

Bio-openings Skin as a Practical Application of Biomimicry(Butterfly Inspiration)

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ABSTRACT: One of the physiological functions of bird's feathers is to create insulation like butterfly, which represents the protection mechanism of the climatic conditions. In birds, the insulation enhances with the increase in feather volume and its unique arrangements in the skin, which makes birds more protected at very low temperatures through dead pores. This research focus on three main themes running in parallel through these studies: 1) Design of responsive systems with enhanced adaptive properties; 2) visual impact through employing a range of response mechanisms elements; 3) the possibilities of improving the environmental performance and Interesting of strategies for practical application of the technology in bio-openings design. Achieving aims come from analysis examples of bio-openings skins, conclude criteria to get benefits from environment and then discover how achieve adaptation to buildings from butterflies inspiration through openings skins design system to improve building performance.

KEYWORDS: Inspiration, Nature, Butterfly, Openings, Biomimicry, Bio-design, Bio-openings, Bio-skin, Environmental, Adaptation, Technology creativity.

I. INTRODUCTION

The open and covered areas on bird's body are arranged to create the perfect balance in its weight, have better compatibility between body movement and feathers, and most importantly, help the body to retain its perfect temperature.[7]. we can achieve deign simulation of bio-design through supporting this features (see figure 1)such as arts, knowledge, science, experiments and technology for more efficiency.

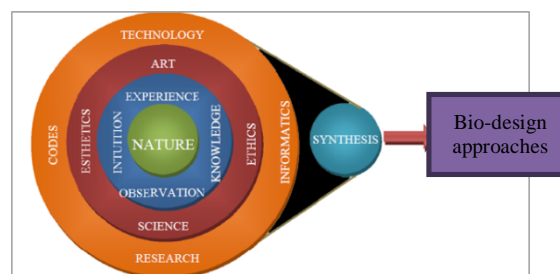


Fig. 1. Bio-deign simulation approaches. Created by author based on McLendon, 2005.

One of the important tasks of bio-design is to provide opportunities for bio-openings skin design that adapt with surround environment conditions. The expression of bio-openings come from two part; 1) bio = biomimicry (inspiration fromnature to architecture); 2) openings = the holes in buildings skins that control on environmental process (ventilation-lighting- thermal comfort- energy). This approach concern themselves with intense differentiation of bio-openings study as systems. In addition, energetic interventions that are evolved from:

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- Their specific behavioral tendencies in given environment
- Their mutual relationship between nature and openings through architects and support this relation.
- Passive modulation strategies that are sustainable for bio- openings design.

II. LITERATURE SURVEY

Nature is an inspiration for the bio-openings design. This approach depended on discover nature properties and then explain how architects using them in design openings systems, examples (see figure 2). This properties are simulated such as branching system, mechanism system, protection system or other physics properties as show in chart below.

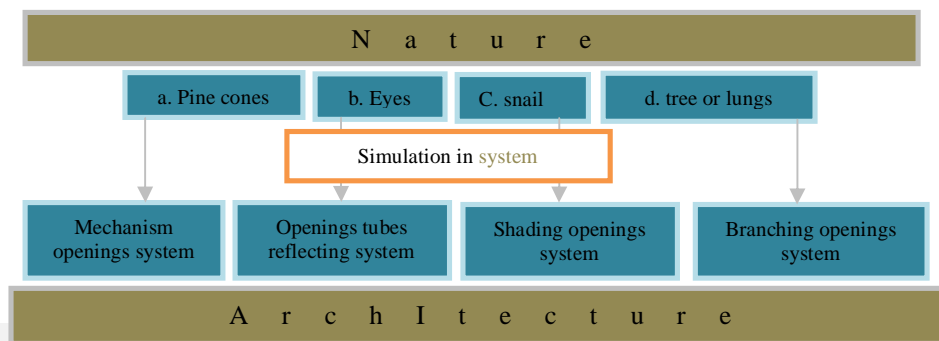


Fig. 2. Influences of systems in nature approaches of biomimicry in openings application. Created by author

2.1. Example 1: Pinecones:

1. What is a pinecone? Pinecone is one of important type of plants that attracted architects to study it (see figure 3). Architects notice many properties through study it in lab. The important one is humidity effect on its skin. This property make it breathing and give it feature of life as show in the first time you see pinecone.

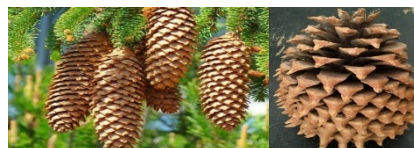


Fig.3. pinecone shape as a natural model. Source: <https://www.pinterest.ch/pin/485262928582620051/>

2. What is a Behaviour of pinecone (adaptive tool)? In advance, by responding to high relative humidity the pinecone change element of skin movement to open or close (see figure 4). Pinecone system has mainly been focused on testing of small-scale prototype structures with different shapes arrangements of responsive elements as show in figure 5.[15]



Fig.4. showing the behaviour of pinecone that open and close according to humidity. Source: <https://www.vectorstock.com/royalty-free-vector/two-pine-cones-vector-1751223>

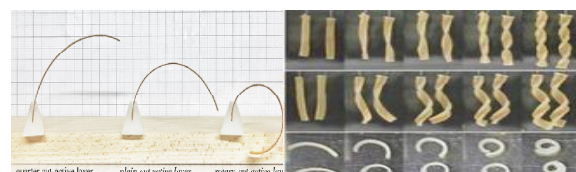


Fig5. Analysis pinecone to elements of structure in the different three shapes (quarter-cut active layer, plain-cut active layer and rotary-cut active layer) according to the humidity change. AD Journal, 2008

3. What is the concluding system of openings skin from pinecone? The dynamic behaviour in cross section of cladding elements and the inherent variability of their response would give buildings with responsive envelopes a rich texture

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reminiscent of that of natural organisms as show in figure 6. It is this possibility to simultaneously contribute towards climatic adaptability and environmental performance. Potential of the technology that probably provides it is most progressive and viable building related applications as experiment in figure7. [15]

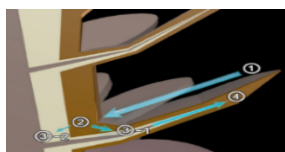


Fig. 6.Design of opening in adaptive façade as pinecone properties. Source: Hensel, 2007



Fig. 7. Showing use pine cones properties in the bio-openings design and Cross section of pinecone and application of it in adaptive facades. Source: AD Journal, 2008

In arid climate, pinecones building systems could be configured to help maintain thermal comfort through enhanced natural ventilation in hot dry weather (see figure 8). In addition to, pinecones systems could be designed to control illumination and prevent excessive solar gain and glare based on the assumption of a link between relative humidity and the amount of available daylight that called mechanism openings system. This system have sensor and control system. When humidity change, control system move the louvers to permission getting suitable amount of light. [25]

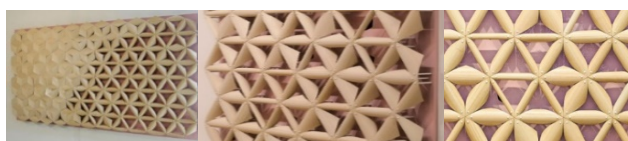


Fig. 8. Pinecone as a pattern of openings in adaptive building skin. Source: <https://academic.oup.com/aob/article/99/3/375/2464324>

4. What is the architecture application from pinecone?The general categories of possible applications for pinecones as sensors or actuators or in larger scale applications such as openings in building skins (see figure 10), roofs of stadiums and semi-indoor spaces. [14]. Responsive elements preinstalled into retrofitted modular cladding or integrated as part of the windows could be preprogrammed to fold providing shading in dry sunny weather and open up in humid conditions when the sky is overcast to maximize the use of daylight.

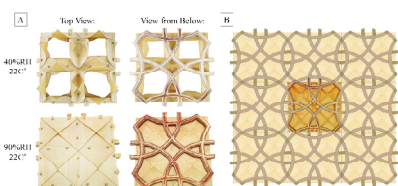


Fig. 9. (A) illustration of the under structure design achieved when several modules are assembled together (B) active layers of plain-cut and rotary-cut wood veneer are more responsive than those with quarter-cut veneer active layers. The figure shows the response of initially straight samples (at 45%RH and 22C°) to wetting by sprayed water. Source: Hensel, 2007



Fig. 10. The dynamic facades in architecture building from pinecone such as Splenda theatre.
Source:<http://homeklondike.site/2017/02/28/biomimicry-design-spiky-durian-roof-ofsingaporean-theatre/>

5. Application successful:The building skin serves as a barrier between the internal and the external space, it is argued that the use of responsive system to enable its adaptive behaviour and employ it for control over the interior climate and user comfort is one of their most important building applications. Roofs inspiration from pinecones could fold or deploy when exposed to rain creating a watertight shelter and managing water runoff. In large-scale buildings, requiring more substantial weather sealing could be used as a pinecone behaviour in the building systems controlling air movement and the exchange of heat and moist air between the indoor space and the outdoor environment through continuous passive adjustment of porosity.

