

Involucri biomimetici

Biomimetic Envelopes

La possibilità di trasferire le esperienze ricavate dallo studio del mondo animale è l'esperienza formativa di design presentata in questo articolo. La pelle è un organo complesso e sofisticato che si presta a varie funzioni quali protezione, sensazione, regolazione dei liquidi e della temperatura corporea.

In modo simile le facciate degli edifici dovrebbero assolvere, oltre a quello estetico, molteplici altri ruoli poiché costituiscono l'interfaccia tra i loro abitanti e gli elementi.

Le ricerche e i progetti biomimetici proto-architettonici qui presentati, ispirati dallo studio della pelle di diversi animali, sono performativi e interattivi; tengono in considerazione le condizioni ambientali dinamiche, migliorandole

e assecondandole anziché semplicemente sfruttandole, creando così un modo più sostenibile di costruire e vivere.

How to translate the lessons learned from the analysis and observation of the animal world



Ilaria Mazzoleni

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is the design learning experience presented in this article. Skin is a complex and incredibly sophisticated organ that performs various functions, including protection, sensation and heat and water regulation.

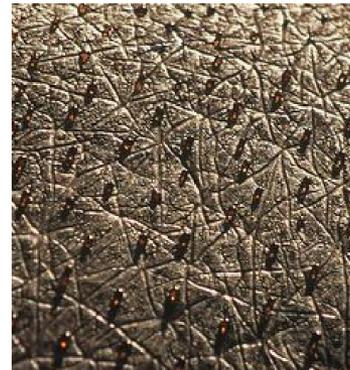
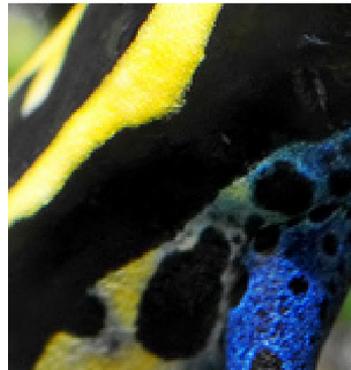
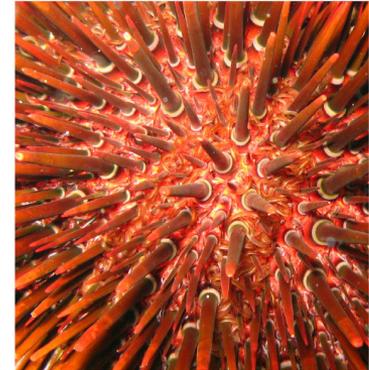
In a similar way building envelopes serve multiple roles, as they are the interface between the building inhabitants and environmental elements. The resulting architectural building envelopes proto-architectural research and design projects here presented, inspired by the study of animal skins, perform and respond; they take into consideration various dynamic local environmental conditions, enhancing and supporting them rather than exploiting them, creating a more sustainable way of building and living.

'Biomimicry [is] innovation inspired by nature. In a society accustomed to dominating or "improving" nature, this respectful imitation is a radically new approach, a revolution really. Unlike the Industrial Revolution, the Biomimicry Revolution introduces an era based not on what we can extract from nature, but on what we can learn from her.' (Janine Beynus)

Biology – especially ecology - are disciplines that can influence design projects in unexpected and interesting ways. How environmental and climatic conditions have influenced the evolution of behavioral and physiological traits of animals can inform and inspire fields such as design and architecture. The term biomimetics, in all its faceted variations (bionics, biomimicry, bioinspiration) has been in use since the 1950s when Otto Schmitt defined it as "biology + technology" and applied it mainly within the field of engineering. In the field of architecture, however, this term has been adopted only within the last five to ten years and, too often erroneously, refers to studies limited to the imitation of the morphological aspects of the biological world. A major challenge facing the field of architecture today goes beyond the basic quest of aesthetics towards a responsible attitude of the built environment for the future.

The projects that follow are the results of a collective investigation born from the author's ongoing professional research and her academic collaboration with her students at the Southern California Institute of Architecture during the Spring of 2010.

