Introduction

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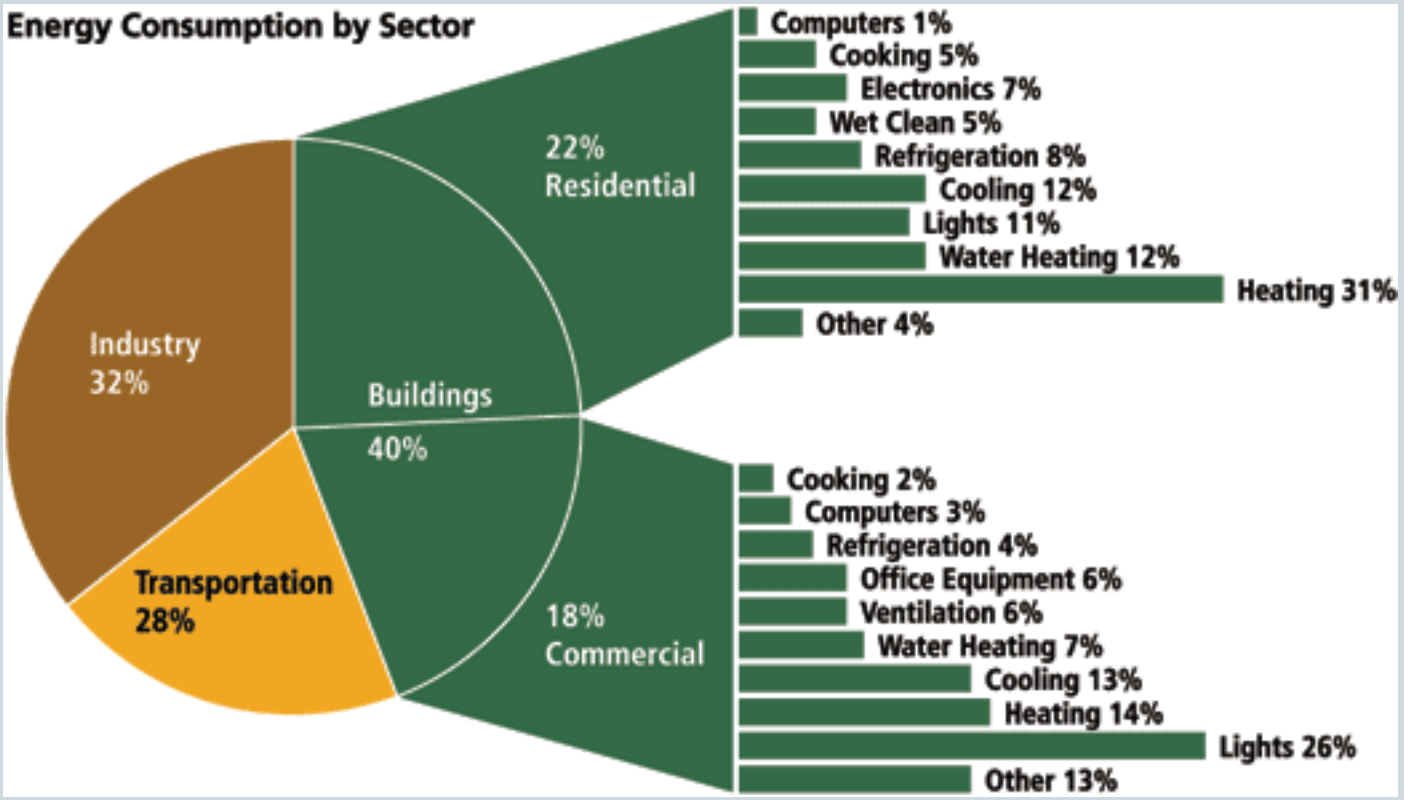
Research objectives: Activity of design, sustainable development and digital instrumentation for architecture and urban planning

Biomimicry

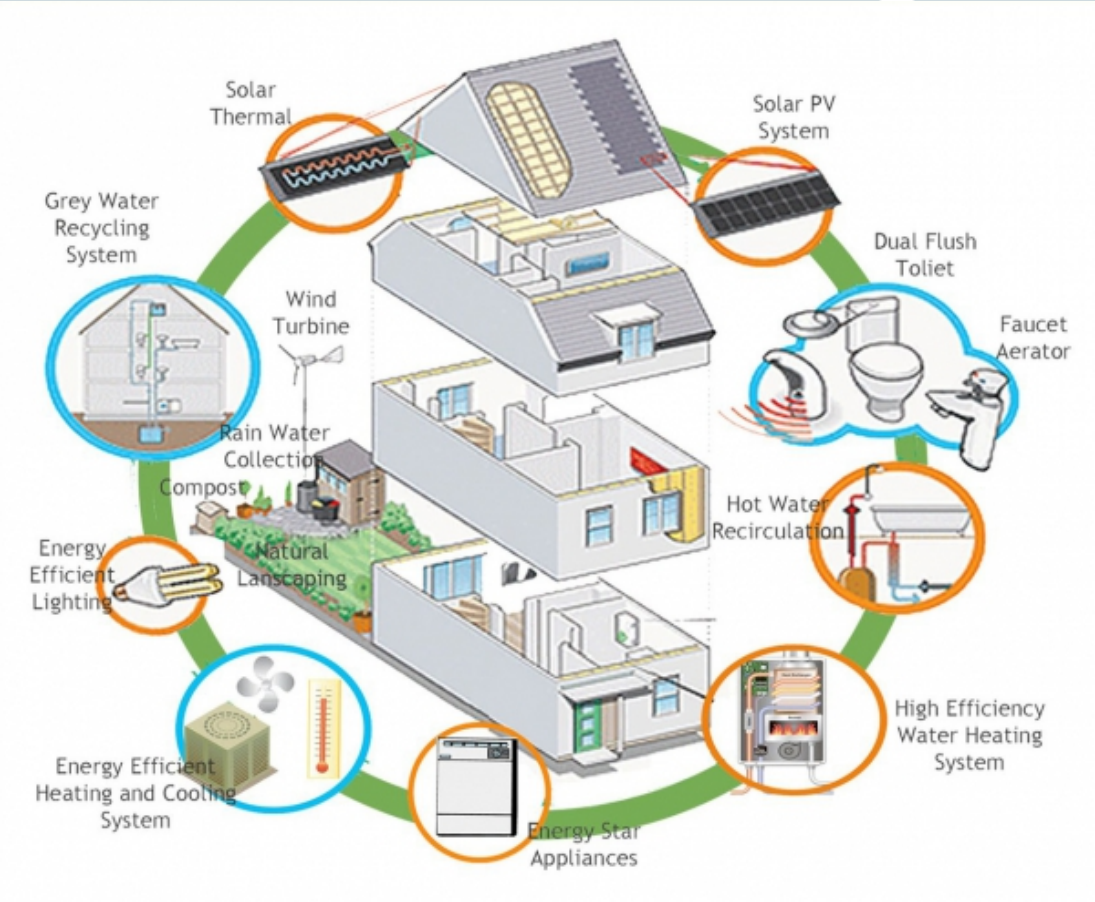
OPTIMISATION STRATEGY FROM NATURE TOWARDS SUSTAINABLE SOLUTIONS FOR ENERGY-EFFICIENT BUILDING DESIGN