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2.2. Example 2: Decapod (lobster):

1. What is a **Decapod**? Scientific Name is Decapod and Habitat is almost all warm seas (see figure 12 for body components). Architects Jobs frequently mentions values that are very important of **lobster eyes** in this organism. Lobsters have a pair of eyes located at the base of their antennae. These eyes are incredibly sensitive to light, are unable to see images clearly and cannot distinguish between colours. A lobster's eyes can, however, detect movement and shadows (see figure 11). [14]

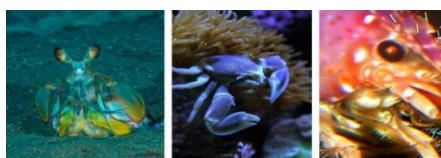


Fig. 11. Lobster eyes under thermo-camera. Source:

<https://weathervaneseafoods.com/up-close-live-maine-lobster/>

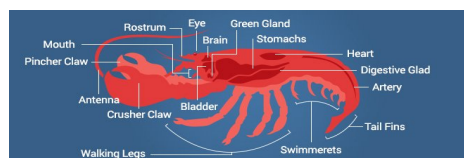


Fig. 12. Body component of decapod. Source:

<https://timroot.com/comparative-eye-anatomy-video/>

2. What is a Behaviour of **Decapod** (adaptive tool)? Lobster eyes: The eye of a lobster focuses reflected light onto the retina using a perfect geometric configuration of square tubes. The optic system of the eye of certain lobsters developed in a way that they do not need a bent lens, to change the direction of light in order for them to see; instead, they use spherical square tubes, with mirrored surfaces (see figure 13). Even more intriguing is that the sides of each one of these square tubes are like mirrors that reflect the incoming light. This reflected light is focused onto the retina flawlessly. The sides of the tubes inside the eye are lodged at such perfect angles that they all focus onto a single point (see figure 15). The question is how we can mimic this system in architecture in a sustainable manner. [17]

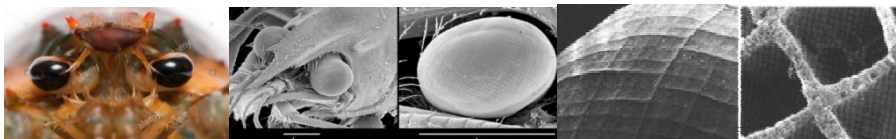


Fig. 13. Lobster eye on micro-Nano scale. Source: <https://www.alamy.com/stock-photo/lobster-eyes.html>

Note: The most outstanding characteristic of the lobster eye is its surface, which is composed of numerous square. These squares are positioned most precisely.

3. What is the concluding system of openings skin from lobster eyes? The interesting part in this is to take this system and product of nature and place it into architecture, until it is possible to learn something new from it. The optics consists of a grid of micro channels each with a square cross-section. The entrance apertures of the channels are situated on a spherical surface and the individual channels point towards the centre of the sphere. Technically this type of optics is often realized by bending a micro channel plate in two directions. Light hitting the smooth sidewalls of the channels is reflected towards a focal point. In figure 14 the focal points are located on a sphere with roughly half the radius of the aperture sphere. The exact position depends on the geometry of the channels and on the distance of the light source. [25]

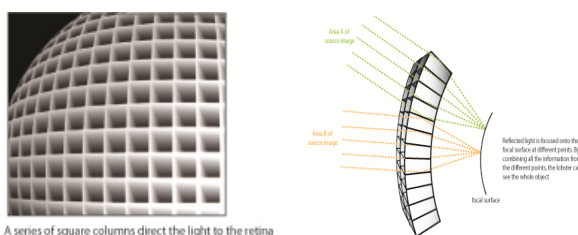


Fig. 14. The mirror boxes of a lobster eye. This optics provides a very large angle of field; theoretically, it could image light from nearly any direction. Source: <https://thefotosgratis.eu/hot-spot-heating-pveducation.html>

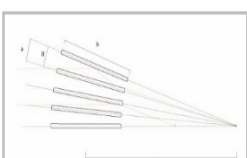
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The single Lobster Eye Schmidt modules developed so far by architect. Here plates have dimensions of $d \times l \times t$ and are arranged with spacing a . The modules have focal length f and field of view pure and are optimized for the energy given in the last column (see figure 15). The mirror boxes must be the right depth, two to three times the width, so that most rays are reflected from two of the faces, but not more. The unsoldered 'tail' of the mirror boxes intercepts Rays that pass straight through, its refractive index decreases in such a way that appropriate critical angle reflex ion continues to occur through the clear zone as show in figure 16.[22]



Module	size d[mm]	thickness t[mm]	distance a[mm]	length l[mm]	foc. length f[mm]	resolution r[arcmin]	FOV [°]	energy [keV]
macro	300	0.75	10.80	300	6000	7	16	3
middle	80	0.3	2	80	400	20	12	2
mini 1	24	0.1	0.3	30	900	2	5	5
mini 2	24	0.1	0.3	30	250	6	5	5
micro	3	0.03	0.07	14	80	4	3	10

Fig. 15. Geometry of the square tubes. Source:

https://www.researchgate.net/figure/The-single-Lobster-Eye-Schmidt-modules-developed-so-far-by-our-collaboration-Here_tbl1_228628055

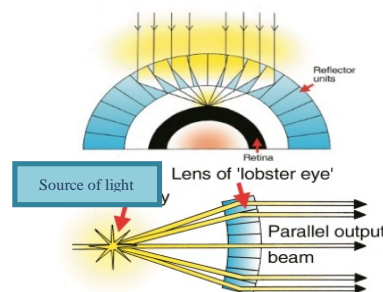


Fig. 16. Showing the reflector tubes to light in the concluding system of openings skin from lobster eyes. Source:

<https://creation.com/lobster-eyes-brilliant-geometric-design>

4. What is the architecture application from **lobster eyes**? Architects convert this behaviour to important application that used in façade system. This system can control on lighting that pass through it (see figure 17).[2]. It consists of an alternative configuration of Lobster-eye optics, which mimics the imaging principle of the eyes of lobsters (see figure 18). Incoming light is reflected off the walls of many tiny square pores arranged on a sphere and pointed towards the co-centric spherical centre. The reflection surfaces are configured orthogonal to each other. [26]

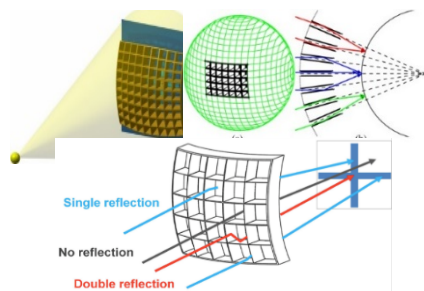


Fig. 17. Simulation façade from lobster eye technique under sunrays phase 1. Source:

http://ep.bao.ac.cn/?page_id=13

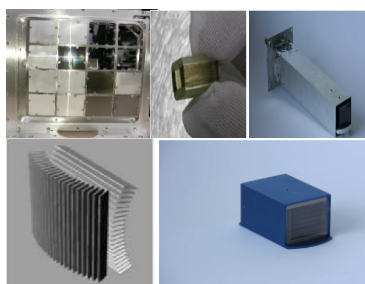


Fig. 18. Physical model of façade from lobster eye technique under experiment phase 2. Source:

https://www.researchgate.net/figure/The-single-Lobster-Eye-Schmidt-modules-developed-so-far-by-our-collaboration-Here_tbl1_228628055



Fig. 19. Zaha Hadid Design of SleukRith Institute in Cambodia. source: <https://www.telegraph.co.uk/travel/galleries/zaha-hadid-unfinished-buildings/>

5. Application successful: This system can control on lighting that pass through it successfully. When the sunrays fall on the façade system that consists of cubes in different position (special arrangement according to sun altitude in a choice environment), it reflect part of this rays and permit to the other to pass. This process support suitable amount of lighting in the interior space and reduce heating on it according to the materials use on this system.

