THERMAL BIOMIMICRY IN ARCHITECTURE
reflexions on a thermal newly emerging process

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Lucie Baron

BUDAPEST UNIVERSITY OF TECHNOLOGY AND ECONOMICS
Architectural Research for Exchange Students
Department of Building Energetics and Service System

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Chief Lecturer: Csaba SZIKRA
Lecturer: Zoltan MAGYAR
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“All art is an imitation of nature.”
Seneca

“Animals, plants, and microbes are the consummate engineers. They have found what here on Earth.”
Janine Benyus
Mercedes-Benz looked towards the boxfish for their bionic car concept. Noting the aerodynamics and efficiency of the boxfish’s shape, the engineers decided to apply the characteristics of the fish to a car. The result is a very streamlined vehicle with a 65% lower drag coefficient than other compact cars out at the time (2005).
REFLEXIONS

What is the thermal comfort?

What is biomimicry in architecture?

How to use thermal biomimicry in architecture?

Examples of thermal biomimicry processes
Life on earth is made up of an ever-changing, incredibly complex network of interconnected, independant organisms. Some form of life has managed to sustain itself on earth for the past 3,8 billion years, meaning that life has survived of trial an error, testing, the selection has resulted in a 99,99% failure rate.
In other words, the species thriving today are the sucess stories.
That is the reason why designers need to consider nature a a source of energetic, environmental, technical, structural answers to the current disorders. These designs are only the start, but they provide an exciting foretaste of the lessons to be learned from biomimicry.

Why biomimicry ?
Biological design are resilient, adaptable, regenerative, multifonctional and most of the time zero waste.
Biomimicry forces a new set of questions that can be applied to the design process.
Biomimicry is an emerging paradigm that can help lauch designers into their new role as sustainability interventionists.

This research aims to have a reflexion on the energetic biomimicry, in therm of the behaviour level of biomimicry, and its application on the human confort for living or working.
INTRODUCTION
In 2013 in Monaco, the Secretary-General of the United Nations Ban Ki-Moon announced that soon it will be too late to save our planet and that our consumption pattern is incompatible with the health of the planet. "Our ecological footprint is disproportionate". Responsible for 50% of the natural resources, 40% of the produced waste, 30% of the greenhouse gas emissions and 16% of the consumption of water (according to André de Herde), the construction field has to change.

The advantages of learning from biological examples are that they benefitted from over 3.8 billion years or experiencing through evolution. In that way, they can help us for finding new solutions to answer to the actual issues for sustainable developments. As Janine Benyus said in her book, "Animals, plants, and microbes are the consummate engineers. They have found what here on Earth."

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THERMAL COMFORT
Energy-efficient buildings are only effective when the occupants of the buildings are comfortable. If they are not comfortable, then they will take alternative means of heating or cooling a space. But its high subjectivity makes the thermal comfort difficult to measure, depending on the air temperature, humidity, radiant temperature, air velocity, metabolic rates, and clothing levels. In that way, each individual experiences are based on our physiology and state.

According to the ANSI/ASHRAE Standard 55-2010, thermal comfort is defined as "that condition of mind which expresses satisfaction with the thermal environment and is assessed by subjective evaluation."

A cold sensation will be pleasing when the body is overheated, but unpleasant when the core is already cold. At the same time, the temperature of the skin is not uniform on all areas of the body. There are variations in different parts of the body which reflect the variations in blood flow and subcutaneous fat. The insulative quality of clothing also has a marked effect on the level and distribution of skin temperature. Thus, sensation from any particular part of the skin depend on time, location and clothing, as well as the temperature of the surroundings.
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How to measure the thermal comfort?

Six factors determine the thermal comfort:

- **Metabolic rate**: The energy generated from the human body,
- **Clothing insulation**: The amount of thermal insulation the person is wearing,
- **Air temperature**: Temperature of the air surrounding the occupant,
- **Radiant temperature**: The weighted average of all the temperatures from surfaces surrounding an occupant,
- **Air velocity**: Rate of air movement given distance over time,
- **Relative humidity**: Percentage of water vapor in the air.

As we can see, the thermal comfort depends on objective factors, including the air temperature, radiant temperature, relative humidity, and air velocity. But it also depends on subjective factors, including the metabolic rate and clothing. A comfortable place for one person won’t compulsory be comfortable for someone else.