Building and Energy



Building sector is the largest end-use energy consumption

Building and Energy



Sustainable products means…

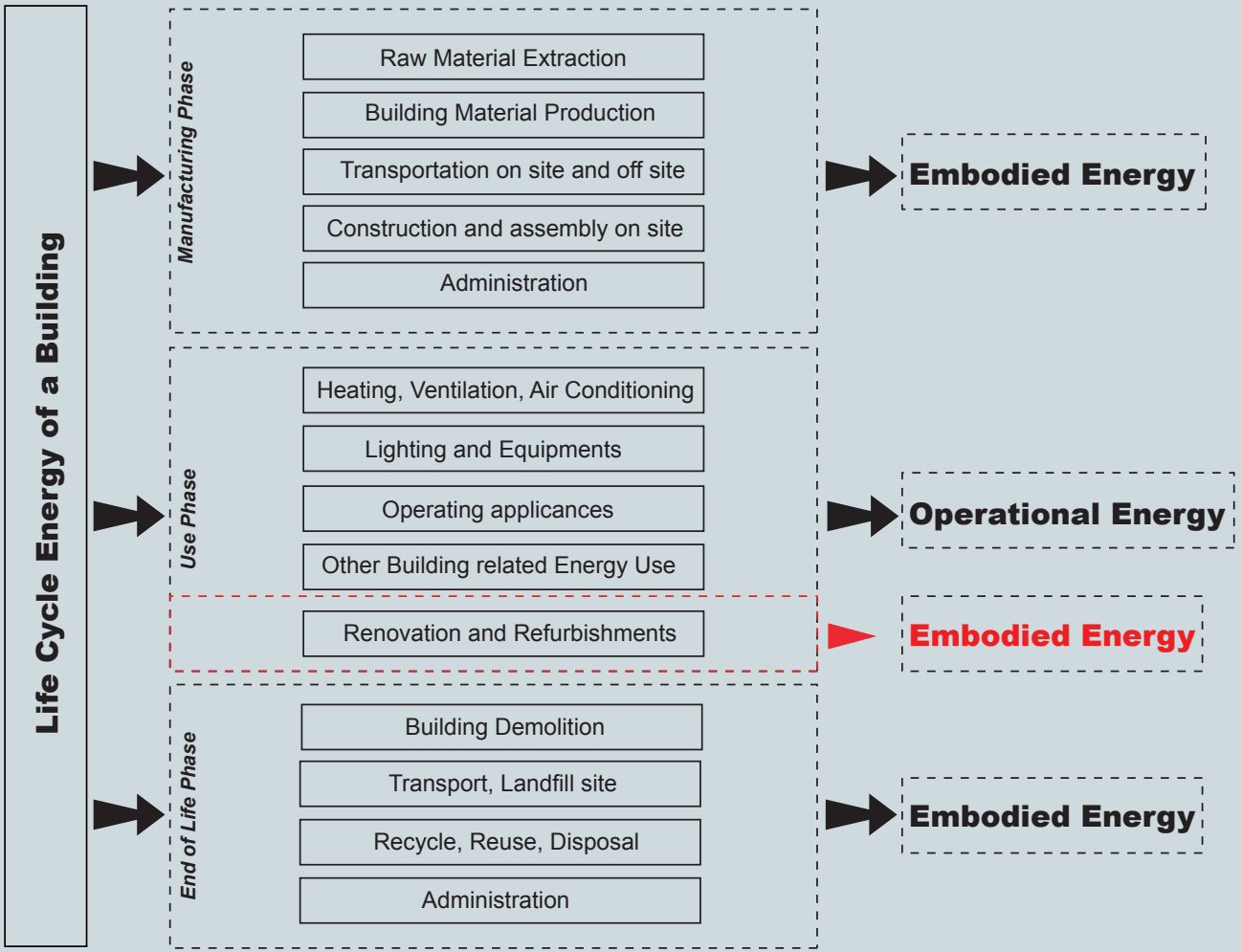
Sustainable in its manufacture

Or

Sustainable in its application ?

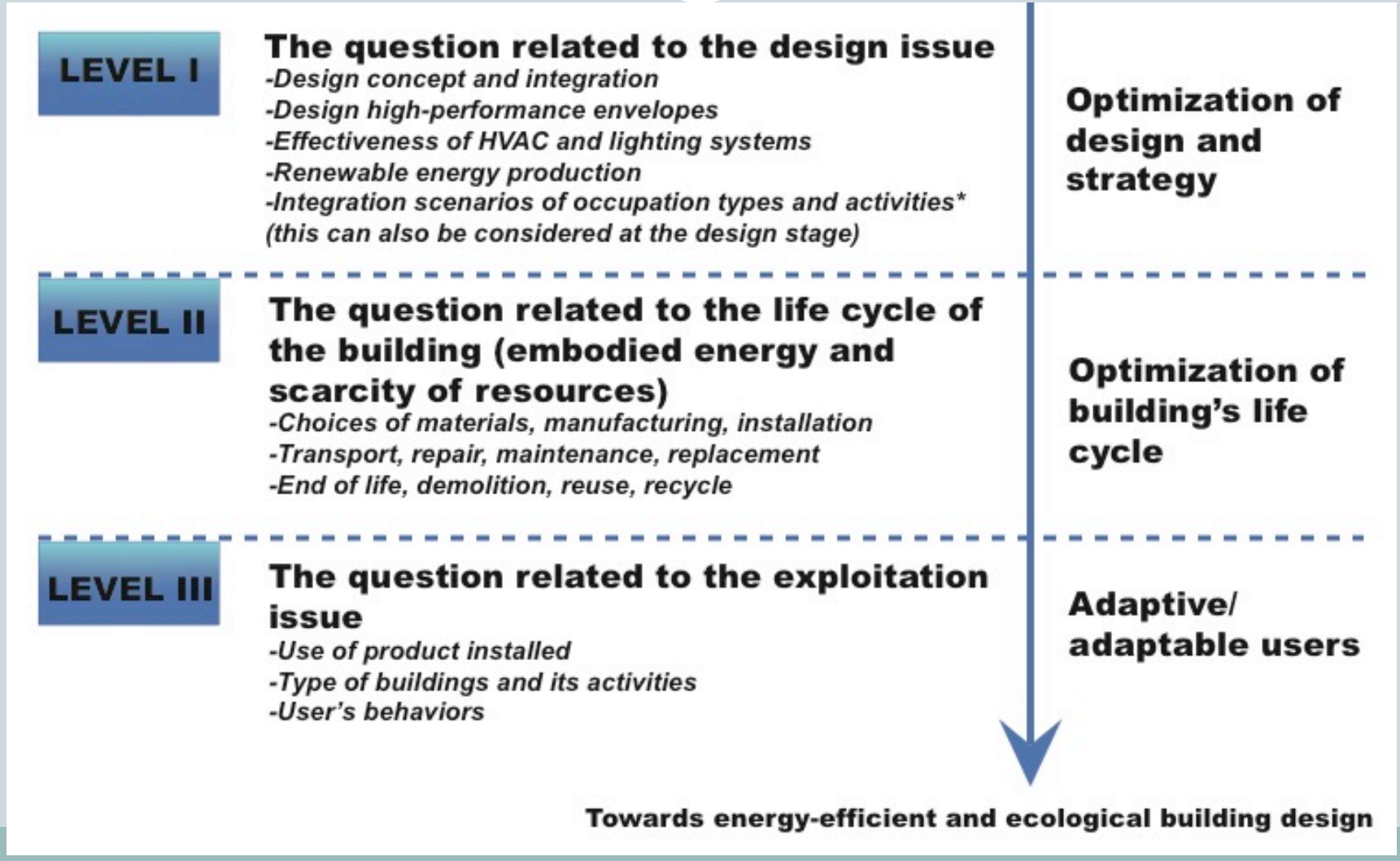
Towards ecologically energy efficient building design is not just the result of applying one or more insolated technologies, rather it is an integrated whole-building design process including its life cycle along with an understanding of building occupancy and activities

Types of energy

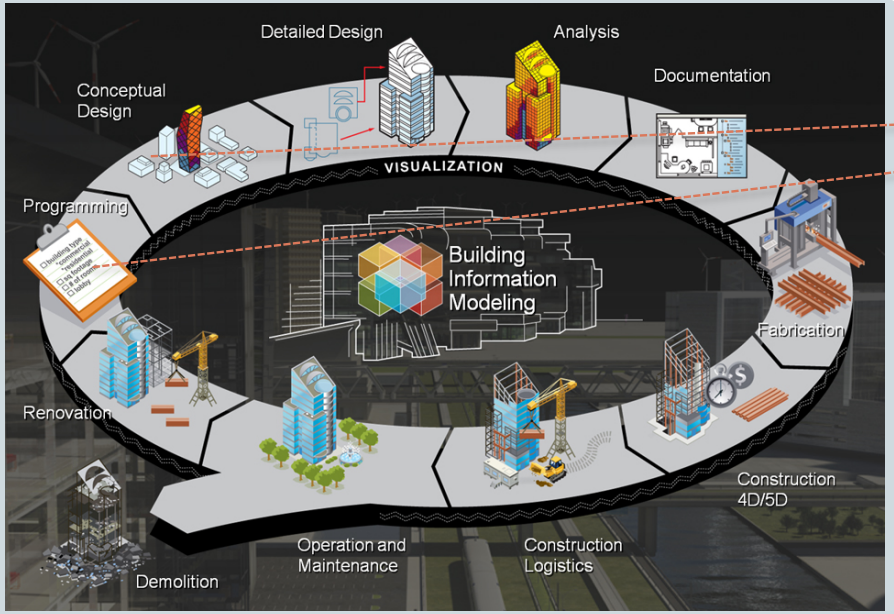


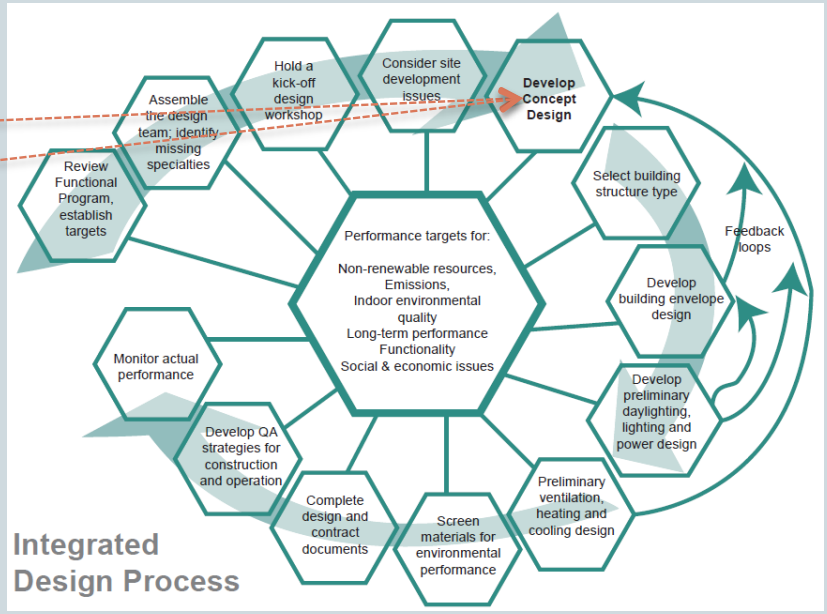
Life cycle energy of the building and types of energy in each phrase

