REDESIGN OF THE INTEGRATION OF BUILDING ENERGY FROM METABOLISMS OF ANIMAL: THE *RIMA* PROJECT

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ABSTRACT

Buildings are a very special kind of machine. In terms of hygrothermal conditioning, it can be said that they switch on and off to maintain a regular temperature in relationship with the activities carried out inside of them. It is a strategy very similar to that developed by the 'warm blooded' animals, which maintain their temperature with a high metabolism rate.

There are numerous passive strategies in architecture that allow to have an effective control over the indoor conditions in order to maintain the levels of comfort needed for human habitability with a lower energy consumption. In the same way, animals have several methods for thermal regulation. Some of them are the *rete mirabile* structure in tuna, the regulation of the temperature in a bee hive or the control of the gases inside a silkworm cocoon.

With these precedent ideas, the researchers will explain a project funded by the Spanish Economics and Competitiveness Ministry. The project tries to explore new design strategies for the energy and building services systems in buildings from biomimicry concepts. The main source for this research will be a thorough analysis of the 'cold blooded' animals' metabolisms, although other temperature control methods of other living beings will be taken into consideration. The project proposal is to create a new way of thinking how energy and building services are integrated and designed in a building, taking into consideration the knowledge imported from a different area of knowledge.

Therefore, the project proposes a reassessment of the paradigm established of the methodology used for design the energy systems in buildings, with an approximate technical view from other areas of knowledge.

Keywords: Integration, energy, metabolism rate, building services, architecture

INTRODUCTION

Below, 'What' is the project and 'Why' the researchers have chosen this working path is exposed.

- What? The architect members in the project are involved in the design, calculation and execution of building services and energy systems in singular buildings since 2000 [1]. These singular projects also require singular solutions with alternative point of view, and in this **highly innovative solutions searching framework** is where it must be understood what it is sought in the project.
- Why? The dynamism of the current society and the requirements demanded to the architecture and construction make essential theoretical and technical reformulations. These may be obtained from the architecture itself or based on the existence of consolidated knowledge in other areas.

Solving these requirements from the knowledge platform representing biology, involves the use of already optimized models during thousands of years that own extraordinary operation systems in regard to the energy optimization. Even though, they require a 'technological' translation for their application in the architecture that is not always neither evident nor direct.

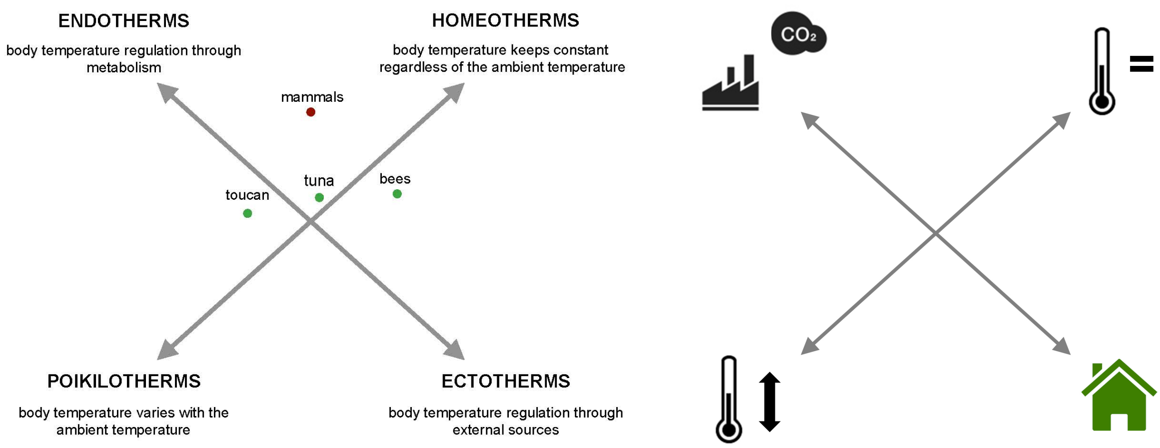

Figure 1: These images show the parallelism between animals and buildings. On the one hand, animals can be classified regarding their mechanism for heat gains; this concept in buildings is extrapolated to the classification regarding the CO2 emissions. On the other hand, animals can be homeotherms or poikilotherms in regard to their temperature variation in relation with the ambient temperature, in buildings is assumed as well the indoor temperature variation depending on the use of the spaces.

METHODOLOGY

How is a project of this nature conceived? Given its singularity, it has also been necessary an alternative approach different from 'traditional' projects developed by the team of architects and biologists.