Thermal comfort is calculated as a heat transfer energy balance. Heat transfer through radiation, convection, and conduction are balanced against the occupant's metabolic rate. The heat transfer occurs between the environment and the human body, which has an area of 19 ft². If the heat leaving the occupant is greater than the heat entering the occupant, the thermal perception is "cold." If the heat entering the occupant is greater than the heat leaving the occupant, the thermal perception is "warm" or "hot."
The six parameters which determine the thermal / human comfort
Predicted Mean Vote

The Predicted Mean Vote, or PMV, refers to a thermal scale running from Cold (-3) to Hot (+3). It relates the six thermal comfort factors listed above to each other through heat balance principles and produces a sensation scale. The recommended acceptable Predicted Mean Vote range is between -0.5 and +0.5 for an interior space, according to ASHRAE 55.

Predicted Percentage of Dissatisfied

The Predicted Percentage of Dissatisfied, or PPD, refers to the percentage of dissatisfaction of the occupants in a room, concerning the thermal conditions. The recommended acceptable PPD range is less than 10 % of persons dissatisfied for an interior room, according to ASHRAE 55.

Adaptive Comfort

When people feel uncomfortable in the thermic surrounding environment, people generally change their behaviour in order to restore their comfort. That what is called adaptive comfort. This can be by the way of changing clothes, changing activity level or acting directly on the surrounding environment, as opening or closing a window. Some designers work a lot on the possibility to have a great degree of control over the thermal environment, such as in the naturally ventilated buildings.

ANSI/ASHRAE Standard 55 (Thermal Environmental Conditions for Human Occupancy) is a standard that provides minimum requirements for acceptable thermal indoor environments, conditions that are considered as acceptable to a thermal comfort for occupants. The most recent version of the standard was published in 2013.
The recommended PMV is between -0.5 and +0.5, and the recommended PPD is less than 10% of dissatisfied.

The seven points scale

-3 cold  -2 cool  -1 slightly cool  0 neutral  +1 slightly warm  +2 warm  +3 hot
BIOMIMICRY IN ARCHITECTURE
Biomimicry, before?

2100 years ago, the roman architect Vitruve used to define the architecture as an “imitation of the nature”. He applied this theory by comparing temples proportions to the human and natural ones.
Eight centuries ago, Chinese people in the village of Hongcun were considered as the first bionic architects. They set out their village in a shape of a cow, while creating an hydraulic network in a shape of its digestive system.
During the Industrial Revolution, a lot of constructions were inspired by the meaningful system found in plants and animals, such as the Bary’s greenhouse, Lily House, in Strasbourg, or the Crystal Palace in London, designed by Joseph Paxton.

Bary’s greenhouse, Strasbourg, Joseph Paxton
Several architects and engineers, such as Frei Otto or Frank Lloyd Wright designed buildings by copying natural shapes with specific structures and proportions. For example, the Olympic Stadium of Munich, the Guggenheim in New York, or the headquarters of S.C. Johnson & Son Inc.
“When we look at what is truly sustainable, the only real model that has worked over long periods of time is the natural world.”

Janine Benyus
What is biomimicry?

In her book “Biomimicry: Innovation Inspired by Nature” in 1997, the scientist and author Janine Benyus defines the term biomimicry as a “new science that studies nature’s models and then imitates or takes inspiration from these designs and processes to solve human problems.”

The goal is to create products, processes, and policies—new ways of living—that are well-adapted to life on earth over the long haul. The core idea is that nature has already solved many of the problems we are grappling with. Animals, plants, and microbes are the consummate engineers we have to inspire from.

We can also consider three levels of biomimicry that may applied to a design problem, such as the form, process and ecosystem. Form and process are aspects of an organism or ecosystem that could be mimicked. Ecosystem however is what could be studied to look for specific aspects to mimic.

Designing intelligent building inspired by nature

To design a biomimetic building, it is important to recognize the problem we are confronted to, and then to look about how do the nature could have solved the same problem. As part of a final thesis in 2006 about the imitation of natural intelligence on the buildings, Brian Atkins declared three parameters to create an intelligent building:

- Buildings have to **know** what is happening inside and outside,
- Buildings have to **choose** the most efficient way in order to keep a comfortable, convenient, and efficient environment,
- Buildings have to **react** quickly to changes.
HOW TO USE THERMAL BIOMIMICRY IN ARCHITECTURE?

Examples of thermal biomimicry processes
We can list some simple lessons learnt from nature to apply to buildings:

- Use waste as resource,
- Diversify and cooperate to fully use the habitat,
- Gather and use energy efficiently,
- Optimize materials sparingly,
- Don't foul their nests,
- Don't draw down resources,
- Remain in balance with the biosphere,
- Run on information,
- Shop locally.