The 3 issues related to energy-efficient building design towards sustainability



The questions related to design issue

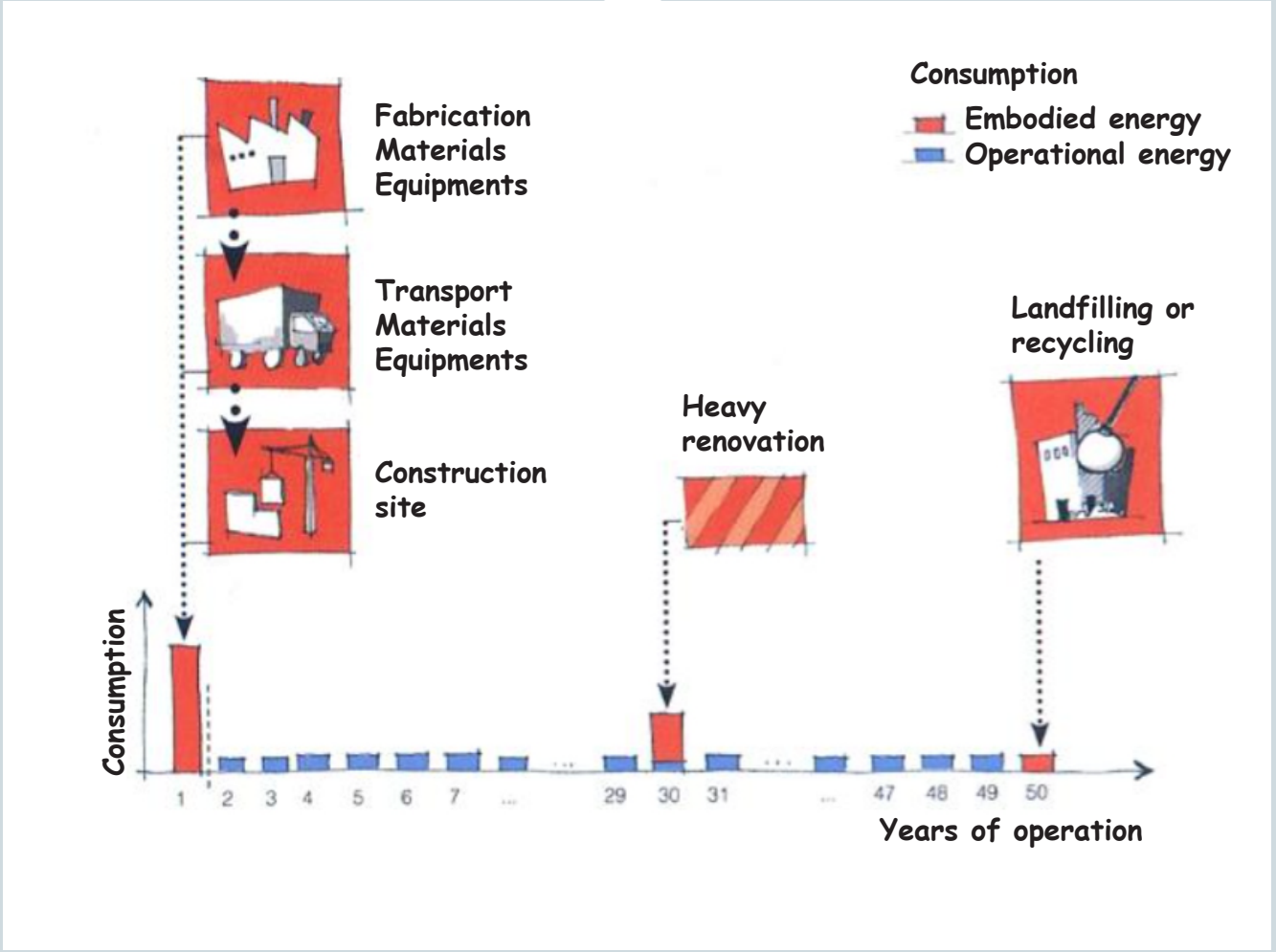




During pre-design and design phase can effect the whole operational and embodied energy. Because architects can envisage multi-criteria requirements, such as, envelop design (reduce overall energy of the building), material choices (transportation, manufacturing and end of life), HVAC systems, user types and their activities.

There are two types of approaches ‘technology and low-cost’ one that is more towards new technologies and the other more passively oriented. We need to understand the advantages and limitations of the two approaches according to multi-criteria requirements and specificity of the project.

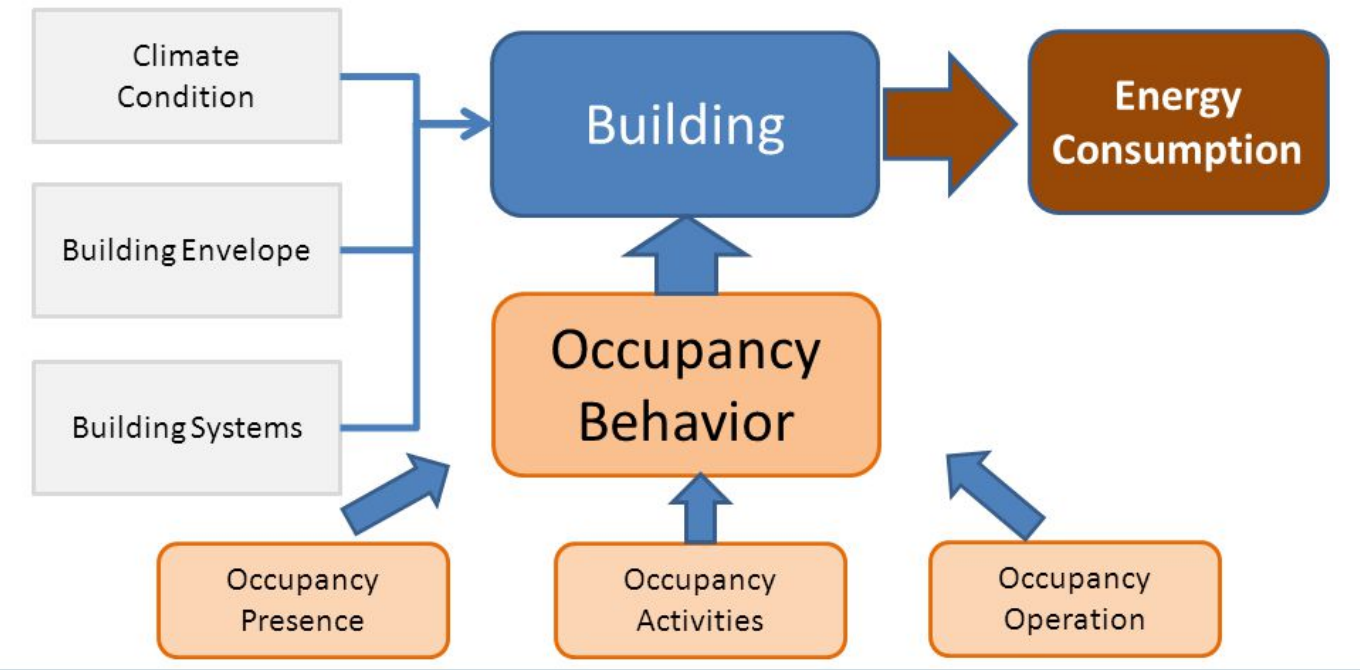
The question related to the life cycle of the building (embodied energy and scarcity of resources)



An example of distribution of consumption on an office building

The question related to the exploitation issue

BUILDING ENERGY PERFORMANCE AND OCCUPANT BEHAVIOR



One of the most significant barriers for achieving the goal of improving energy efficiency of buildings is the lack of knowledge about the factors determining the real energy use. Often, there is a significant discrepancy between the designed and the real total energy use in buildings. The reasons of this gap are generally poorly understood and largely have more to do with the role of human behavior than the building design. Recently, there are many studies focus on investigate the influence of occupant behavior on the energy performance of a building

Nature seems the only true sustainable example

We learn that natural organisms are resilient, optimized, adaptable, based on systems and values that allow life to survive and evolutionary develop.