2.3. Example 3: Snail:

1. What is a **Snail**? A snail is a shelled. The name is most often applied to mollusks. However, the common name snail is also used for most of the members of the molluscan class Gastropod that have a coiled shell that is large enough for the animal to retract completely into (see figure 20). "Thrombosis is not limited to hydrothermal vent faunas, but also

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occurs in terrestrial species. For example, the desert snail *Sphincterochilaboissieri* can survive in the desert at temperatures of up to 50 °C. [11]



Fig. 20. A snail is a shelled that cover mollusks organism. Source: <https://www.architectmagazine.com/design>

2. What is a Behaviour of **Snail** (adaptive tool)? Insulating the snail from the surround environment: How desert snails survive high temperatures: The surface of the shell is highly reflective, resulting in 95% reflectance within the near infrared, 90% in the visible spectrum (a). While the maximum air temperature might reach 43 °C (109 °F), surface temperatures can reach 65 °C (149 °F). However, shading and the rough surface of the soil results in a temperature of 60 °C (140 °F) (d). During the heat of the day, the snail retreats into an upper whorl where the temperature is an even cooler 50 °C (122 °F) (b). Heat flows in the direction of lower temperature, result in heat flow through the shell, with resultant decrease higher in the shell (c). Copyright Biomimicry 3.8 Institute as show in figure 21 and 22. [9]

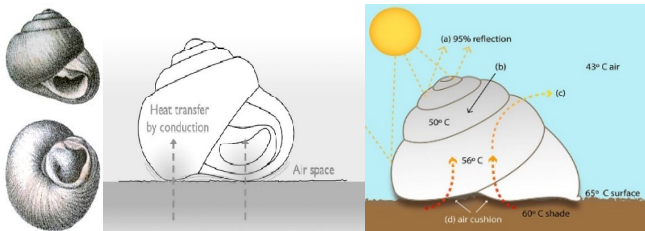


Fig. 21. Showing how snail reduce thermal degree to the organism to live and analysis insulating it from the ground. Source: <https://asknature.org/strategy/shell-protects-from-heat/#.XJjvnJgzblU>

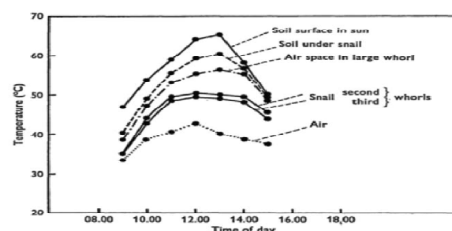


Fig. 22. Temperatures recorded in and around a specimen snail. Source: <http://homeklondike.site/2017/02/28/biomimicry-design-spiky-durian-roof-of-singaporean-theatre/>

3. What is the concluding system of openings skin from **Snail**? The behaviour of this system is different to others. It has multi-purposes that have benefits to bio-openings simulation such as shading, insulation, airflow and many others. All of this properties are protect buildings form surround environment and improve their performance as show in table 1.

Table 1: showing behaviour of openings properties according to analysis snail in lab. Source: researcher based on Korhonen, 2001

Openings system	behaviour
Shading	Observations show that the temperature of the soil surface under the snail is less than that of the surrounding environment because this specific spot is shaded by the snail's shell. Consequently, less heat is transferred to the body of the snail through conduction.
Air as Insulation	When the snail withdraws inside the shell, it retreats into the upper whorls rather than the larger lower whorl that is in direct contact with the ground. The body of the organism fills only the upper parts of the shell leaving the rest filled with air. This insulates the body of the snail from the ground. Scientists demonstrated the importance of the airspace by measuring the temperature of the body of the snail when the space was filled with air, and comparing this with another reading taken after the space was filled with water. The results showed that air insulation kept the snail five degrees cooler. Due to its curvature, the shell touches the ground in only a few spots, reducing direct contact Between the shell and the ground and leaving, a layer of air in between that acts as an insulator.
Heat Flow and Air Movement	Because of the different mechanisms mentioned above, temperatures of the components surrounding the snail vary. From highest to lowest they are: parts of soil that carefully exposed to the sun, soil under the snail, airing the largest lowest whorl, air in the upper whorls and air surrounding the snail, as illustrated. Therefore, heat will flow from the higher temperatures to the lowest (surrounding air) with minimum effect on the body of the snail. One might argue that difference will create air movement through the large whorl of the shell.
Evaporative cooling	Experiments show that the weight of a dormant snail changes from day to night. This is because the snail absorbs and stores water at night, and then releases the water through evaporation during the day when the temperature increases. This observation reveals the importance of evaporative cooling in regulating the body temperature of the desert snail.

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4. What is the architecture application from **Snail**? There are many building in different types using a snail idea for many functions such as (shading- ventilation- isolation and reduce heating- cooling). This system can solve openings problem and improve building performance as show in figures blew.



Fig. 23. Natural Home Shaped like a Shell. The great inspiration for your building design, home design and architecture. Source: <http://www.marvelbuilding.com/natural-home-shaped-shell-nautilus.html/plan-of-natural-home-shaped-like-a-shell>

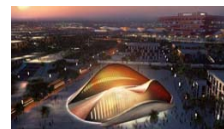


Fig. 24. Insulating snail openings form the Emirates Pavilion at Shanghai Expo 2010. Source: <https://arabic.arabianbusiness.com/gallery/2010/may/17/39877>



Fig. 25. Latvian architects Mailitis were selected to design the Latvian Pavilion for this year's Shanghai World Expo like snail. Source: <https://www.archdaily.com/48851/latvia-pavilion-for-shanghai-world-expo-2010>

5. Application successful: This system of snail success in forming an entity isolated form from the surrounding environment with sufficient requirements of quantity of lighting, ventilation and cooling, in addition to thermal comfort for vacuum users.

2.4. Example 4: leaveand lungs (branching):

1. What is **leavesand lungs**? Leaf is a plant as the part of tree and lungs is an important member in organism for breath. The two natural model have the same main feature. This feature is branching (see figure 26, 27). [8]. the branching is an important system in bio-openings design simulation as show in the next paragraphs.



Fig. 26. X-ray of Cole... branching system of venation. Source: AD Journal, 2008



Fig. 27. Branching network of pulmonary arteries and bronchi. Resin cast of the system supplying blood and air to the lungs. Source: AD Journal, 2008

2. What is a Behaviour of **leavesand lungs** (adaptive tool)? Branching patterns appear in great abundance in natural systems (see figure 28), ranging from overall plant morphologies, to respiratory and vascular systems of organisms, to rivers and climatic phenomena such as lightning strikes. Natural branching systems provide for energy efficiency. [8]

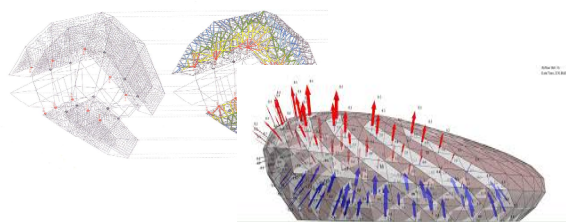


Fig. 28. Principles abstracted from branching system. Source: <https://www.cibse.org/getmedia/d056089f-5286-400d-9bbb-2dec3d9fb222/USING-SMART-MATERIALS-TO-MIMIC-NATURE-IN-ARCHITECTURE.aspx>

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3. What is the concluding system of openings skin from **leavesand lungs**? Branching is one of solution to openings system. The study was to adapt to a number of influences such as Sun path and prevailing winds. There was specific program in this system since its main objective was investigating the ventilation system through branching networks (see figure 30). Through the analysis, several environmental aspects were observed. Upward airflows from the system to interior spaces. The lateral air distribution via lateral connections towards surface conduits (see figure 29). Airflow towards the negative pressure zone due to pressure differentials. Suction from the negative pressure side. [5]

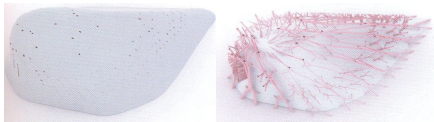


Fig. 29. Digital model of branching morphology. Source: Hensel, 2010

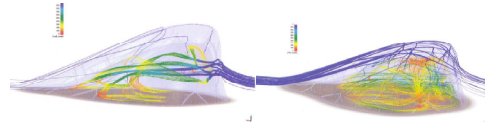


Fig. 30. CFD of airflow in evolving system. Source: AD Journal, 2008

4. What is the architecture application from **leavesand lungs**? A new multi-use complex for Nasr City in Cairo Designed to obtain LEED Gold Plus standing, the building features a solar roof, green terraces, sky villas, and a vertical system of gardens and solar heating tubes. The two plots of the complex are connected via sky bridges. Aiming to limit its own carbon footprint, the building recycles part of generated waste as grey water, while a system of mesh surface and second skin of white steel and cables integrates photovoltaic cells, thermal tubes, and vertical gardens. In effect, the roof surface curves down and inward to transform into "Megatrees," allowing natural ventilation throughout the levels and providing shade and protection from sound. Inspired by the technology of branching that is passed fresh air through pipes before entering a building, allows for climate control (see figure 31). Integrated airshafts along the cores will provide natural ventilation to each apartment, while walkable photovoltaic cells using UV radiation will cover the solar roof to generate much of the building's energy. [27]