In the projects presented, we expanded the term biomimetics by investigating the animal kingdom as a source of knowledge and inspiration. We took the perspective of naturalist J. Benyus, stating in the book *Biomimicry*, "...[to] use Nature as Model,



Measure and Mentor.” We concentrated on aspects of architectural innovation that provide functionality drawn from biological adaptations - rather than mimicry - to the designed elements. Our team worked with biologists to look at the opportunities the natural world offers as inspiration. We focused on the analysis and understanding of different types of animal skins and translated the learned principles into the built environment. Skin is a complex and incredibly sophisticated organ that performs varied functions, including protection, sensation, and heat and water regulation. In a similar way building envelopes serve multiple roles, as they are the interface between the building inhabitants and environmental elements (e.g. water, air, sound, light and temperature). Building envelopes offer safety

and privacy insulation, and ventilation. The resulting architectural building envelopes perform and respond; they take into consideration dynamic local environmental conditions - enhancing and supporting them rather than exploiting them - creating a more sustainable way of building and living.

Each building envelope, much like the animals used as inspiration, is optimized to its environment. Each project takes into account the thermal, acoustic, or visual characteristics of the environment and attempts to utilize these unique features to create an optimal envelope for that environment. During the course of this investigation we studied eight animals and developed corresponding design proposals for each. These related to the topics of sensation,

coloration, energy regulation, water management, and the use of local and renewable resources. Four animal analyses and their proto-architectural projects were presented.

Animals for these projects were chosen to reflect a variety of types of skins from different climatic regimes. All animals have skin, which serves the same essential functions for all organisms. However, the way in which skin achieves these functions can vary widely, taking the form of scales, fur, exoskeleton or feathers, to name a few. The projects in our class focused on specific functions that were unique to the selected animal's skin. The biology of an animal and the environment it lives in determine these functions. Hard scales serve to protect a pangolin in Africa from

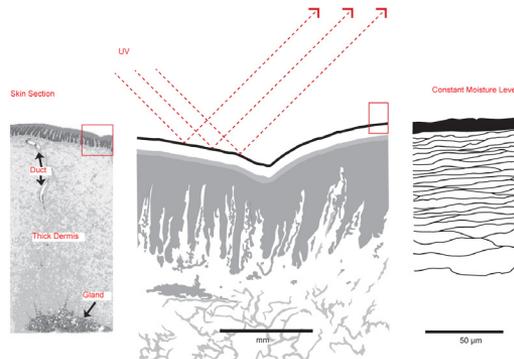
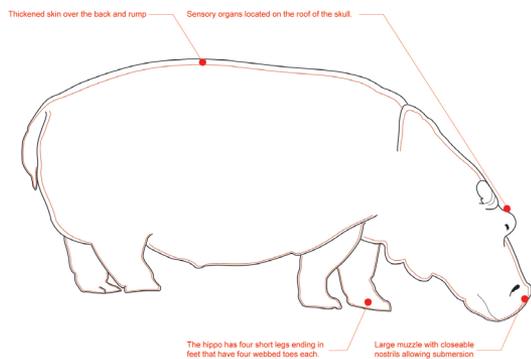
both its prey and predators, yet the scales of a lizard are important in preventing water loss in a desert climate. Water loss is avoided in a desert beetle with behavioral adaptations and a hard exoskeleton. Large, bare-skinned mammals, such as hippos, need to protect themselves from water loss and UV rays from the sun. Insulation from cold can occur through the thick fur of a snow leopard that lives in the mountains, while a tundra swan has layers of feathers. A hummingbird's colorful feathers serve to attract mates, while the skin of a tropical poison dart frog provides moisture balance.

The process by which each animal analysis was carried out was analogous to the one subsequently used to design and describe the building envelope. We first developed an understanding of the climatic

characteristics of the environment in which the animal lives, followed by a study of the morphological and physiological strategies the animal uses to survive in its particular environment. Each animal had adapted to its environment, so studies of biomimetics need to take an integrative approach, focusing on the animal but also, importantly, the climatic regime it evolved in. After having an overview each animal's adaptation we focused on each animal's skin – the different layers, primary functions, how other physiological systems interact with the skin, and how the skin interacts with the environment. The resulting sectional line drawings aided in learning and defining the stratification and functioning of the skin. Through this close and detailed analysis a design lesson emerged, highlighting the fundamental elements of the skin

and inspiration for the design of the architectural element. For example, the overlapping scales of a lizard inspired the design of a shelter in the Mojave desert while the different types of feathers in swans inspired the development of a building envelope that would react to the temperature regimes of different seasons while creating/producing a sense of softness to the building envelope. The exploration and development of the design echoed the steps of the animal analysis; each project was integrated and inserted into its respective environment responding to comfort throughout the different seasons. The generation of both 3D renderings and detailed 2D line drawings allowed the performative and adaptive aspects of the design to be experienced.