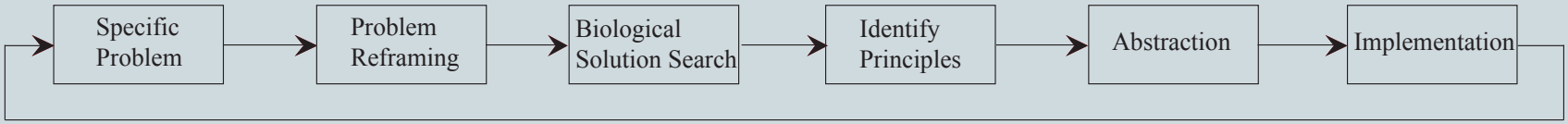
Biomimicry

Since a prehistory, man has been always inspired by nature. But the concept of Biomimicry is beyond just a concept of bio-inspiration. It is considered as a new scientific method that combine interdisciplinary collaboration to develop innovations towards sustainability.

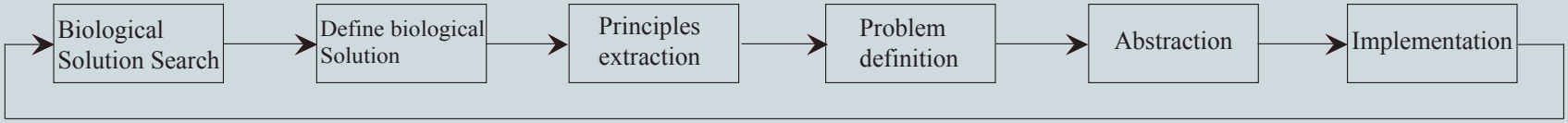
The term biomimicry was invented by the biologist and environmentalist ***Janine Benyus***, author of the book ***Biomimicry: Innovation Inspired by Nature, 1997***. Biomimicry is defined in her book as a new science that studies nature in order to imitate it or to draw inspiration from it to solve human problems. ***The concept of biomimicry, as supported by J. Benyus, proposes to draw inspiration from the brilliant ideas developed in nature to design our innovations from a perspective of sustainability***. Benyus suggests ***looking at nature as a model, measure or mentor***.

1. *Nature as a Model*: Biomimicry studies the models of nature, then imitates or draws inspiration from their characteristics to solve human problems.
2. *Nature as Measure*: Biomimicry proposes to use the standards of ecology to judge the 'rightness' of our innovations. After 3.8 billion years of evolution, nature has learned: what works, what is appropriate, what lasts.
3. *Nature as a Mentor*: Biomimicry is a new way of considering and appreciating nature. It introduces an era based not on what we can extract from the natural world but on what we can learn from it.

The Process sequences in biomimetic research



(a)



(b)

(a) Top-down process: *is to start with a human need or a design problem and then to look at how other organisms or ecosystems in nature solve this problem, also named 'problem driven' or 'design looking to biology' approach.*

(b) Bottom-up process: *is to identify a particular characteristic, behavior or function in an organism or ecosystem, and then to investigate what design problem it might address, also named 'solution-driven' or 'biology influencing design' approach.*

The 3 levels of Biomimicry

ORGANISM

refers to a specific organism like a plant or animal and may involve mimicking part of or the whole organism

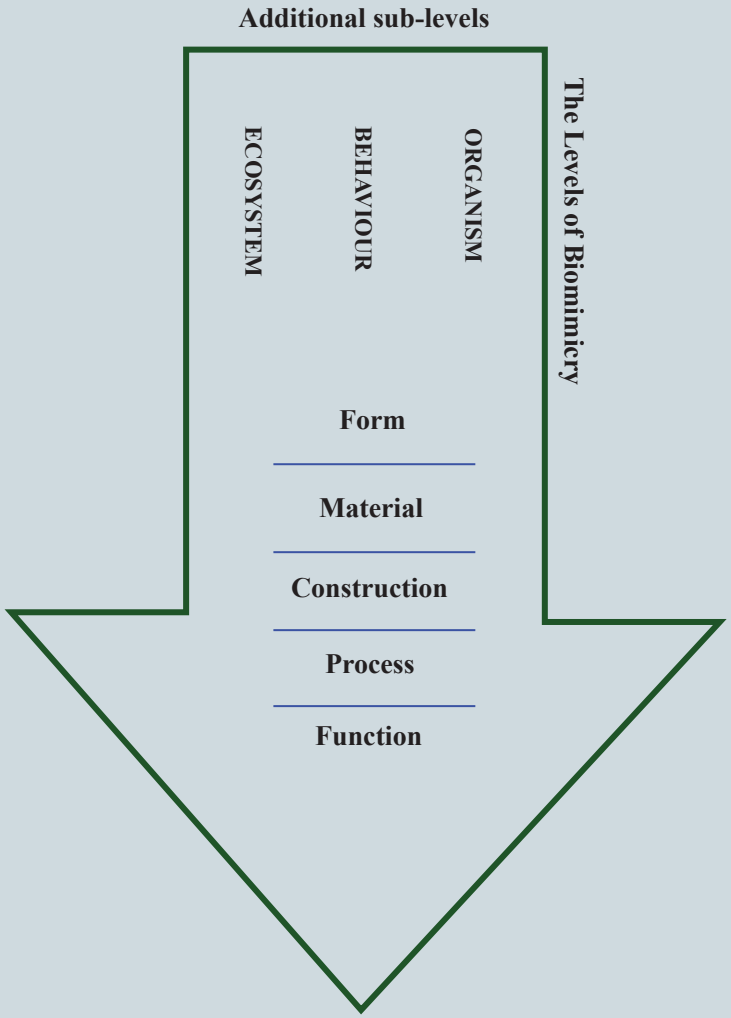
BEHAVIOUR

to explore and understand how an organism relates and behaves in its own environment

ECOSYSTEM

intends to create a whole ecosystem, which incorporates the other two levels to achieve a sustainable environment.

The 3 levels and 5 sub-levels of Biomimicry in Architecture



Within each of the three levels, a further five possible dimensions to the mimicry exist. The design may be biomimetic for example in terms of :

what it looks like (form)

what it is made out of (material)

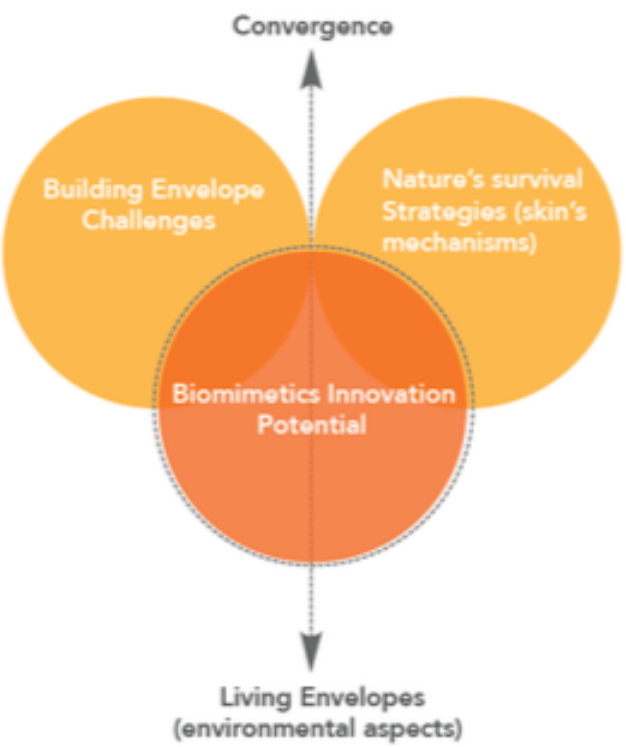
how it is made (construction)

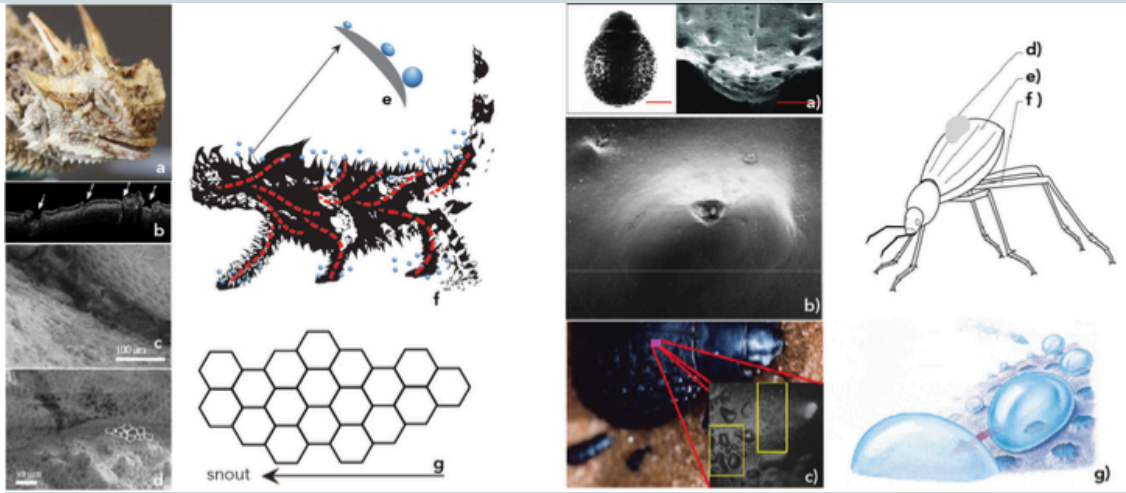
how it works (process)

what it is able to do (function)