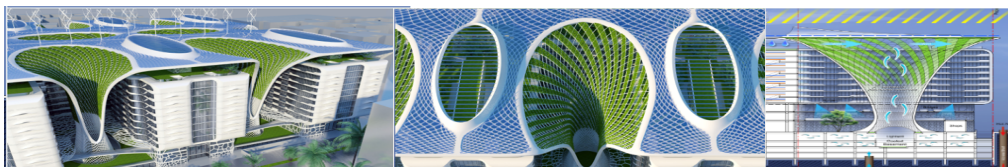


Fig. 31. Vincent Callebaut Designs Sustainable Mixed-Use Complex for Cairo. Source: <https://www.archdaily.com/565550/vincent-callebaut-designs-sustainable-mixed-use-complex-for-cairo>

5. Application successful: This system of openings operation (branching openings system) were abstracted and applied in computational process. In addition to create a highly effective ventilation system.

III. METHODOLOGY

the system's behavior needed to be taken into account during the design process. This enables a computational evolution in which manipulation in the element setup, component assemblies and the overall system related to environmental modulations. This environmental modulations step need to pass on strategy as show in figure 32.

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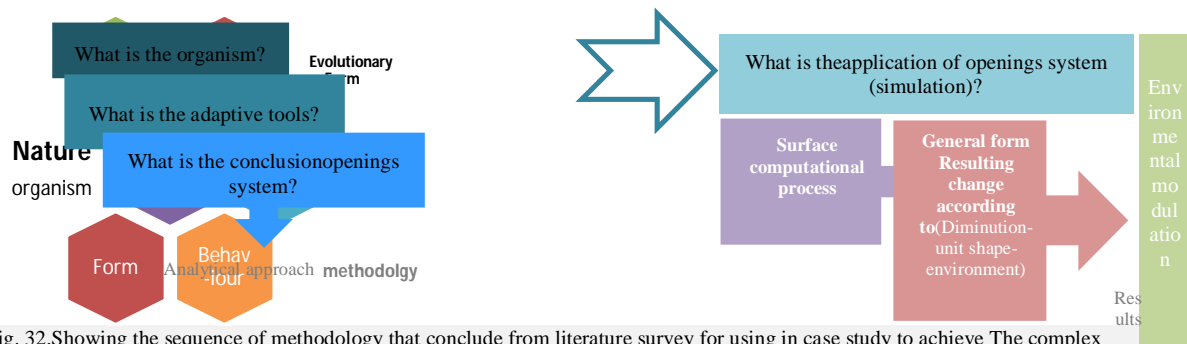


Fig. 32. Showing the sequence of methodology that conclude from literature survey for using in case study to achieve The complex dynamics of the mutual modulation of environmental influences. Created by author

The following aspects will be analyzed in order to evaluate the application of the biomimetic principles in morphogenetic computational bio-openings design analysis as following in table 2:

Table 2: explaining the meaning of further analysis points. Created by author

Point	describe
Systems	Organisms and natural systems are often composed of a number of interrelated components that act on a continuous scale from the micro to macro structure for a necessary requirement as similar to needs of openings system in building skin design. [22]
Adaptation	Term adaptation may refer to an especially important feature for an organism's survival. In architecture, Adaptation is the evolutionary process whereby a building skin becomes better suited to its environment. The better-suited forms reproducing more successfully by natural selection. [19]
Evolution	Growth is a complex process intertwining contributions of environment and phenotypic dependencies. In nature, the genotype comprises the genetic constitution of an individual, while the phenotype is the product of the interactions between the genotype and the environment. One unit of openings like a cell in human skin that represent building skin. Pattern get from collect the similar units of bio-openings in growth surface (facade) that dealing with environment. [1]
Form & Behaviour	Biological forms and their behaviour emerge from process that process consists of a complex series of exchanges between the organism and its environment. Furthermore, the organism has a capacity for maintaining its continuity and integrity by changing aspects of its behaviour. Form and behaviour in organisms are the same in skin of building's form and behaviour through its openings design. [6]

IV. BUTTERFLY AS A PRACTICAL APPLICATION OF BIO-OPENING SKIN

The pretty organism in this study is butterfly. I notice its colorful wings, flexibility, and lightweight and funny in general so I become very excited to know more and more about it. I believe this organism can solve more than fifty problems of architecture including openings system.

1. Analytical approach in butterfly:

These part analysis properties of butterfly as case studies to show the benefits of it (see figure 33). Second, explaining how it adapt with its environment, how use in opening design approach and how achieve goals.

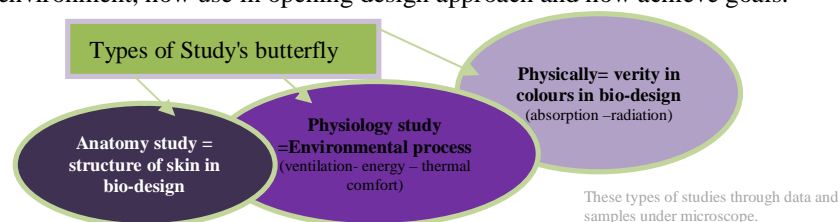


Fig. 33. Showing the types of study in butterfly in this part and the benefits to use in architecture bio-design. (created by author)

The adaptive toolsof butterfly (wings):A butterfly has four wings, two forewings and two hindwings with strong muscles that move the wings up and down as show in figure 34.

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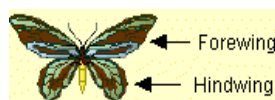


Fig. 34. Showing the two parts of butterfly wings (forewings and hindwings). Source: www. Zoology zoom school.com

1.1. Butterfly Wing structure: There are two mainly parts of wing structure (wing structure- wing scales).

A. Wing structure elements: Wings are made of layers (membranes) that are nourished and supported by tubular veins. The veins also function in oxygen exchange ("breathing") as show in figure 35 and analyze in table 3.[8]

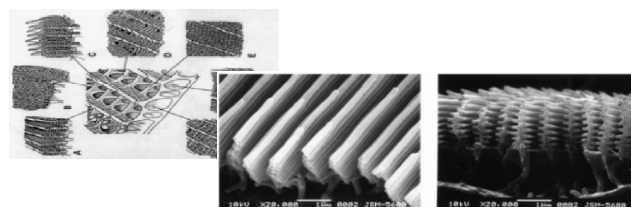




Fig. 35. Wings structure components in Cross-section of the wing and analysis layers under microscope. Source: www. Zoology zoom school.com

Table 3: explaining the Analyzation of structure's properties in butterfly wing under microscope. Created by author

Analysis properties of structure in butterfly wing under microscope.
a. The scales vary in shape in different species, some being rectangular, hexagon, while others have a shape similar to teardrops. An individual scale typically measures about 50 microns across (0.05 of a millimetre) There are basic types of scales – pigmentary scales and structural scales.
b. Structural scales are responsible for the refraction, diffraction and interference patterns of light as it strikes or passes through the semi-transparent structural scales. Almost all butterflies and moths have a mixture of pigmentary and structural scales. The latter are bigger than the pigmentary scales. They overlap them, but the semi-transparency enables the colors of the pigmentary scales to be seen through them. In most cases, the structural scales tend to be architecturally more elaborate – their form seems to be achieved almost as in a digitalized self-formation process.

Another study: compare between wings structure of sister species, which are living in different environments; this time concentrating on their inner structure wings as show in table 4. This study proved the difference between the ratios of openings in structure in two species.

Table 4: comparison between two species cover of wing. Created by author based on Vukusic, 2004

P.daphnis species		P.marcius species	
	Fig. 36. P. daphnis, dorsal view and SEM picture of the scale's structure.		Fig. 37. P.marcius, dorsal view and SEM picture of the scale's structure.
It has revealed that scales from P.daphnis (A) inhabiting the low altitudes and relatively warmer climate. the polycrystalline blue cover scale of P. daphnis is structurally much more dense than absorbing structure apparent in P.marcius species so The small size of the unit in the pattern allows more precise environmental adjustment and vice versa. [19]		P.marcius was lacking this structure at lower temperatures. Both structures have been put under identical illumination conditions to record their thermal measurements. Those of darker colored attained temperature 1, 5 times those of lighter appearance. This was due to reduced reflectivity resulted from the absence of crystalline structure, increasing the proportion of solar radiation absorbed in the blue-UV region. [19]	

B. Wing scales: butterfly's wing magnification, Covering the wings are thousands of colorful scales, together with many hairs (setae) means "scale wing" in Greek (see figure 38). These wing scales are tiny overlapping pieces of chitin on a butterfly wing in different patterns. This gave inspiration of a building that could have different expression during daytime.