- Firstly, it has been necessary a knowledge compilation from biology that was understandable for architects. So that, numerous technical datasheets have been created in order to compose an analysis basis from which to make proposals development. It has drawn the attention of the researcher the lack of existence of biology database from an engineering point of view [2]. In this case, the data sheets generated in the project gather the technical data from the animals that could be relevant for architects such as body and ambient temperatures or climate and location. In a brief summary the main strategies of the animals are described and the possible application ideas related with the architecture are listed. In order to facilitate a deeper analysis the datasheet includes the references used for the descriptions.
- Communication (meetings, emails, telephone…) between the team of biologists and architects has been abundant and flowing.
- Given the staff and economical limitations, only the possibilities that could be completed within the timeframe of the project were selected to develop.
- The main references in the world of biology that would apply in architecture were selected from the analysis and working meetings. The extrapolation of results to architecture was performed with the modelling, simulations, and scale-models of architects.

This analytical data sheets have been the absolutely necessary starting point for the development of the project and several months of work were required for their execution. However, they require longer work path that would necessitate additional time and personnel.

RESULTS – 3 EXAMPLES

The researchers have proposed several working plans, always with cold-blooded animals since that was the basis of the project. However, this paper collects the three most developed strategies so far, given the limitations of the space for their exposition:

Tuna's *rete mirabille*

These large fishes own a characteristic that only a few fishes share: the counter current heat exchanger also known as *rete mirabile*. This system allows tuna to achieve and maintain higher body temperatures than ambient temperatures, so that, tunas tolerate to swim in deep seas.

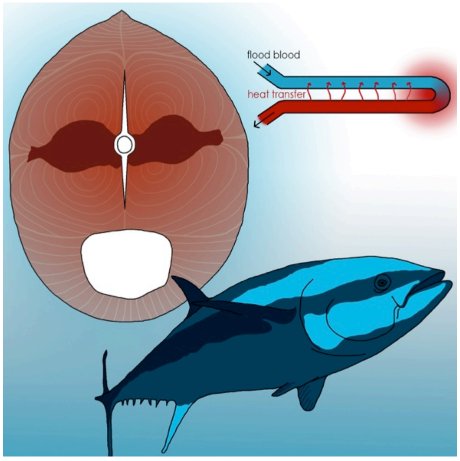

Figure 2 (left): Tuna's thermal behaviour in water. Despite the cold environment where it lives, tuna's body temperature is higher and stable thanks to the inner disposal of dark muscles and the redistribution of heat in the rete mirabile. */ Figure 3 (right): The researchers are currently developing heat recovery system for office buildings optimized from Tuna's thermal behaviour.*

The heat is generated in the central tissues, muscles and organs, named red muscles. This is distributed throughout the blood vessels net to the areas with direct contact with the external ambient. Here, since the blood vessels are in parallel, the heat is transferred to the coldest blood current, thus maintaining an optimal temperature for its operation [3].

The tunas are a perfect example of heating storage, distribution and optimisation. According to architectonical application there are several questions that may be studied such as, what if the high thermal load spaces are located in the center of a building? And what if a heat recovery system is designed/installed to use this heat for other locals? Given the relation between the red muscles percentage of the total volume and the efficiency of the *rete mirabile* [4], can we obtain the optimal relation between the ratio high thermal load space-to-whole building?

First approaches of the researchers have shown that a 'tuna organisation' in office buildings guarantees lower heating demand than other spaces distributions, merely attending to the space distribution.

Toco-toucan and the heat dissipation

In the opposite side of tuna's heat storage and distribution is the heat dissipation. Like other birds, the toucan uses its bill for heat dissipation. In this case, toucan has the largest bill in relation to the body volume [5].

The toucan is able to regulate its heat loss through its bill due to the blood vessels grid on it. This system allows the loss of the excess heat generated by the toucan (during flight) or by high ambient temperatures. It can dissipate 400% of the generated heat when it is beneficed from favourable airstreams [6].

Nowadays in buildings, the use of cooling towers in cooling systems is widespread. Unlike the toucan, the heat dissipation in cooling towers is achieved due to evaporative cooling, carrying legionella risk and high maintenance costs [7]. So that, it may be ask, what if we avoid the use of cooling towers? Is it possible to replace the cooling towers in buildings by a cooling system based on natural convection?