The animals and design projects featured here do



not provide us with definite solutions, but rather open the door to further questions. They encourage us, as designers and biologists, to pursue our studies to better understand the complex and magnificent natural world.

HIPPOPOTAMUS (*Hippopotamus amphibious*)

Sarah Maansson & Worrowolan Raksaphon

“The Porous Skin” project is based on controlling the intake of daylight and the control of temperature, using the hippopotamus (*Hippopotamus amphibious*) skin as a model for sun protection, permeability and thermal regulation.

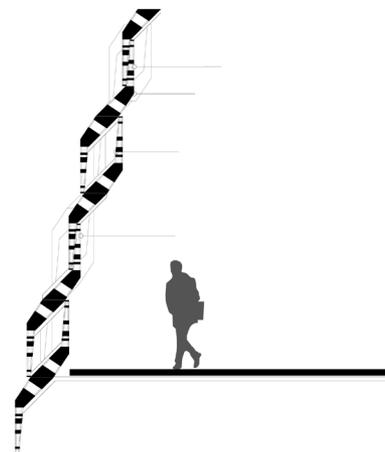
Hippopotamus skin has the ability to protect itself from the sun’s UV-light, by secreting a fluid from glands deep within the dermis that functions as a sunscreen when the hippo is out of the water. This protective quality is the main element of inspiration for the design of the project’s building envelope.

The hippopotamus is a pachyderm, a thick-skinned animal, with skin consisting of a very thick dermis

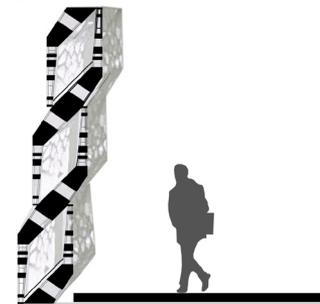
and a thin epidermis. The thickness of the skin varies throughout the body, from more coarse over the back, becoming more thin and pliable on the belly and on the inside of the limbs. Similarly, the project has as exterior building skin a system that filters sunlight, depending on its depth. Thinner sections let in more light while thicker sections act as a sun screen. Controlling the amount of sunlight that comes in to the building is the first step towards controlling the regulation of temperature.

The hippopotamus’ semi-aquatic lifestyle can inform the building infrastructure design such as the *use of water to cool the building*. The project site coincides with the hippopotamus’ habitat – the Okavango Delta, Botswana. The winter months are dry and cold with hot rainy summer months during the river’s delta floods. The hippo is thus able to take advantage of abundant water for cooling during the summer.

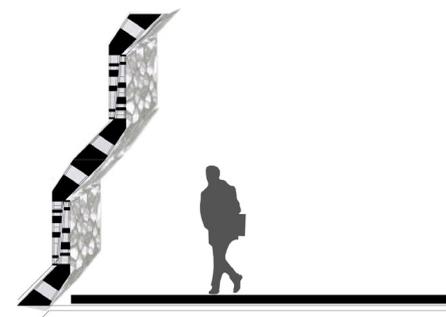
Bringing together the ideas of varying thickness and water to cool, a system of *movable panels* is designed to control the indoor temperature in order to provide comfort to the inhabitants. During the

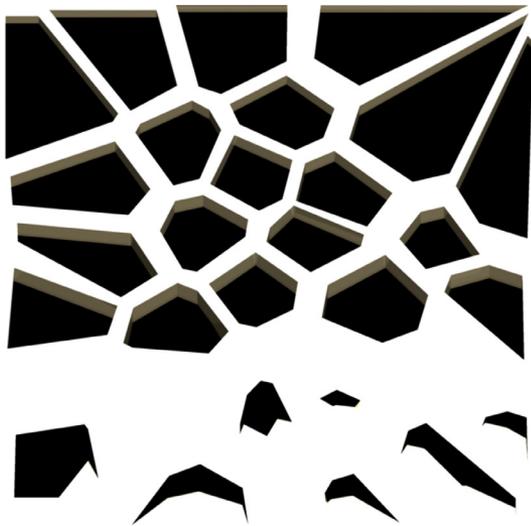


Wall. Summer condition - all in position A.