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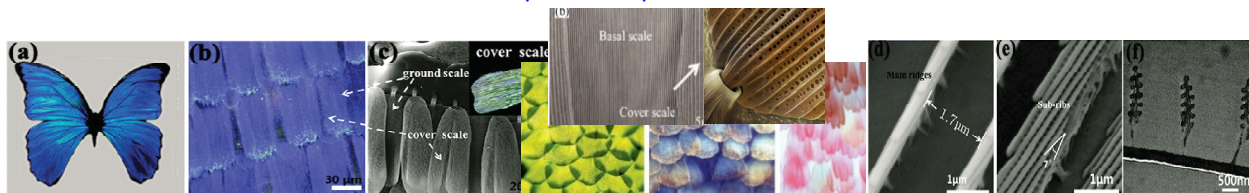


Fig. 38. Showing the parts of butterfly wings (wing scales). SEM images of micro- and nanostructure of the butterfly wing: a-b) multiple scales covering the wing's surface; c-d) inner chitin structure of each scale. Wing anatomy The wing membranes are translucent, but are partially or fully covered in a dust-like layer of colored scales. AD Journal, 2008

After, I study the component of butterfly wing. I need to study process that did in this wing to complete another part in the image of wings butterfly behavior in environment.

1.2. Butterfly wing behavior: These behaviors appeared in some properties as following:

A. the Coupling of the Wings: During flight, the forewing and hindwing are held together and function as one wing. The front edge of the hind wings (called the frenulum) connect with hooks on the hind edge of the forewing. [8]

B. Wings at Rest: butterflies hold their wings vertically. Moths hold their wings horizontally when at rest. [18]

C. Sense of Touch In order to protect themselves from predators, caterpillars use different strategies: Caterpillars sense touch through tiny hairs (setae) that are all over the caterpillar's body. These tactile hairs grow through holes in the pinaculum (dark, flattened plates on a caterpillar's body) of the exoskeleton. These hairs are attached to nerve cells, and relay information about touch to the insect's brain. [24]

D. Analysis Thermal degree in butterfly wing structure: Butterflies are poikilothermic organisms to regulate their body temperature internally must rely on the external thermal environment – as they need a temperature of 40°C in their thorax for the muscle motors to function properly. It is well known that they can thermo-regulate by behavioral means, altering their posture to open or close the wings, thus varying the exposure of the dorsal surface to solar radiation, warming the flight muscles or preventing from overheating. Scales play an integral role in the transfer of solar radiation by conduction to the thorax, since without them the temperatures of the thorax are lowered as show in figures blew. [29]

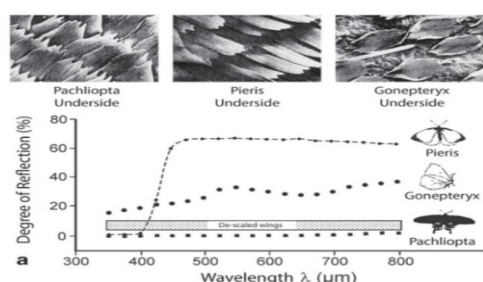


Fig. 39. Degree of reflection and scale form in butterfly species Pierisbrassicae, Gonepteryxramni and Pachlioptaar istolochiae. <http://www.enchantedlearning.com/subjects/butterfly/anatomy/index.shtml>

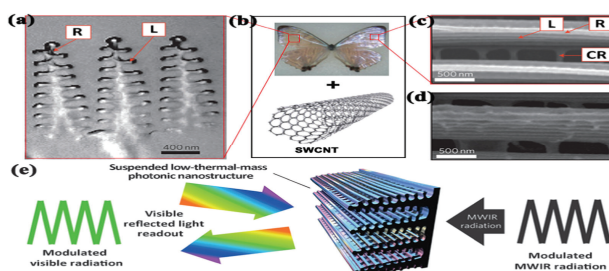


Fig. 40. The principle of uncooled thermal detection based on the air-filled photonic architecture of iridescent scales of a Morpho butterfly. Experimental schematic of MWIR radiation and visible reflected light readout for a Morpho Nanostructure. https://hpi.de/fileadmin/user_upload/fachgebiete/plattner/teaching/Ringvorlesung/Master_Nils_Strelow.

E. Bio-inspired sensors: When the wing scales were exposed to mid-wave infrared radiation (MWIR), the temperature of the CNT-doped wings increased and caused the structures to thermally expand, resulting in a change of reflective spectra. The surface-deposited CNTs play a key role in the sensing processes, as their exceptional absorption of IR radiation and high thermal conduction improve the sensitivity of IR detection. Combining the advantages of SWCNTs and the low thermal mass (the ability of a body to store thermal energy) of butterfly wings results in a sensor that possesses a temperature sensitivity of 18–62 mK and a heat-sink-free response speed of 35–40 Hz. [28]

F. Flexibility in butterfly wings lead to movable system of openings: This form of adaptation occurs for thermal comfort, balance between internal and external, and then always plays a role in the expression of environmental adaptation (see figure 41). [20]. Next part of image is physics study in butterfly. As showing in next paragraphs.

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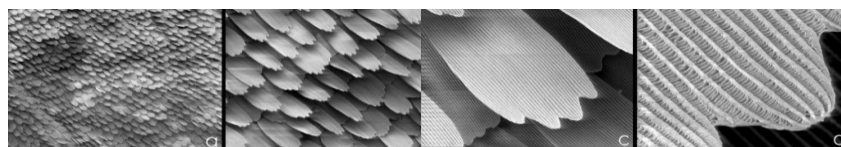


Fig. 41. Showing zoom in pieces that covering wing of butterfly under microscope. [http://mohan.mse.gatech.edu/Research/nanooptics_biological/nanooptics_biological.htm](http://mohan.mse.gatech.edu/Research/nanooptics/biological/nanooptics_biological.htm)

1.3. The butterfly colored wings: Some butterflies have shiny, vividly colored wings. From different angles, you see different colors as show in figure 42. This effect is called iridescence. Sunlight of different colors winds up reflecting off these materials in different directions. [23].

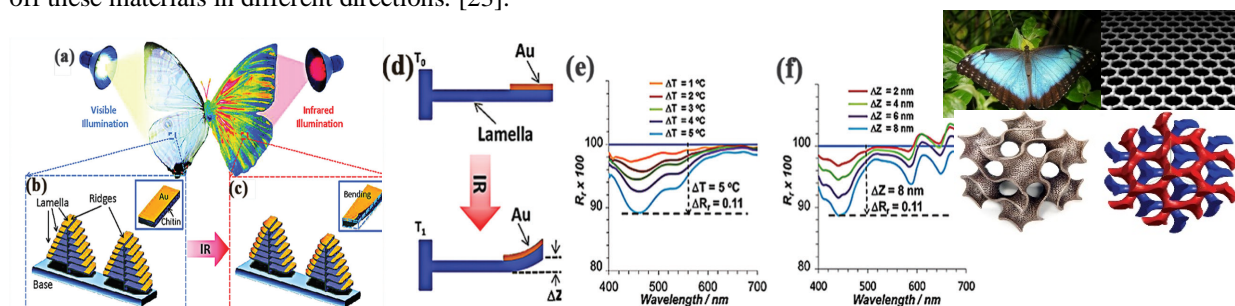


Fig. 42. Showing different colors From different angles of light and these wavelengths in 3d sections.

http://www.nanotechnology.hu/reprint/laserphotrev_5_27_biophotonics2011

The Troides Magellan's butterfly is just a perfect example to prove it. Its wings displays very contrasted colors – yellow fluorescent and iridescent hind wings and ultra-black forewings. The latter manage in the thermal radiation of the butterfly as a negative feedback that is stabilizing the body temperature. Their structure combines of both, structural scales and pigmentary ones to achieve the intensity of its color. The black wings absorb an extreme 98% of the visible range of solar spectrum, which means the large amount of energy is absorbed. However, heat accumulation is dangerous for butterfly that needs to remain a constant temperature of the body in order to be able to fly: therefore, it emits infrared radiation as a black body to avoid overheating as show in figure 43. [21]