Biomimetic Approaches to Architectural Design for Increased Sustainability, Zari, 2007

Example of Biomimetic design project *Organism*





Problem specific: *Water shortage, arid area*

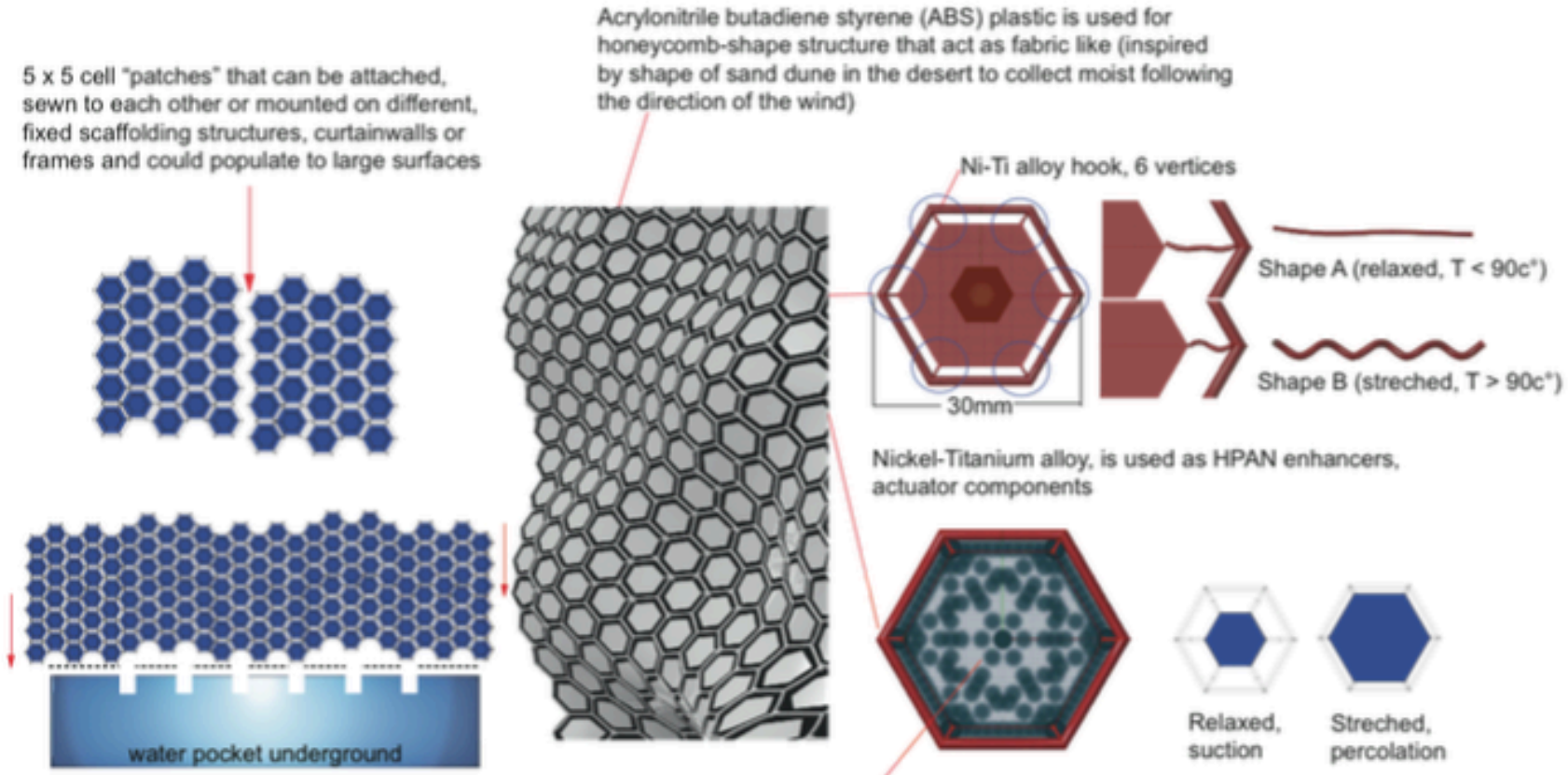
Design: *New Material for a contemporary envelope*

Approach: *Biomimetic design process*

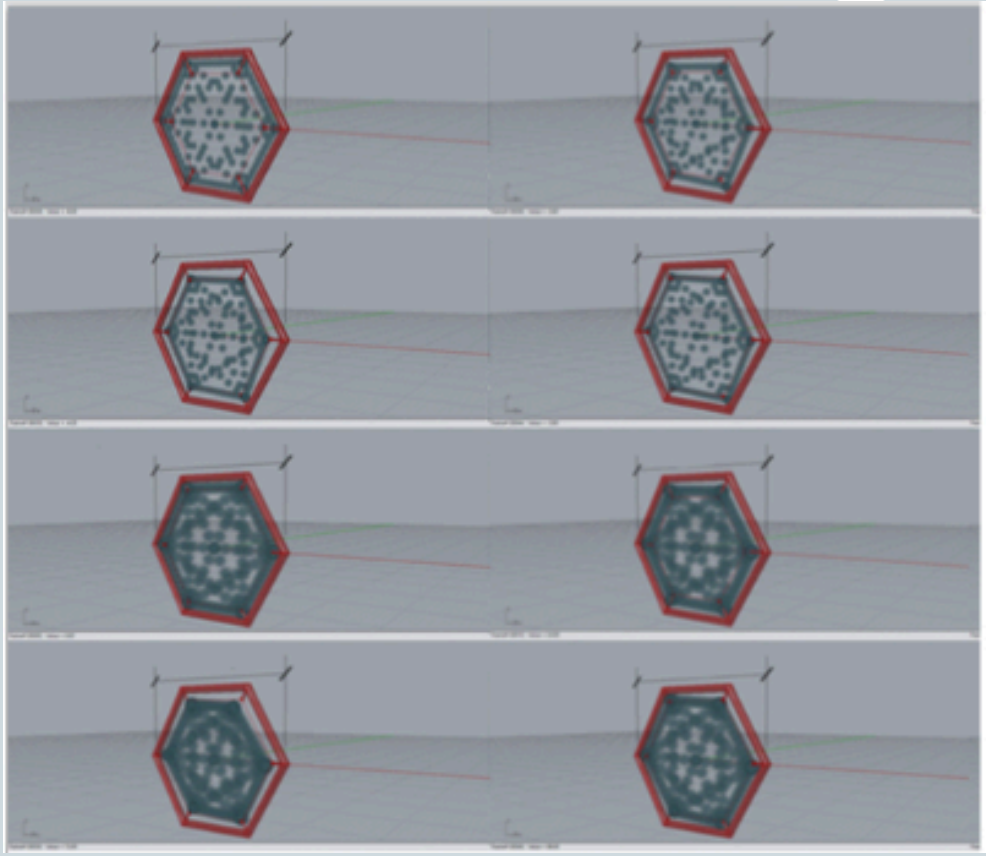
Observe/study nature (Biology) -> Abstract/Transfer -> Application

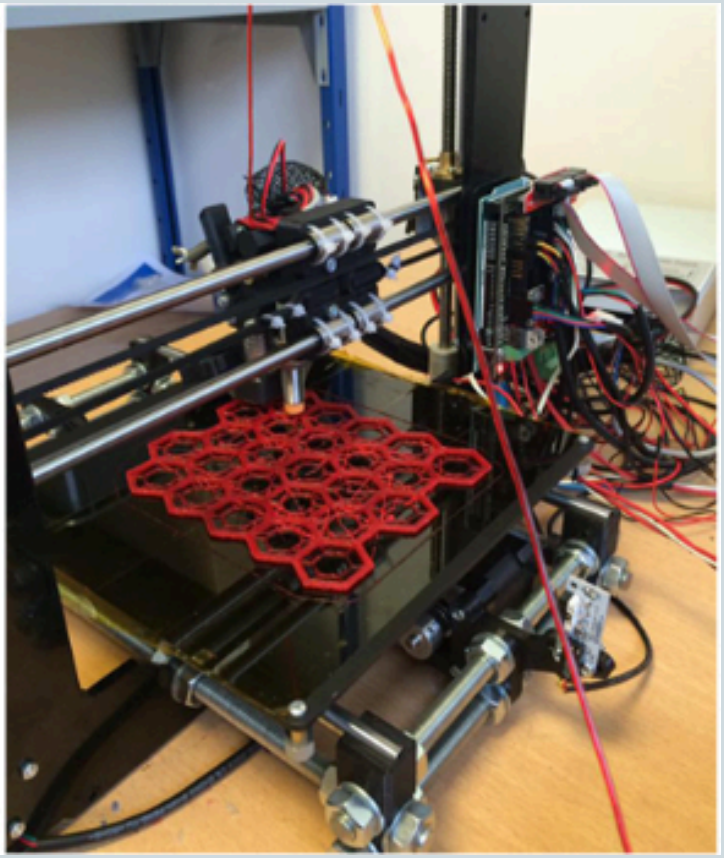
Animals' skin properties (arid area) *Hygroscopic (absorb)* *Smart Material (SMM & HPAN)*