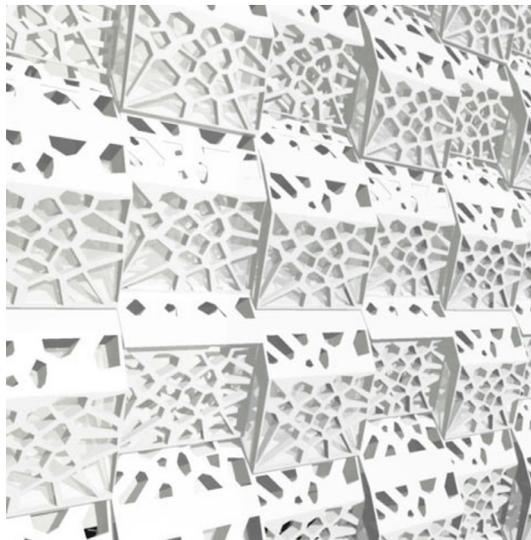


Wall. Winter condition - all in position B.

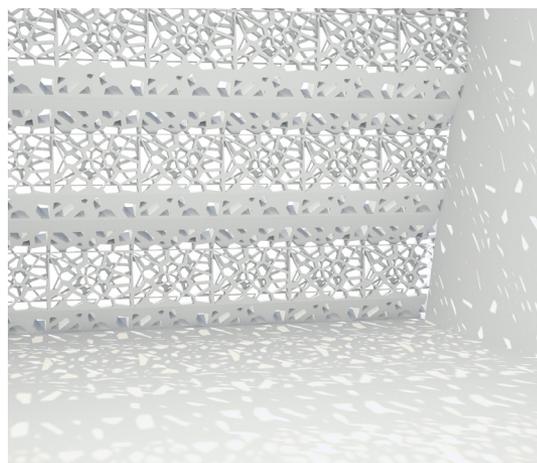
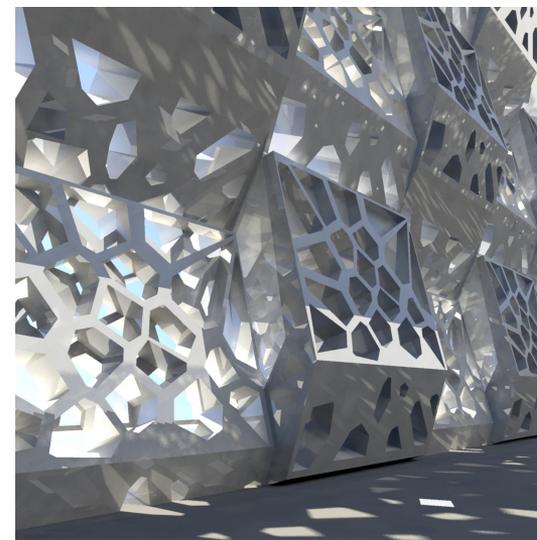




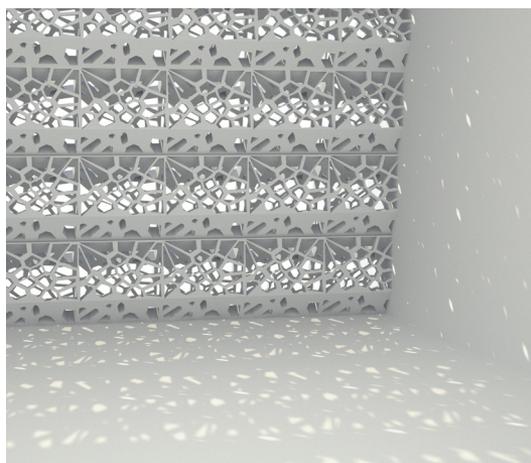
Panel Pattern



Wall system



Winter condition_max. intake of light - min. retention of water.