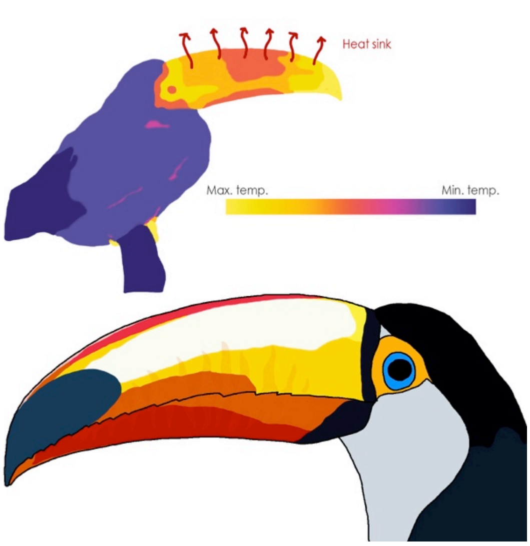

Figure 4 (left): Toco – toucan heat sink. The bill of the toucan is not only a sexual attraction item. It also has thermal properties. Thanks to its large surface, it works as a heat sink, releasing heat and maintaining body temperature lower. / Figure 5 (right): The researchers are working on a heat dissipation system in buildings that will allow the deletion of cooling towers. The solution involves larger machines (like the tuna case) but will eliminate the complex maintenance easements of cooling towers.

Bees

Bees and other social insects are well known because of their good organization within hives. Some of the specimens may work focused on foraging, other ones on defending the colony, some others take care of larvae.

In terms of thermal regulation, automated functions and strategies are also implemented within a hive. The case of the beehive is remarkable as bees can both regulate their temperature when the ambient temperature is high and low.

The most important place of the beehive is the brood comb where larvae are engendered. There, the temperature must be constant and within some tight limits: 32º C to 36º C [8]. In order to achieve these temperatures, bees show up three different strategies: one for heating and two for cooling.

Heating. Bees leave empty some places amongst larvae. They make use of these ‘holes’ to locate themselves and generate heat by contracting their thoracic muscles. In this way, heat is released ensuring a good brood development.

Cooling. In order to achieve a general cooling process inside the beehive, some specimens try to catch some water droplets and spread them within the colony. Some other individuals place in the entrance of the hive and flap their winds to produce wind mimicking a fan. This combination of facts creates an evaporative cooling effect within the hive.

If bees want to avoid heat from entering into the hive, they can do it locally. Using a technique called ‘heat shield’, bees are placed between the ‘walls’ of the hive and the larvae catching the external heat. Once they cannot absorb more heat, they go away and cool themselves flying or even regurgitating the nectar. [9]

This strategies, may lead to a different way of designing building services. Could be more effective to place autonomous machines than a big one to supply heating or energy? Could some spaces be isolated by using removable thermal cushions?

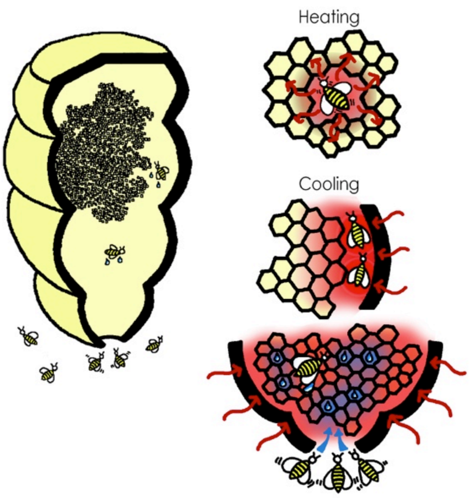

Figure 6 (left): Beehive thermal regulation. Bees are able to control the inside temperature within their hive. Both for cooling and heating, bees develop strategies to increase or decrease temperature. / Figure 7 (right): The researchers have developed two prototypes of HVAC equipment with Peltier cells that would allow an autonomous HVAC system without a central ‘brain’.

CONCLUSION

Even though the initial intuition that originated the project was optimistic about the results that could be achieved, the project has demonstrated the possibilities:

- The possibilities of future projects cover a wide spectrum, from the temperature and humidity control by passive measures (without machines) to the redesign of control networks based on nature’s neuronal networks. Architects and engineers will be who would select ‘what’ according to their lines of work.
- The multidisciplinary collaboration with biologists, is comprehended as essential as neither architects nor engineers know sufficiently in depth this subjects, but it is also true that biologists do not know the full potential of applying their knowledge in other areas [10].

The information exposed here will have a greater development in the technical papers that are being prepared right now. However, the exposition of these data in a forum like CISBAT intends to insist on the importance of the extrapolation of this working methodology to other projects and researchers.

ACKNOWLEDGMENTS

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