Example of Biomimetic design project



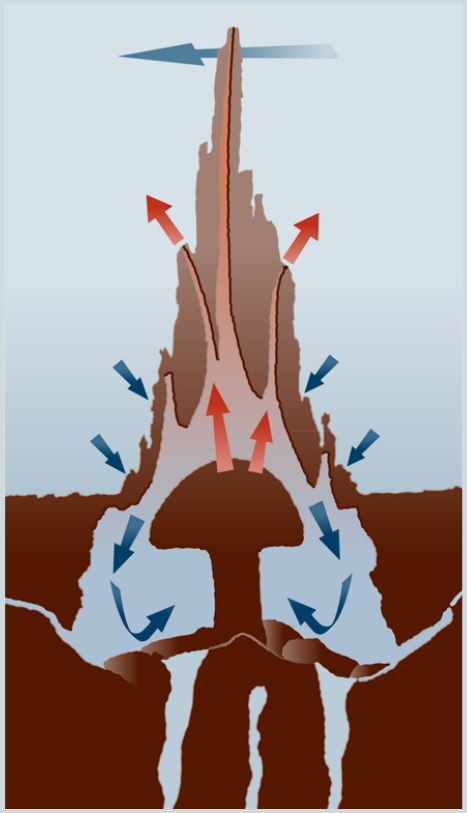
Example of Biomimetic design project

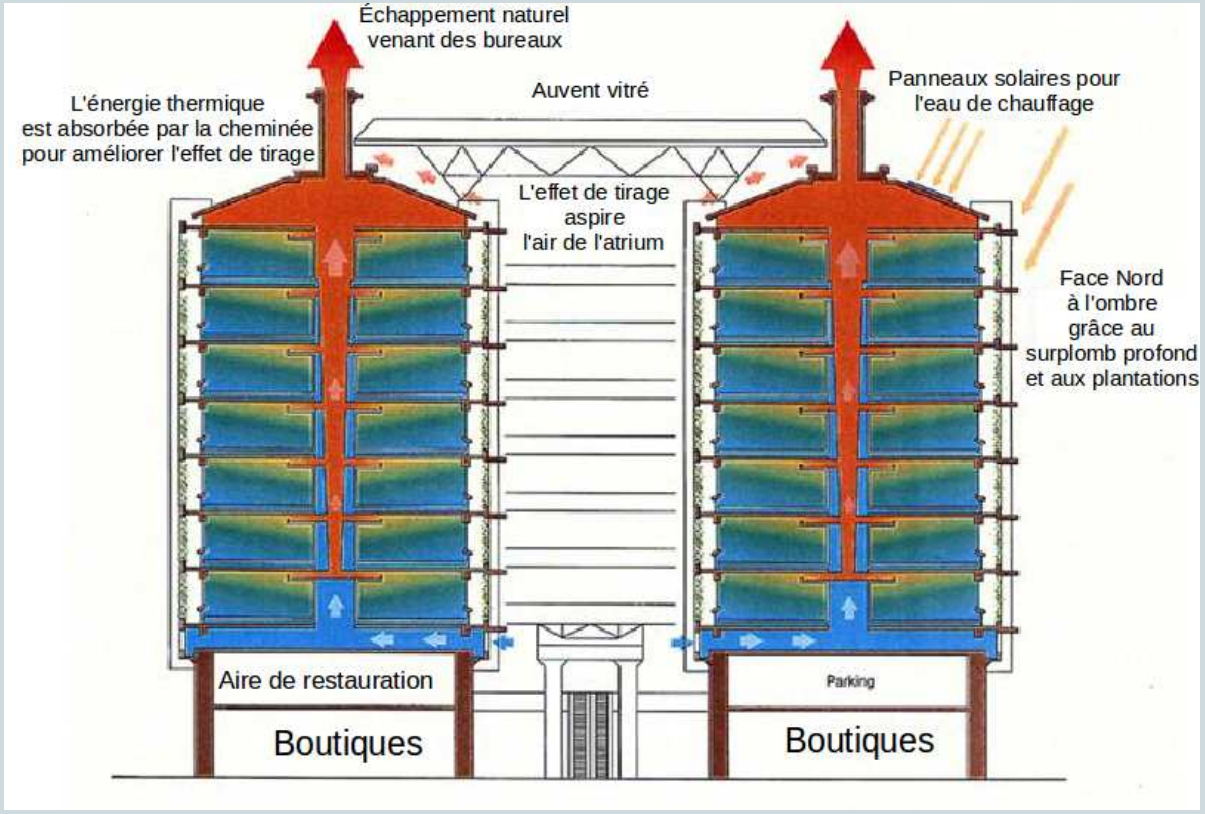




Left: Simulation and Physical Properties: A Single component's performance simulations to study Alkaline Hydrolyzed Polyacrylonitrile (HPAN) behavior with Ni-ti alloy as actuator components going from tension to relaxation. Simulation executed using Rhinoceros 5.0 + Grasshopper version (0.9.0076) + Kangaroo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

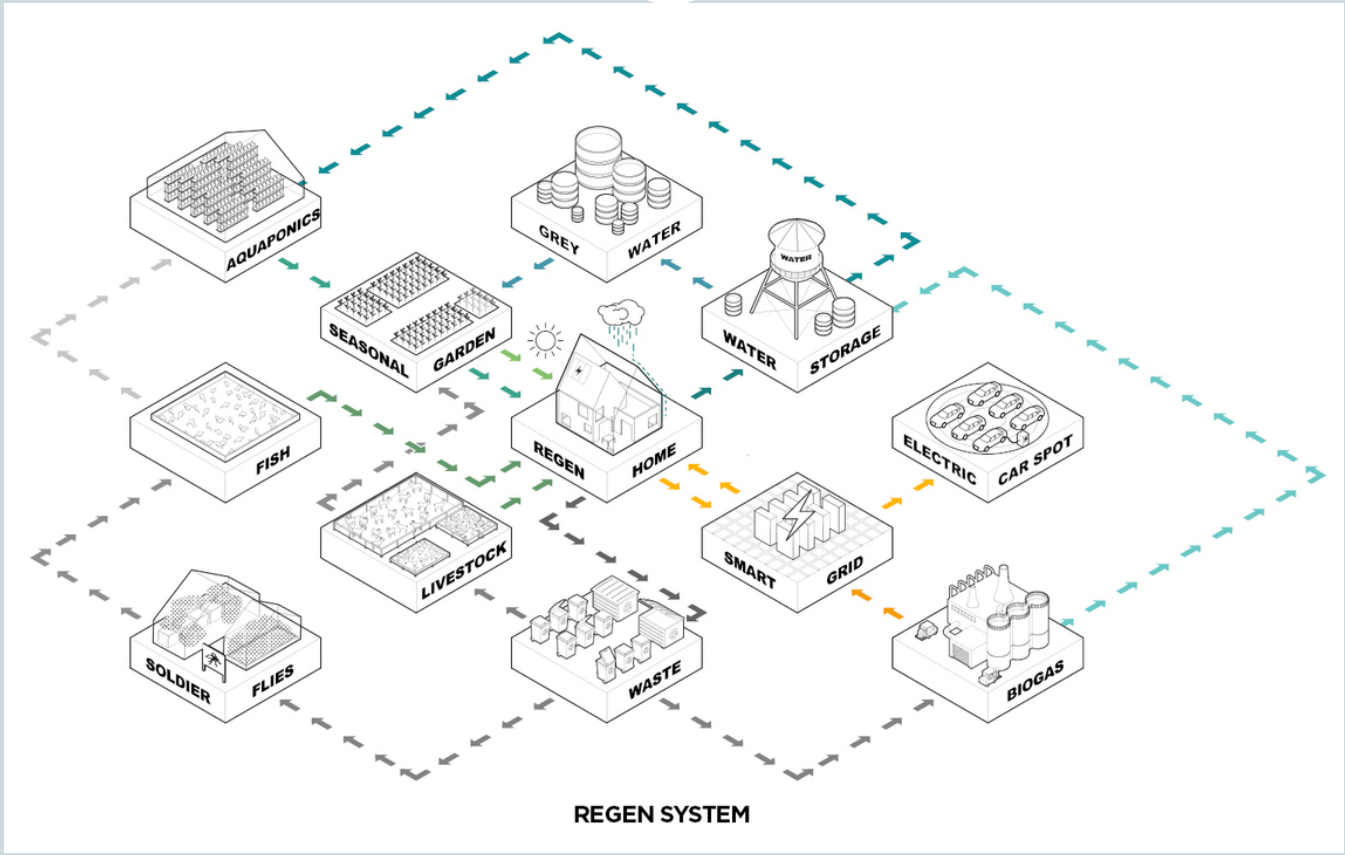
Example of Biomimetic design project *Behaviour*





The Eastgate Building, Harare, Zimbabwe – Passive ventilation system from the African termite mound, Architect: Mick Pearce

Example of Biomimetic design project *Ecosystem*



Regen Village, Almere, Neatherland, eco&regenerative - Waste becomes resources – Nexus: Food-Energy-Water within the neightbourhood (Also to be developed in other EU countries), Architect: *Effekt*

https://www.effekt.dk/regenvillages/, 2016

The inventive Principles that nature and technology use to solve problems are very different

TRIZ

12 %

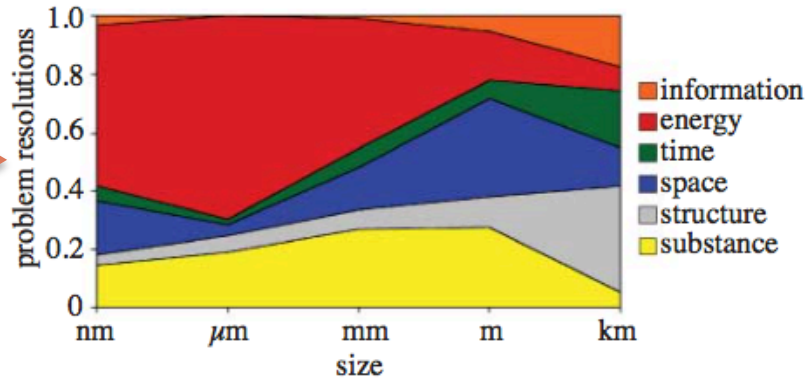


Figure 2. Engineering TRIZ solutions arranged according to size/hierarchy.