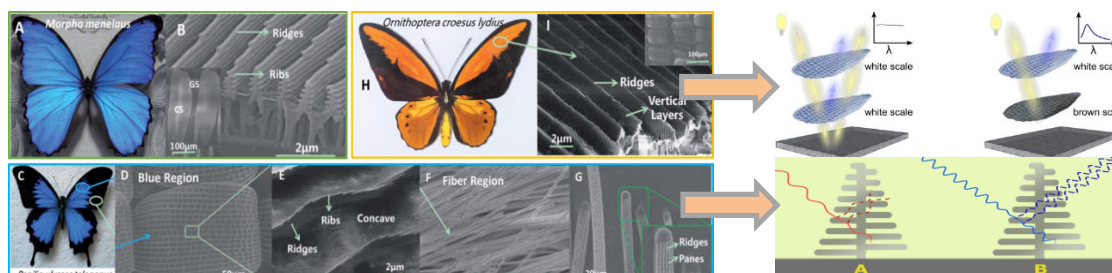


Fig. 43. Showing different colors of butterfly's species that suitable for surround environment. <https://microscopy-analysis.com/editorials/editorial-listings/butterfly-mystery-exposed>

2. Inspiration openings system from butterfly:

Let us start to think of a multilayer structural façade system (see figure 44), which would be based on the same butterfly's properties for process of cooling and heating by means of reflection and absorption of solar radiation, depending on the time of the day and season of the year.

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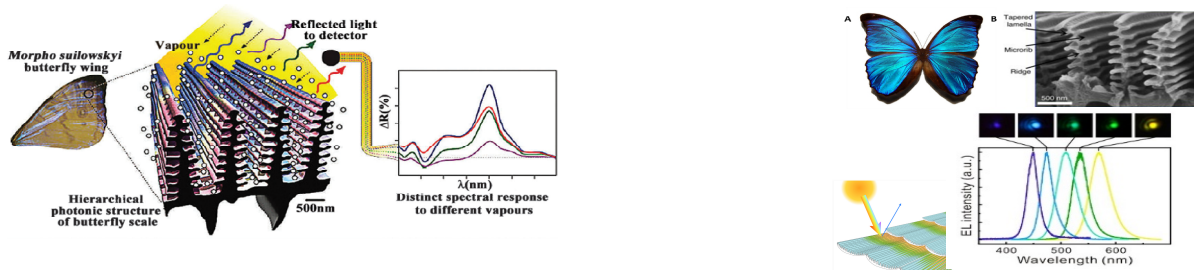
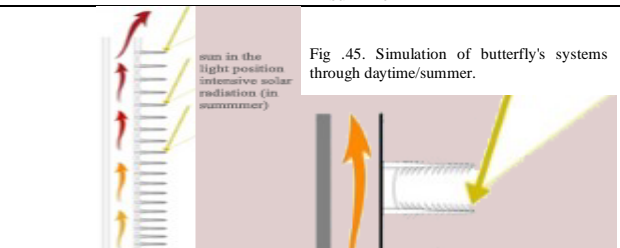
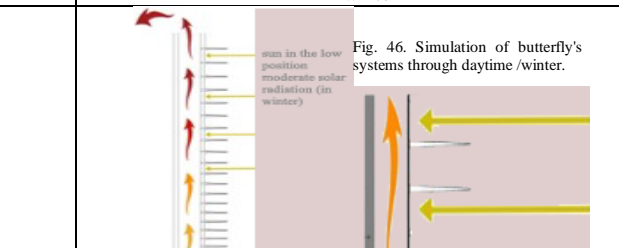


Fig. 44. Illustrate the butterfly environmental process through its component of wings. <http://theconversation.com/africa/topics/butterflies>

2.1. How can openings become as smart as wings of butterflies? The adaptation methods of butterfly in different environment are not the same so we can get a benefit from this method to design openings and make they adapt with surround environment (see table 5).

Table 5: comparison between butterfly wings simulation in summer and winter. Created by author

In summer	In winter
 <p>Fig. 45. Simulation of butterfly's systems through daytime/summer.</p>	 <p>Fig. 46. Simulation of butterfly's systems through daytime/winter.</p>
<p>During the summer or the daytime when sun is in the high position and we experience intensive solar radiation, as shown in the pictures on the left, the air from inside of the building would be redirected to the outside by natural convection in order to remain inner comfort for building. Combined together with the reflection caused by the geometry of the expanded material from the outer layer of the facade, unpleasant heat would remain outside of the building.</p>	<p>As the high range of daily temperature altitudes characterizes the desert climate, it would be more than convenient to be able to absorb some warmth before it gets dark and cold. Therefore, using the same airflow tunnel and by some openings in the outer layer of the structure after its retraction, heat could be transported towards the inside of the building.</p>

Wings of Butterflies have different species according to surround environmental condition but have common properties (see figure 47) that act their character as chart blew. All of these characteristics becomes more interesting when being applied to architecture in the verity climates as show in table blew.

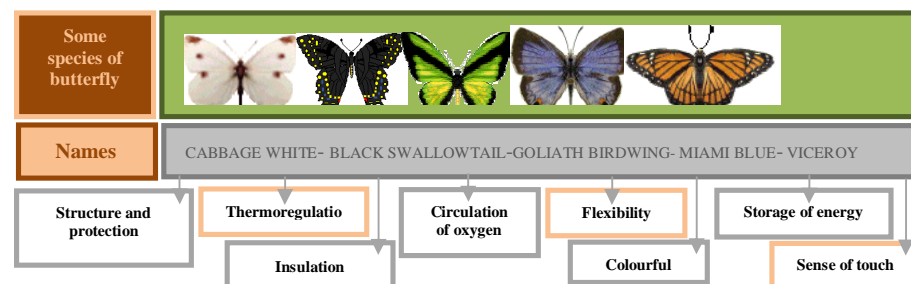


Fig. 47. Potentials of butterflies have more characteristics types to bio-design in architecture. (created by author)

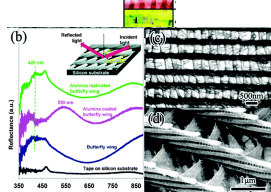
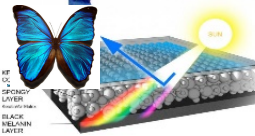
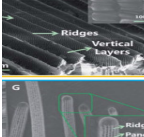

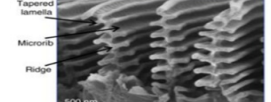
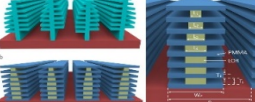
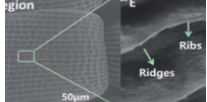
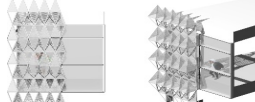


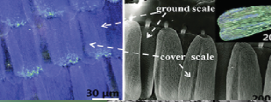

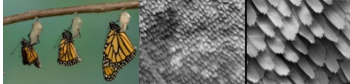

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Table 6: applied butterfly's properties to different architecture application in opening systems. Created by author

properties	behavior	application	describe
Varity in colors			Fig. 48. This property use in different materials in architecture that absorb sun rays, analysis it to the primary 7 colos and then reflect one only according to the amount of rays that reach to its surface. This system inspered glass materials in this field.
Air circulation (ventilation)			Fig. 49. The movement of louvers make an air flow inside the spaces according to butterfly properties in addition to the complex structure that support to attract cold air flow to inside.
Amount of heat and lighting			Fig. 50. The shading system that simulate from wing structure. This system reflect part of sunrays and permit to pass suitable amount of them to interior spaces without glare.
Protection and shading			Fig. 51. The louvers work as opening shades to control on lighting according to sun altitude with different openings angles.
Shape of wings			Fig. 52. Roof that has awing shape can control on environmental process more than usual roof when we make openings on it.
Scales of skin (pattern)			Fig. 53. The important notice feature is the continuous pattern in butterfly's wing that make a balance in facades.
flexibility			Fig. 54. The lightweight and easy moving of butterfly wing attract architects eye to use them in flexibility vertical openings system in walls to make dynamic spaces.

3. Practical application of bio-openings system

From the previous methodology, there are criteria that use in bio-openings design. The practice application in this part inspiration from butterflies. The building adapt with a number of existing influences environmental influence and project requirements as shown in figure 55.



Fig. 55. The building was to adapt to a number of existing influences and constraints (Adaptation process). Created by author

The suggested design approach is evaluated according to Achieve goals so I put the important functions of openings in the goals for study as shown in table 7 that illustrate requirement of surface to achieve goals through bio-openings design systems. This goal leads to sustainability.