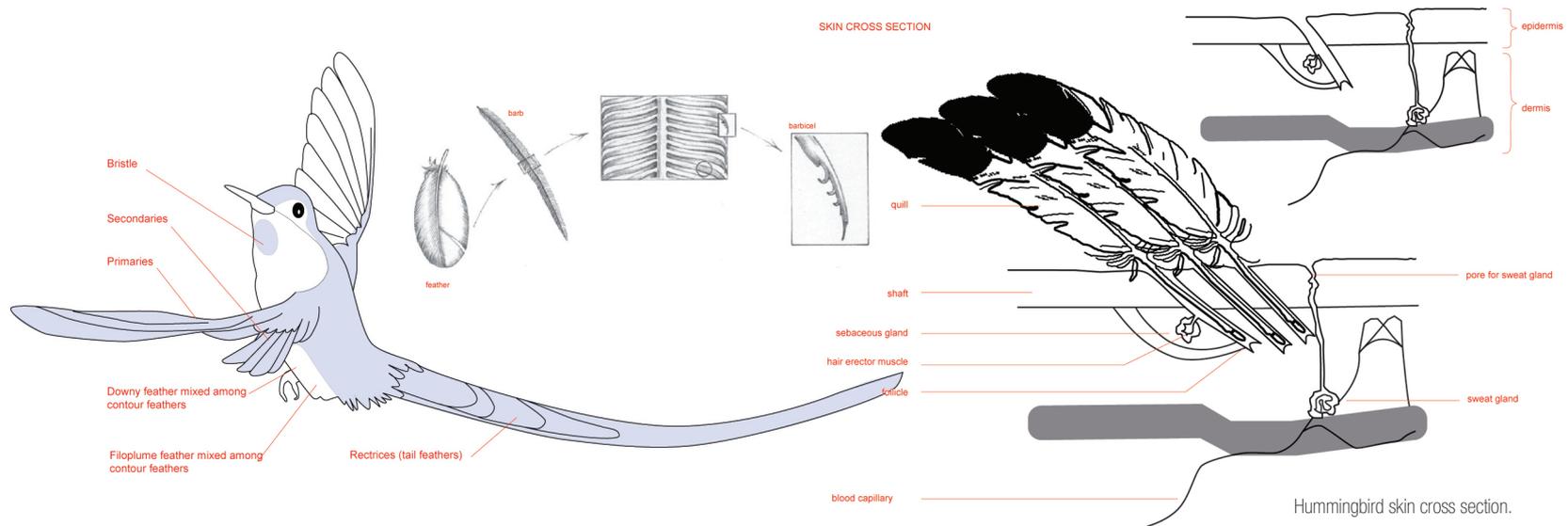


Summer condition_max. retention of water - min. intake of light.

hot and wet summer season, the panels are set to position A, allowing water in through the outer layer of the building envelope to cool the interior of the building. When panels are set to position B, more sunlight can permeate the façade and warm up the living spaces.

A system of cells of varying sizes creates the basic structure of the panels, running from the thin, almost perforated to thicker and denser.

The varying thicknesses regulate the transfer of heat between the exterior and interior of the envelope. Changing the angles of the cells controls the direction of sunlight coming in to the building. Sunlight can be allowed in at certain times of day or to specific areas of the building, changing the size of the aperture decreases the overall amount of light.



VIOLET-TAILED SYLPH HUMMINGBIRD (*Agelaiocercus coelestis*)

Alina. Amiri & Joanna-Maria Helinurm

The Violet-tailed sylph (*Agelaiocercus coelestis*), a hummingbird native to Ecuador, has *attractive blue, violet and green iridescent feathers* which inspired the color scheme for designed pavilion. The pavilion is in Parque la Panecillio in the city of Quito, Ecuador, a city 9,000 ft above sea level and 15 miles south of the equator. Its location results in a temperate climate with high humidity but cooler temperatures averaging 65°F.

Color is a device for aesthetics and a powerful means of *communication*. It attracts people, and portrays and registers dynamically atmospheric changes.

Especially bright colors can be powerful means for communication and facilitator of activities recording and happening. Moreover color communicates energy and *enthusiasm* thus the person experiencing the space from within and from afar begins to have various sensual responses to the physical environment.