+ Substance
+ Energy

BioTRIZ

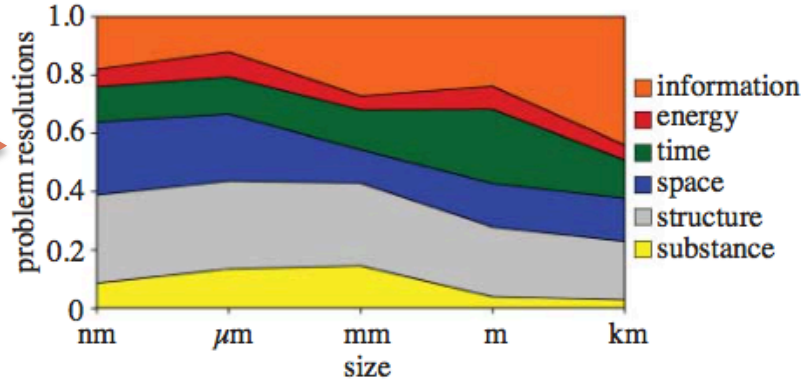
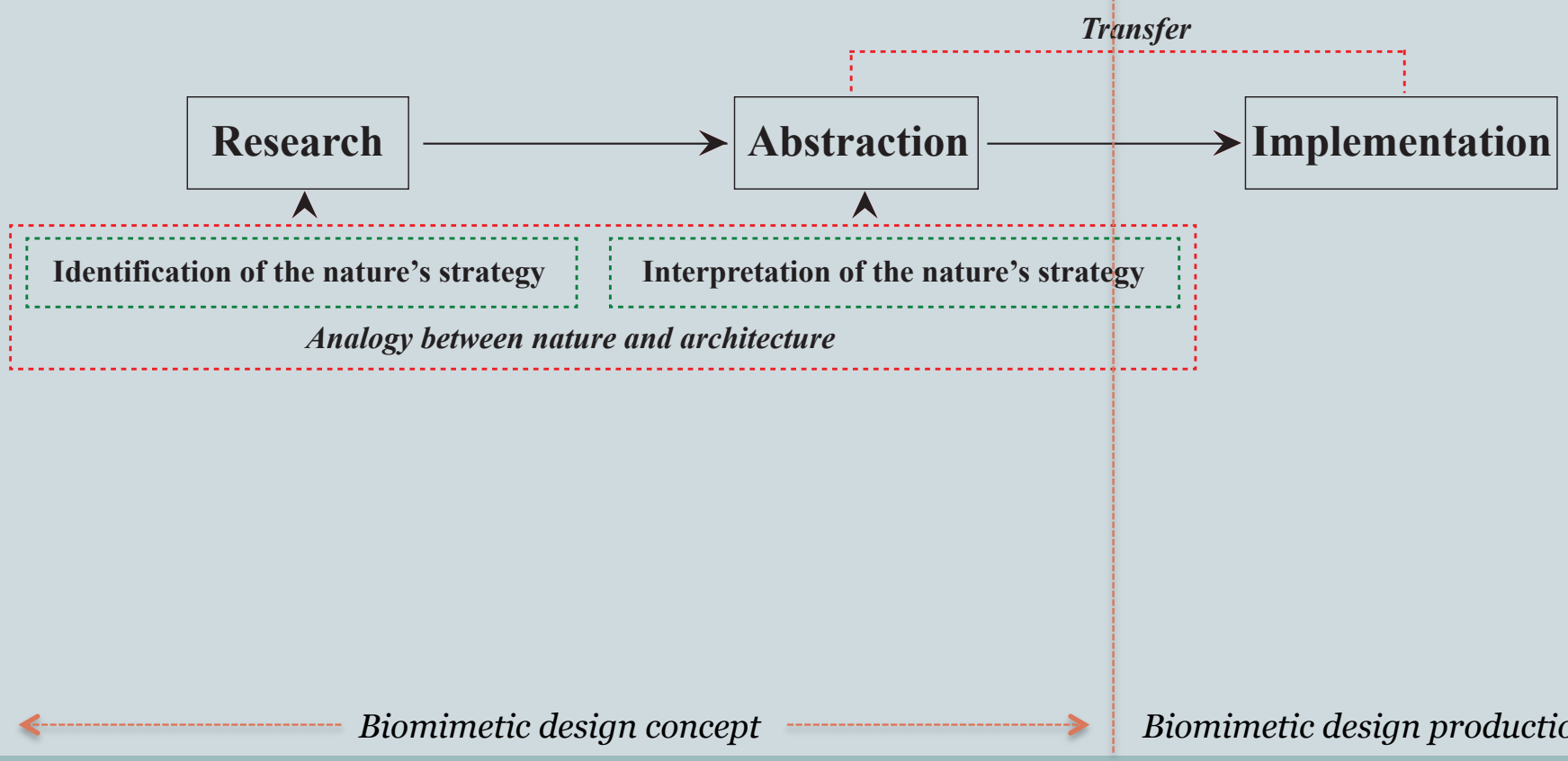


Figure 3. Biological effects arranged according to size/hierarchy.

+ Information
+ Structure
+ Time

Biomimetics - its practice and theory- Vincent-J. R. Soc. Interface. 2006-471-82

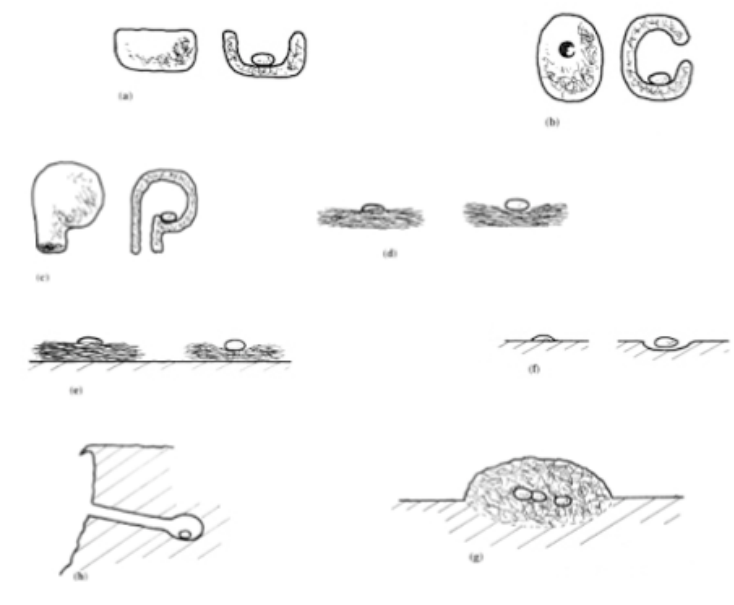
Biomimetic design methodology



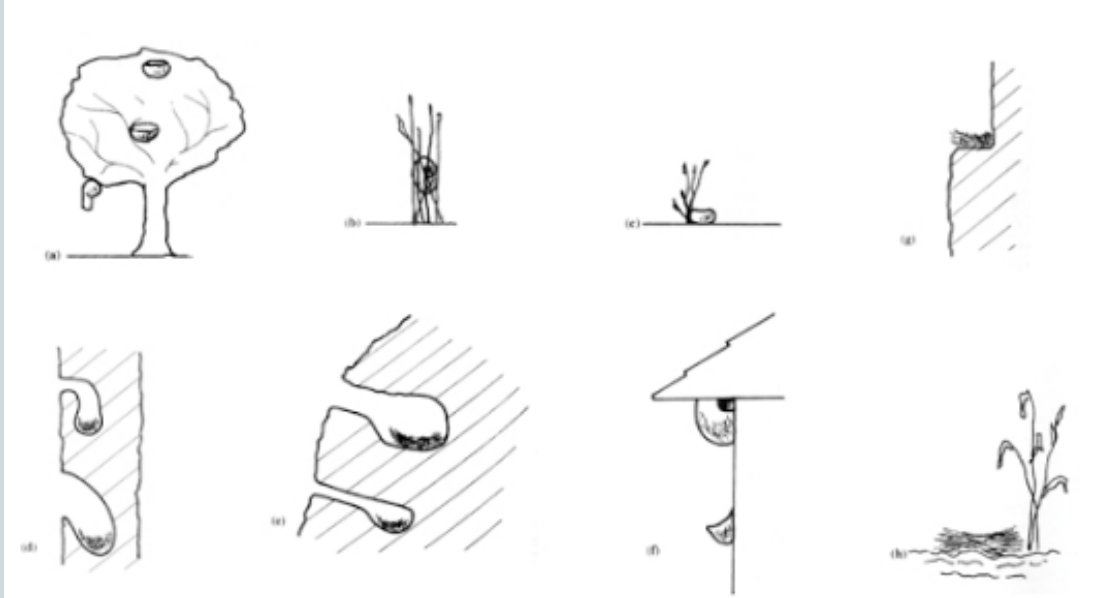
Nature role model: Structure built by animal

PROCESS CONSTRUCTIVE IN THE BIRDS

What criteria as a track of reflection to set strategies for energy-efficient and constrictive durable?