CH2 Building in Melbourne, Australia
Mick Pearce, 2006
The organisms which learn how to survive in our environment evolve. This all depends on the type of behavior that the organism exhibits in the environment. Not only do well adapted living organisms evolve but also the organisms that learn how to evolve by watching the behavior from other organisms.

In behavior level of biomimicry, it is not the organism itself that is mimicked, but its behavior.

An architectural example of process and function biomimicry at the behavior level is demonstrated by Mick Pearce’s East gate Building in Harare, Zimbabwe and the CH2 Building in Melbourne, Australia.

Both buildings are based in part on techniques of passive ventilation and temperature regulation observed in termite mounds, in order to create a thermally stable interior environment.
The architect Mick Pearce worked with Arup Group limited to create a termite-inspired ventilation system to cool a building in Harare, Zimbabwe. Instead of air-conditioning, the Eastgate building is modeled on the self cooling mounds of termites that maintain the temperature inside their nest to within one degree of 31 °C, day and night while the external temperature varies between 3 °C an 42 °C.
Countercurrent Heat Exchange
Inspired By Birds

Animals living in extreme conditions of climate developed some particularities in order to confront and survive to the cold or hot. Ducks and penguins living in cold climates developed some innovative adaptation. The veins and arteries in their feet have a countercurrent configuration, warming the blood close to the animal’s core and cooling the blood at the edge of their extremities. This system is made in order to maximise efficiency. Some designers adapted that system to ameliorate the design of shell tube heat exchangers used for industrial-scale heating and cooling.
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Breathing façade inspired by the natural skin

In his project, Tobias Becker thought about a new technology, inspired from biomimicry, and especially from the organic skins. As the skin, the system consists on the control of the necessary flow of light, matter and temperature between the inside and the outside.

By increasing or decreasing the size of the apertures that are scattered across the façade, the façages changes constantly, creating in the same time a particular feeling with the environment. The ever-changing pneumatic muscles allow a specific amount of air, light and visibility, according to the user’s preference.

The concept appears to be limitless, for flat or sinuous curved surfaces, with white or colorful and translucent or opaque muscles.

Two glass surfaces are sandwiching the pneumatic muscles. In the area between the two glass panels, only a slight underpressure is required to opening each muscle.

Operating a breathing skin façade would require minimal energetic input.

Mandelbachtal, Germany, Tobias Becker
Life on earth is made up of an ever-changing, incredibly complex network of interconnected, independant organisms. Some form of life has managed to sustain itself on earth for the past 3,8 billion years, meaning that life has survived of trial an error, testing, the selection has resulted in a 99,99% failure rate. In other words, the species thriving today are the sucess stories. Some principles are even common across species and are found across almost all organisms. These principles that we call Life’s Principles are intented to represent nature’s strategies for sustainability, that is, how life has sustained on earth for billions of years.

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How biomimicry can be applied to architecture, Michael Pawlyn, Financial Time, 2016

Breathing Skins Showroom, Archdaily

5 Natural Air-Conditioning Designs Inspired by Nature, National Geographic

Beyond biomimicry: What termites can tell us about realizing the living building., J Scott Turner and Rupert C Soar

Breathing facades: a new concept to create dynamic thermal ambiance in buildings located in hot climates. Mahmoud Elghawaby.

Biomimicry - Architecture learnt from the nature, Ateeb Hussein, 2015

Is biomimicry the answer to environmentally sustainable architecture? Annabelle Brading

 References

Thermal comfort in buildings, Designing Buildings Wiki

Le confort thermique (the thermal comfort), energie-environnement

Le confort thermique (the thermal comfort), Energie - efficacité des bâtiments tertiaires

Biomimicry in architecture, Michael Pawlyn, Riba Publishing, 2011

Biologie et architecture - Cité des insectes et des sciences naturelles, Immersion dans le cas de la biomimétique, Ben Mansour Oumnia, 2015

Le biomimétisme: une architecture vivante, les écosystèmes naturels: application aux systèmes humains, Laura Schermesser, 2014

Biomimicry Institute, Janine Benyus

Ted talk and web site
“The architectural profession is rapidly embracing digital design technologies developed and applied in the framework of biologically inspired processes. Put simply, nature is the largest laboratory that ever existed and ever will.”

Michael Fox and Miles Kemp
Interactive Architecture