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Table 7: illustrate requirement of surface to achieve goals through bio-openings design systems. Created by author

A. Required goals
1. Developing a surface structure.
2. Reduce consume of energy.
3. Related cross-ventilation
4. Reduce thermal degree in interior spaces for thermal comfort.
4. Control on lighting.

3.1. Simulation of bio-openings system (pattern): When see the scales in butterfly wing, shows how shingles on house vs the scales of the butterflies are jointed. The shingles with its nails is secured but the butterflies scale looks almost as if it can move and rotate. If the shingles of a facade would have had the same properties it would allow a living facade, a facade that can function as protection from the sun during day and rotate and function as something else during night.

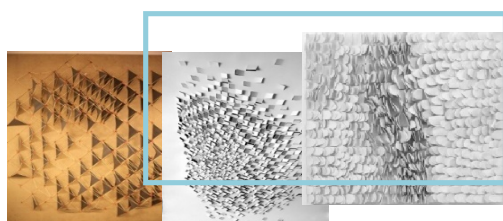


Fig. 56. Development of the folded component system (fauves's simulation) of researcher as the same of Hensel through paper models fabricated by cutting plotters. Source: the researcher based on Hensel, 2010

A functional full-scale prototype consisting of units of bio-openings that make a geometrically pattern variant components was constructed and tested. The small size of the unit in the pattern allows more precise environmental adjustment and vice versa. Adjusting the size and volume of each scale with parametric design (pattern) as show in figure 57, working with systems are things that has to be further explored with the help of grasshopper and rhino.

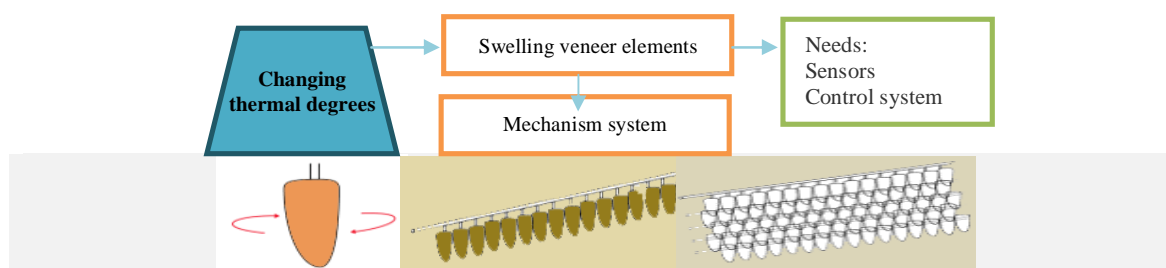


Fig. 57. Environmental modulation of responsive surface showing make a sort of mechanics that allows the shingles to move the facade will get different expressions and properties. Created by author

3.2. Experiment of System (mechanism openings system): there are some level to consist the skins following in figure 58. The important levels that the bio-openings design pass through are experiment units, collect pattern and development skin of facades.

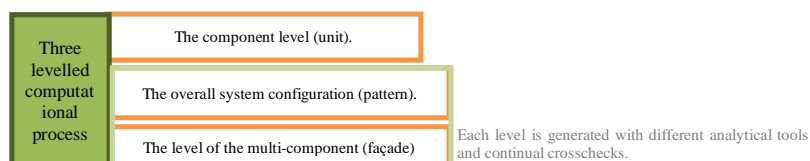


Fig. 58. Showing multi-levelled computational process. Created by author

A. experiment of some units: Once exposed to changes in thermal degree, the veneer composite patches move and thus facilitate the opening and closure of each component resulting in porosity across the openings skin, which is both a

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structure and responsive skin. This high level of integration and interaction of openings form, structure and behaviour system performance enables a direct response to environmental influences.

Environmental Modulation: Depending on the model development, simulation needs to recurrently interface with appropriate analysis applications as show in figure 59. For example, physics dynamics technology for the investigation of thermodynamic relations, light and acoustic analysis. In this iterative growth and proliferation process, each element adapts its morphology by calibrating its functional requirements with its particular sub-location in the overall a simulated environment. A sequence of finite element analyses conducted during the design phase evolved the structure in such a way that the pre-tensioned membrane elements became a thermal math of the system, not just a cladding.

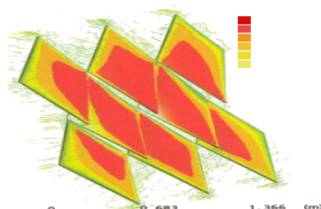


Fig. 59. Revit program analysis distribution of thermal degree on louvers as units. Created by author

with analytical tools simulating the system's interaction with precipitation and its related drainage behaviour, this multi-criteria evaluation derived a finely calibrated level of permeability of the porous membrane skin that minimizes wind pressure and simultaneously prevents local accelerations of airflow due to channelling gaps between the membrane elements (see figure 60).

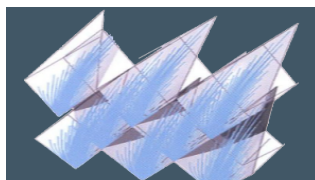


Fig. 60. Rainwater runoff analysis and ventilating Concurrently iterative CFD tests of the system's aerodynamic behaviour were conducted on both the level of the overall system and local components assemblies. researcher based on Hensel, 2010

A further important factor that influenced the system's development was the shading behaviour of the canopy in different seasons and at different times of day, aiming for a mix of shaded and exposed terrace zones that change from winter to summer. Given an extreme change of thermal degrees as show in figure 61, is also rapid with the shift from a closed to a fully opened state taking less than 20 seconds. The system of the developed component integrates a thermal sensor, change actuator and movement control element. The component's direct responses to environmental changes suggest a locally controlled system in which each sub location senses and reacts independently as part of an emergent overall environmental modulation.

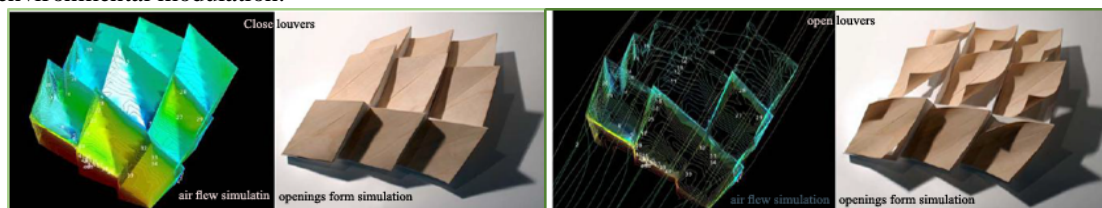


Fig. 61. CFD Analysis of openings Components units. Showed that the resultant calibration in different opening states enables a highly specific modulation of airflow and thermal levels across and along the system. Source: researcher based on Hensel, 2010

B. Evolutionary Form (growth pattern): The computational differentiation operates on a multi-levelled computational process in this project to collect units in one surface to make openings pattern in skin. This pattern support balance in façade.

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Skin Behaviour: The form of the membrane was a result of the required behaviour, which was fed into the system as a number of constraints or parameters, such as protection from wind, cooling, rain, allowing the lighting, ventilation, in addition to the required structural behaviour for thermal comfort. This approach enhances the intricate link between form and behaviour, such as that present in butterflies. The form of butterfly affects its behaviour in the environment, and a particular behaviour will produce verity results in different environments (see figure 62).

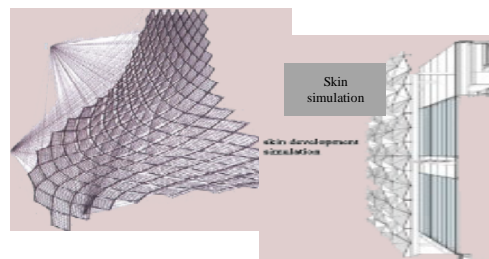


Fig. 62. Showing after collect a pattern of louvers as a skin. Created by author

3.3. Technique of System: This system of opening consists of steel frames that supporting with steel wires and membrane assembly. The glass of opening fix in this structure and the louvers. The louvers have sensors to sunrays and move according to sun altitude with control system as show in figures blew.