Typologies of morphologies possible of nest, a: cut, b: dome, c: dome and tube, d: plateau, e: reads, f: excavation, g: mound, h: excavation, drawing (Jane (PATTERSON, Mike HANSELL, Birds nests and construction behavior, 2005)

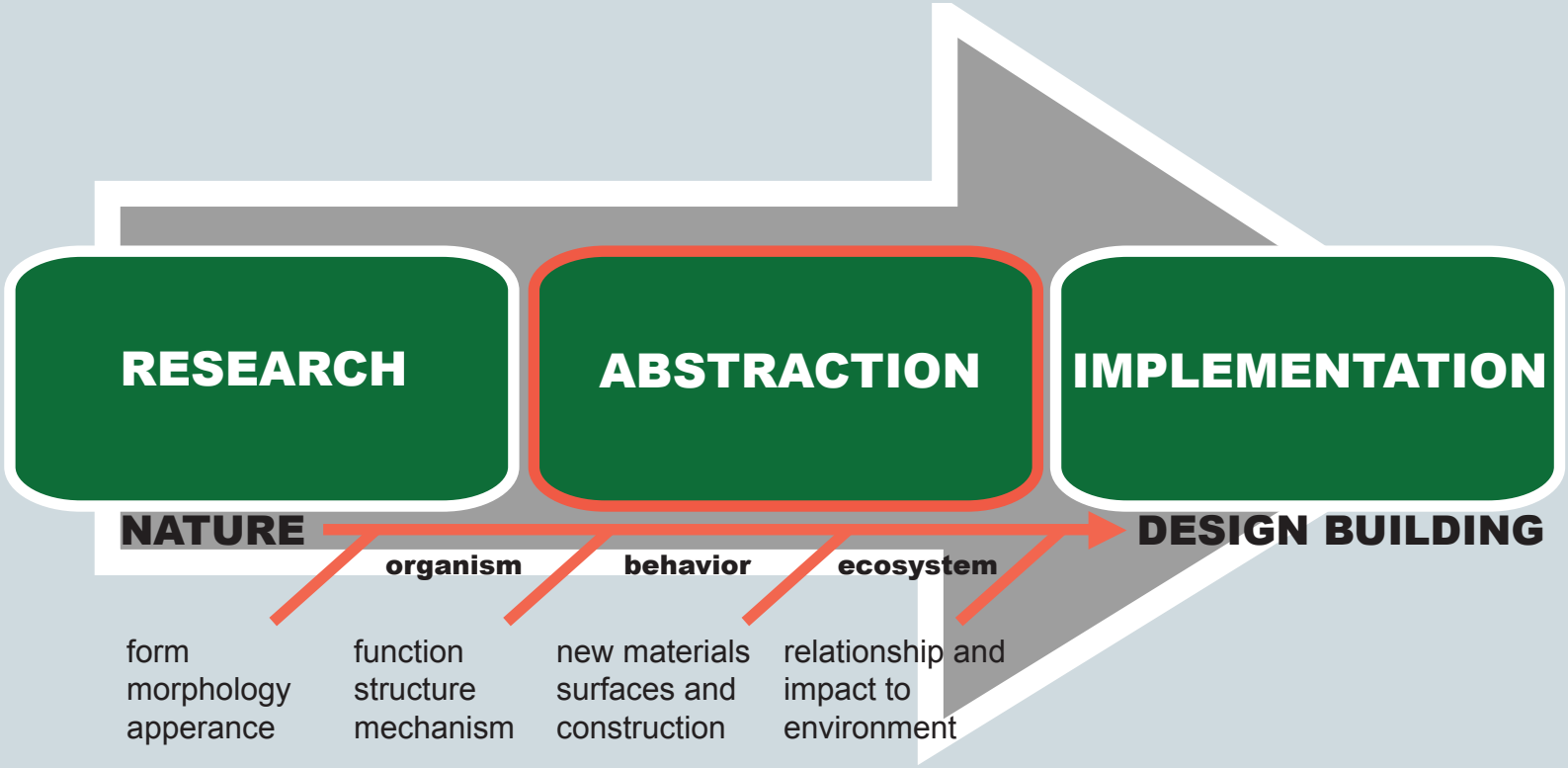


Typologies of sites possible of nest, a: tree/bush, b: grasses/reeds, c: soil, d: hole/cavity tree, e: hole/ cavity ground, f: wall, g: edge, h: water, drawing (Jane PATTERSON, Mike HANSELL, Birds nests and construction behavior, 2005)

Nature role model: Structure built by animal

The formation of nest by weaver gilded

Biomimetic design consideration
Design process & transfer criteria



Biomimetic design analysis based on Ideality tool

Helfman Cohen & Reich, 2017

The issues related to energy consumption of a building	CRITERIA OF BIRD NEST DESIGN STRATEGIES	LIFE CYCLE ENERGY OF A BUILDING (Design principles extract from nature)	Biomimicry levels
The question related to the design issue	**A. Design: Morphology, Site and Materials** ***1. The definition of a form*** -Diversity of morphologies -The morphology as a strategy to external menaces ***2. Insertion into the site*** -The challenges of integration environment -The influence of the geo-climatic conditions of the environment -Setting site value ***3. Selection of Materials*** -Common and abundant materials -Local materials -Materials and Future Needs -Materials adapted to physical capacities	Morphology and functions of the building in relation with the site to optimize and adapt to local environment Management of contradictions designs with multifunctional structures or devices; for example *how we can have more light in the building but less heat?* Envisage activities in the building and type of occupants in a period of time	**Organism** ***+Structure*** ***+Information***
	Information Energy Time Space Structure Substance		

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Helfman Cohen & Reich, 2017

The issues related to energy consumption of a building	CRITERIA OF BIRD NEST DESIGN STRATEGIES	LIFE CYCLE ENERGY OF A BUILDING (Design principles extract from nature)	Biomimicry levels
The question related to the life cycle of a building	**B. Construction: Choices for Implementation** ***1. A local construction*** -Energy Savings in Times of Construction -Local specification of assemblies -Influence of geo-climatic conditions ***2. Constructive responses to implementation constraints*** -The start of construction -A superimposed layer process -Lengths of reciprocal materials and structures ***3. The nest life cycle*** -The life of the nest -The challenges of nest reuse -Destruction of the nest and becoming material	Run to free energy resource from local site Resource management, use local material without the need of distance transportation Selection of materials for accessible and easy assembly to save energy for material production. Selection of the construction site to suit with materials use and production Making wastes becoming resources and reuse materials	**Eco-system** ***+Information*** ***+Space*** ***+Time***
	Information Energy Time Space Structure Substance		

Biomimetic design analysis based on Ideality tool

Helfman Cohen & Reich, 2017

The issues related to energy consumption of a building	CRITERIA OF BIRD NEST DESIGN STRATEGIES	LIFE CYCLE ENERGY OF A BUILDING (Design principles extract from nature)	Biomimicry levels
The question related to the exploitation issue	**C. Operation: Space and Time Management** ***1. Control and maintenance of acceptable internal conditions*** -The heat transmitted by the body of the bird: conduction and homeostasis -Adaptation of behavior to external conditions -Maintenance of nest performance by external conditions ***2. Time of exploitation and natural cycles*** -Temporalities of species -Synchronization of species -Common problems, various behaviors ***3. The relationship to the body in the building*** -The body as a tool	Adaptability and behavioral pattern of occupants in relation with their activities to optimize the use of product installed in the building Evolution with time, adding and reuse rather than change	**Behavior** ***+Information*** ***+Time***
	Information Energy Time Space Structure Substance		

Related Article

Buildings 2017, 7(1), 19; doi:10.3390/buildings7010019
http://www.mdpi.com/2075-5309/7/1/19

Towards a Platform of Investigative Tools for Biomimicry as a New Approach for Energy-Efficient Building Design

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