actuator components.

The structural frame of the hexagon cell, abstracted from the pattern of honeycomb-shaped showing all over scales of the Thorny dragon, is made of Acrylonitrile butadiene styrene (ABS) plastic. The material is hydrophobic, it's efficiency for condensing and trasporting water. The hexagon grid is 30mm in diameter (which could be reduced, in theory, but data cost of augmenting its hygroscopic efficiency, yet exponentially increasing fabrication difficulty and expensiveness). The scaling up problem is addressed with 5 x 5 cell "patches" that can be attached, sewn to each other or mounted on different, fixed scaffolding structures, curtainwalls or frames and could populate large surfaces or relatively small empty spaces on their own (like ducts or windows). During this research project, we drew a parallel and mimic between the Thorny devil's hygroscopic system and the namib desert beetle's fog–basking behaviour to a synthetic, super absorbent polymer (SAP), itself hydrolyzed by alkaline solutions, which can absorb about >10 times its own weight, called Polyacrylonitrile (HPAN) (accurate water absorbency of 40g/g).[23] From the start, it was clear that, though the material does exhibit remarkable properties, the possibility of a similar result in terms of efficiency was not foreseen as a probable one, because the HPAN works with already condensed water and itself does not transport it to a usable place. Then, for the fiber to work in almost any climatic condition, the combination of two materials actuating together in an open-close transition logic to enhance HPAN's properties was proposed as a sensible solution. Our hypothesis was simple: HPAN would be relaxed (at about 2mm's distance) when the temperature would be lower than 90c° (therefore Ni-Ti would be in shape A (a strand), in order to absorb more water than HPAN would on its own. Later to be pulled back to its tension state (when the temperature would go over 90c°) by Ni-Ti's programmed actuation into shape B (a spring) in order to expel and percolate the condensed water inside the HPAN's porous fibers.[24] The proposed Ni-Ti alloys in this paper were selected from a commercially available and hold a transition temperature of 70c° to 90c° so, under normal thermal conditions, they have to be actuated by electricity (very low voltages ranging between 20 and 4000 Milliamps). Yet in an extreme environment like a desert, they could work without electrical stimuli thanks to heat conduction and accumulation alone. In theory it is possible to engineer and design alloys that work at lower temperatures but, since they're not commercially available and this poses a constraint in terms of fabrication hence our decision to simulate commercially available ones just to establish general principles that can be later adapted to specific, custom alloys and cases.