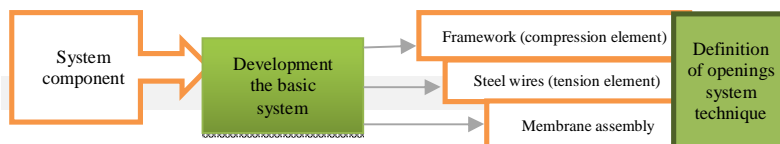


Fig. 63. features of openings in facades that provide the system's skin. Created by author

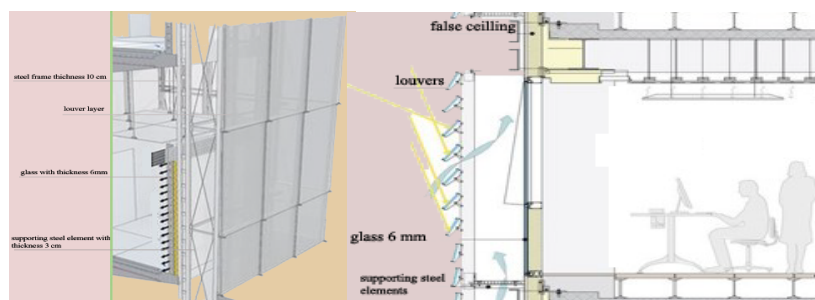


Fig. 64. The parameterization of the component was based on the self-forming behaviour of the membrane element was investigated in relation to the location of the points where it attaches to the compression framework. The variation of the coordinates of the anchor points leads to variant equilibrium states of the acting forces and related membrane shapes. Created by author

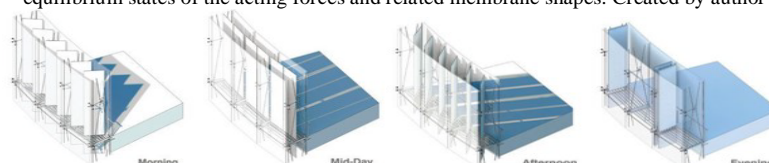


Fig. 65. Changing of louver opening angle in facades skin according to the sun altitude through day. Source: researcher based on Hensel, 2010

3.4. Form Behaviour: The form of the membrane was a result of the required behaviour, which was fed into the system as a number of constraints or parameters, such as protection from wind, cooling, rain, allowing the lighting, ventilation, in addition to the required structural behaviour for thermal comfort. This approach enhances the intricate link between

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form and behaviour, such as that present in butterflies. The form of butterfly affects its behaviour in the environment, and a particular behaviour will produce very different results in different environments as shown in figure 66 mechanism system.

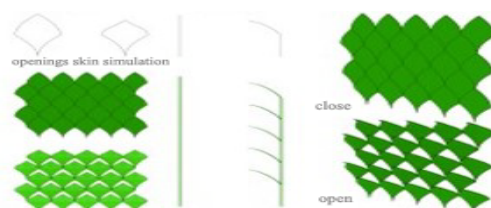


Fig. 66. Showing The form of butterfly affects in openings shape to adapt with environment. Created by author

V. EVALUATION BIO-OPENINGS SYSTEM

The evaluation comes from achievement goals of study as following (see table 8). The evaluation appeared that the study is successful. It gets a point and more than needs.

Table 8: Achievement of objectives required goals and how were they achieved? Created by author.

A. Required goals	B. How the bio-opening achieve it?
1. Developing a surface structure.	1. Developing a surface structure that adapts with the porosity of skin (bio-opening system).
2. Reduce consume of energy.	2. Mechanical devices are used to reduce consume of energy.
3. Related cross-ventilation	3. Related cross-ventilation in response to open veneer movement.
4. Reduce thermal degree in interior spaces for thermal comfort.	4. Reduce thermal degree through shading system that control on heating in interior spaces for thermal comfort.
5. Control on lighting.	5. Control on lighting comes from the system of openings that reflect part of sunrays and permit others to passing according to the sun altitude that effect on opening degree of louvers.

In this system, I find properties more than goals of study as following:

- Protection from wind & rain.
- Flexibility on system use.
- Achieve sustainability principles.
- Lightweight structure.

If a conventional design method applied in order to achieve the same goals and objectives stated above, it would probably be unsuccessful due to the following reasons:

- Difficulty of applying the relevant characteristics of the select veneer without computational means.
- Difficulty of manually calibrating each component to respond to various conditions and orientation within the envelope
- Difficulty of coordinating the articulation of each single element with that of the overall form.

VI. CONCLUSION

In conclusion, by mimicking the nature, the building's skin system could provide ability to transform over time through incorporating intelligent systems that undergo purposeful changes in accordance to external and environmental conditions. These adaptive systems have the ability of inherent movement in their structure and operate dynamically as actuators combined with electronic sensors at low energy supply. From those examples and many others, the information provided from studies of nature could lead to superior performance in buildings, making them more efficient. Concentrating on buildings' façades, skin components (bio-openings) as shown in table 9.

International Journal of Innovative Research in Science, Engineering and Technology

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Table 9: primary benefits from bio-openings skin Created by author.

skin components (bio-openings) that have been designed by such solutions can be fulfilled by the following primary benefits:
1. Implementing elements on building's façade that have the ability to change or rotate shading devices during course of a day.
2. Decreasing the waste of heat during wintertime by blocking/catching cold air through elements on the façade.
3. Improving the efficiency of the building through reducing the increased consumption in energy, which increases the risks on the environment and ecosystem.
4. Decreasing the financial costs that caused by potential energy consumption.
5. Developing a surface structure
6. Reduce consume of energy.
7. Related cross-ventilation
8. Reduce thermal degree in interior spaces for thermal comfort.
9. Control on lighting.

The presented research projects all share a set of common advantages that significantly imply the importance and potential of the suggested design approach (see table 10).

Table 10: the analysis and evaluation of these projects observation Created by author.

Through the analysis and evaluation of these projects, the following issues were observed:
1. The form is a product of all affecting factors interacting with a simulated environment: This setup enables iterative analyses and evaluation cycles, so that the specific form of the system unfolds from the reciprocal influences and interaction of form, material and structure within a simulated environment.
2. Adaptation: in this iterative computational process, each element adapts its morphology by calibrating its functional requirements with its particular sub-location in the overall system.
3. Higher efficiency/multi-functional components.
4. Balancing multiple and conflicting criteria: This morphogenetic process enables the balancing and calibration of multiple, or even conflicting, design criteria and the unfolding of the material system's inherent performative capacity.
5. Integration: Rather than aiming for rationalization or single-objective optimization, computation becomes the means of integration: integration of system-inherent constraints of materials, manufacturing and assembly, and a wide range of external influences and forces.
6. The possibilities of improving the environmental performance and durability of the composites through the substitution of the synthetic passive layers with recycled or natural materials, which have stiffness and strength to enable the use of thicker active layers.
7. Design of responsive systems with enhanced adaptive properties and visual impact through employing a range of response mechanisms and arrangements of hydromorphic elements.
8. Development of strategies for practical application of the technology.

Proposal that would use a natural air convection together with thermal expansion and retraction. It is a mechanical system in different environmental process that we can use in openings design. The butterfly have important purposes (see table below that explaining the reason of more one of butterfly properties for the future research) and then the results of butterfly analysis.

Table 11: explaining the reason of more one of butterfly properties for the future research Created by author.

reasons	describe
Reason1: Camouflage	In which the colour of the animal helps it blend into the environment, hiding the insect. The Australian leaf wing of butterfly is shaped and coloured like a leaf.
Reason2: Warning (or aposematic)	Brightly coloured butterflies make them attractive so the sense of touch is very important properties.
Reason3: notice external behaviour	Colours, patterns and flexibility
Reason4: Deceiving predators into thinking they are bigger than they really are.	Some wings have large "eyespot" which make the butterfly or moth look like the face of a larger animal (like an owl), scaring away some predators.
Reason5: Soaking up heat	Dark-coloured scales soak up heat very well when the butterfly suns itself. Like all insects, butterflies are cold-blooded. When they get too cold, they warm themselves in the sun.

Table 12: the results of butterfly analysis. Created by author.

The results of butterflies analysis shows:
A. The wings membranes are translucent, but are partially or fully covered in a dust-like layer of colored scales. Each scale comprises of a flat plate arising from a single cell on the wing surface. That protect the structure of wings and help butterflies in adaptation through it is movement.
B. There is strong air flow movement passing through the opening in the wing of them from outside to inside that reduce heat. For example, if the air temperature is x degree when it go inside then it come back with x-15 degree.

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C. All body of them always should remain in thermal comfort with constant temperature to save health so in hot weather they takes that need to their body and convert other to energy.
D. They have verity colors of wings according to the weather of places they live that control the amount of heat and light go to inside them through different number of observation and radiation to colors such as (white – black – red- yellow – blue).

The bio-openings simulation from butterfly is a successful skin that lead to sustainability and improve building performance because it can control on lighting, improve ventilation, and achieve thermal comfort in addition to saving energy.

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