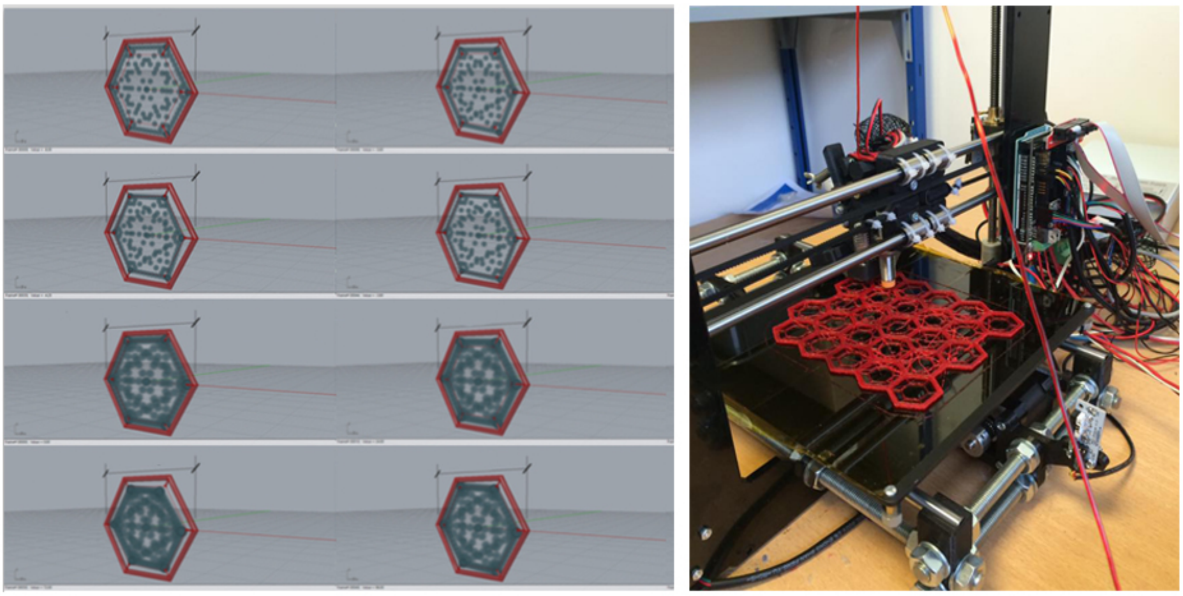

Figure 6. Left: Simulation and Physical Properties: A Single component's performance simulations to study Alkaline Hydrolyzed Polyacrylonitrile (HPAN) behavior with Ni-ti alloy as actuator components going from tension to relaxation. Simulation executed using Rhinoceros 5.0 + Grasshopper version (0.9.0076) + Kangaroo (version 0.099). Right: Test 3D-printing prototype of a 5 X 5 cell - patches[25].

6. Conclusion

The greatest challenge faced by biomimetics is to determine how nano[26] and microstructures function in their relationship with the organism and the environment, especially if these have not been fully explored yet. As in nature, where design develops from small to large scale, the material design should also develop in the same manner as in nature to meet specific building and environmental criteria, acting as design targets to be achieved. The Simulations show that the textile composite should work as required in accordance with the animal skin selection process. Performance in terms of mechanical data and built-ability remain to be tested yet the evidence stongly suggests that the hygroscopic component should have a significant accurate working proefficiency. This research project can conclude that mimicking animal skin depends on the case at hand (both in term of building and biology) yet a methodology can and has been established as a guideline for the decision making process and its subsequent design and implementation process. The results show that, not only is transferring animal skin properties to building "skin" possible and interesting design wise, but that it will enhance our ability to invent ever more complex and efficient façade, building envelope systems and environmental mediation devices while also embedding intelligence and will draw us close to autonomous,self-regulating buildings that could, one day, be bred, "grown" and totally biodegraded into new bio-architecture.

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[1] John, G., Clements-Croome, D., and Jeronimidis, G., *Sustainable building solutions: a review of lessons from the natural world* (Building and Environment, 40, 2005) 319-328.
[2] Louw, G.N. and Seely, M.K., *Ecology of Desert Organisms*, London: Longman Group Ltd., 1982.
[3] Lauralee Sherwood, Hillar Klandorf, and Paul H. Yancey, *Animal Physiology: From Genes to Organisms*, 2015.
[4] Comanns, P., et al., *Passive liquid transport: the Texas horned lizard as a model for a biomimetic 'liquid diode'*, Interface, Royalsocietypublishing, 2015.
[5] Ibid.
[6] Comanns, P., et al., *Moisture harvesting and water transport through specialized micro-structures on the integument of lizards* (Beilstein Journal of Nanotechnology, 2011, 2), 204-214.
[7] Ibid.
[8] Nørgaard,T. and Dacke, M., *Fog-basking behaviour and water collection efficiency in Namib Desert Darkling beetles*, Frontier in Zoology, 2010, 7:23.
[9] Guadarrama-Cetina, J., et al., *Dew condensation on desert beetle skin* (The European Physical Journal E, 2014), 37.
[10] Ibid.
[11] Asknature databased, *Water vapor harvesting: Namib desert beetle*, http://www.asknature.org/strategy/dc2127c6d0008a6c7748e4e4474e7aa1 (accessed June 20, 2016)
[12] Addington, M. and Schodek, D.L., *Smart Materials and Technologies: for the architecture and design professions*, Burlington, MA: Architectural Press, 2005.
[13] Lelieveld, C.M.J.L. and Voorbij, A.I.M., *Adaptable Architecture with the Application of Dynamic Materials. In Lifecycle Design of Buildings, Systems and Materials*, E. Durmisevic, ed., Enschede, The Netherlands, 2009.
[14] An overview of Biomimetics in architecture is to be found in Gruber P., Biomimetics *in architecture - the architecture of life and buildings*, 2011.
[15] Benyus M., Janine, *Biomimicry: Innovation Inspired by Nature*, HarperCollins Publishers, 1998.
[16] Biomimicry 3.8, http://biomimicry.net (accessed March 2, 2016)
[17] Vincent, J.F.V., et al., *Biomimetics – its practice and theory* (Journal of the royal society Interface, 3, 2006), 471-482.
[18] Vakili V., Shu LH, *Towards biomimetic concept generation*, ASME IDETC/CIE, Pittsburg Pennsylvania, 2001
[19] Goel et al. 2009
[20] Gruber, P., Imhof, Babara, *Biornametics: Architecture defined by natural patterns*, http://www.biornametics.com (accessed May 3, 2016)
[21] Xiaoyu Hu and Changfa Xiao, *Superabsorbent Polyacrylonitrile Based Fiber*, (People's Republic of China: Tianjin Polytechnic University, 2004).
[22] Mark Gonzalez, *An Investigation of electrochemomechanical actuation of conductive polyacrylonitrile (PAN) nanofiber composites*, (Rochester, USA: thesis dissertation Masters of Science in Mechanical Engineering, 2013), 27.
[23] Xiaoyu Hu and Changfa Xiao, *Superabsorbent Polyacrylonitrile Based Fiber*, (People's Republic of China: Tianjin Polytechnic University, 2004), 1.
[24] Mark Gonzalez, *An Investigation of electrochemomechanical actuation of conductive polyacrylonitrile (PAN) nanofiber composites*, (Rochester, USA: thesis dissertation Masters of Science in Mechanical Engineering, 2013), 27.
[25] Thomas Zedin, architect DE-HMONP from ENSA Paris-la-Villette in France, Ph.D. candidate at MAP-MAACC and R&D consultant for Vinci-Construction-France, 3D prototype is tasted on 13 June 2016, Vinci construction, Nanterre, France.
[26] Nano refers to one thousandth of one millionth. 1000 million nanometers are one meter. A human hair is about 70 000 Nanometers thick. Nanoscience and -technology deals with functional structures on a length scale of some tens to some hundreds of nanometers. http://www.nano.gov/nanotech-101/what/nano-size (accessed April 20, 2016)

References

Addington M., Schodek, *Smart Materials and Technologies: for the architecture and design professions*, Burlington, MA: Architectural Press, 2005.

Badarnah, L., Nachman, F. and Knaack, U., *Solutions from nature for building envelope thermoregulation*, Proc. of the fifth design and nature conf; Comparing Design and Nature with Science and Engineering, Carpi A& Brebbia CA (eds.), Southampton: WITpress, 2005.

Benyus M., Jenine, *Biomimicry: Innovation Inspired by Nature*, HarperCollins Publishers, 1998.

Comanns, P., Effertz, C., Hischen, F., Staudt, K., Böhme,W. and Baumgartner,W., *Moisture harvesting and water transport through specialized micro-structures on the integument of lizards* (Beilstein Journal of Nanotechnology, 2011, 2), 204-214.

Comanns, P., Buchberger, G., Buchsbaum, A., Baumgartner, R., Kogler, A., Bauer, S. and Baumgartner, W., *Directional, passive liquid transport: the Texas horned lizard as a model for a biomimetic 'liquid diode'*, Interface, Royalsocietypublishing, 2015.

Del Grosso, A.E. and Basso, P., *Adaptive building skin structures, Smart Materials and Structures*, 19(124011), 2010.

Guadarrama-Cetina, J., Mongruel, A., Medici, M-G., Baquero, E., Parker, A.R., Milimouk-Melnytchuk, I., Gonza´lez-Vin, W. and Beysens, D., *Dew condensation on desert beetle skin* (The European Physical Journal E, 2014), 37.

Gruber, Petra*, Biomimetics in architecture: architecture of life and buildings*, SpringerWienNewyork, 2011.

John, G., Clements-Croome, D. and Jeronimidis, G., *Sustainable building solutions: a review of lessons from the natural world*, Building and Environment, 40, 2005.

Lelieveld, C.M.J.L. and Voorbij, A.I.M., *Adaptable Architecture with the Application of Dynamic Materials*. In Lifecycle Design of Buildings, Systems and Materials, E. Durmisevic, ed., Enschede, The Netherlands, 2009.

Louw, G.N. and Seely, M.K., *Ecology of Desert Organisms*, London: Longman Group Ltd., 1982.

Maturana R., Hamberto and Valera J., Francisco, *Autopoesis and cognition: The realization of the living*, D. Reidel Publishing company, 1928.

Nørgaard,T. and Dacke, M., *Fog-basking behaviour and water collection efficiency in Namib Desert Darkling beetles*, Frontier in Zoology, 2010, 7:23.

Vincent, J.F.V., Bogatyrev, O.A., Bogatyreva, N.R., Bowyer, A., and Pahl, A.K., *Biomimetics – its practice and theory*, Journal of the royal society Interface, 3, 2006.

Biography

Nelson Montás, from Santo Domingo, Dominican Republic, holds an architecture degree from the Universidad Nacional Pedro Henríquez Ureña's School of Architecture and Urbanism (2006) in Santo Domingo, Dominican Republic, where he is a registered architect (CODIA 25715) and has practiced the profession since. He also holds a Master of Science in Biodigital Architecture from the ESARQ at the International University of Catalonia (2009) where he also recently fulfilled requirements for Ph.D. accreditation. He is also a visiting researcher at the Ecole Nationale Supérieure d'Architecture Paris - La Villette where he is carrying out research on Shape Memory Materials simulations using parametric tools, under the guidance François Guéna, Ph.D. As a freelance architect with a civil engineering background, he has been a designer, evaluator and construction supervisor at the Potable Water and Sewage Systems Institute in the Dominican Republic. He has also been involved in teaching, namely at the Pontificia Universidad Católica Madre y Maestra's School of Architecture and is involved in active research. (arq.montas@gmail.com)

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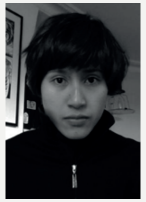
Biomimetic for Building Skin Living

ENVELOPE FOR CONTEMPORARY ARCHITECTURE

As a highly interdisciplinary field, architecture is being influenced by many subjects of natural and social sciences. While many subjects hold an indisputable effect on architecture, biological sciences are currently dominating the current era. It is totally comprehensible for architects to observe and imitate the natural phenomena on behalf of a better living. This article will present how to translate the lessons learned from the analysis and observation of the animal world to design experience. Skin is a complex and incredibly sophisticated organ that performs various functions, including protection, sensation, insulation, temperature and water regulation. The skin interfaces with the environment and is the first line of defense from external factors. Similarly, building envelopes serve multiple roles and they are the interface between the building inhabitants and environmental elements.

In architecture, the boundaries between materials and structures are blurred the same way as in nature. The study of biological systems might be useful for our purposes on how new materials can be designed. The new material is inspired by the study of how animal skins perform and respond according to their different properties; they take into consideration various dynamic local environmental conditions, creating a more sustainable way of building hence living. The projects will be focused on specific functions that were unique to the selected animal's skin. The biology of an animal and the environment it lives in determine these functions. The processes by which each animal analysis will be carried out, will innovate in the design and conception of new materials. Which will, in turn, inform new synthetic designs based on biological systems that will describe new aspects and performance of the building envelope.



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THE POWER OF SKIN

NEW MATERIALITY IN CONTEMPORARY ARCHITECTURAL DESIGN