The hooked barbules of the hummingbird feathers' inspire the pavilion's paneling joint system. The panels are made of two layers of semi-transparent resin and a thin layer of glass to provide additional refraction.

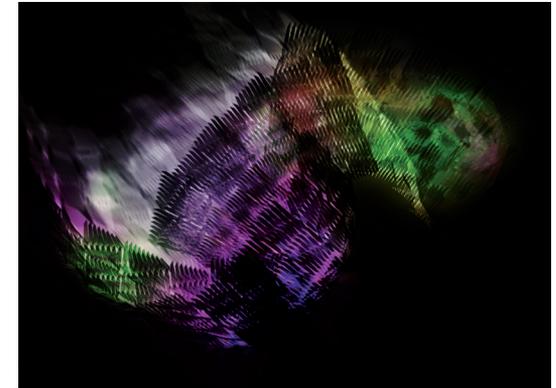
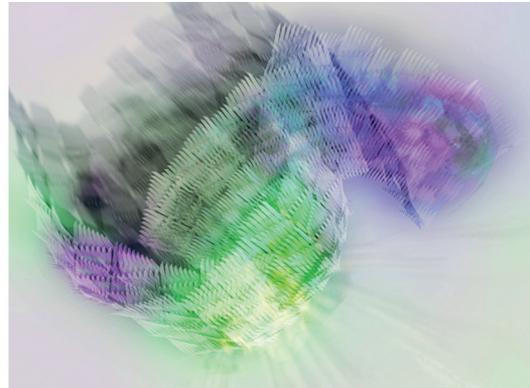
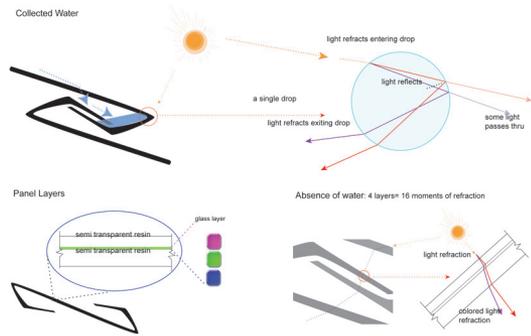
The hooked connection allows for the creation of small water pods which provoke the desired light refraction and enhances the colors' iridescences.

Light refracts differently when it hits water and the dispersal of colored light changes depending on the presence of water and the environmental conditions.

SNOW LEOPARD'S (*Uncia uncia*)

Joakim Hoen & Mamoune Ghaiti

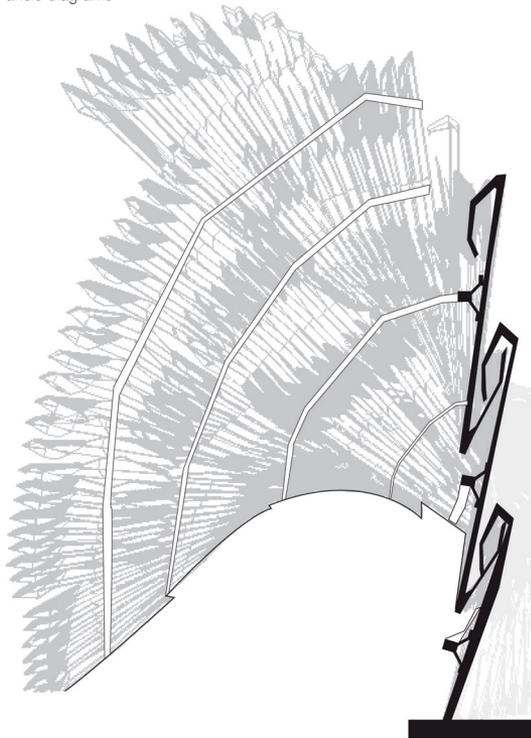
The design team developed a facade system for a small *pod*, inspired by the *Snow leopard's (Uncia uncia)* fur. The pod is located in the mountainous environments of the Himalayas, the natural habitat of the snow leopard and serves as a shelter for one or two researchers. Due to difficult terrain, political conditions, and the extreme climate very little research on the snow leopard has been conducted.

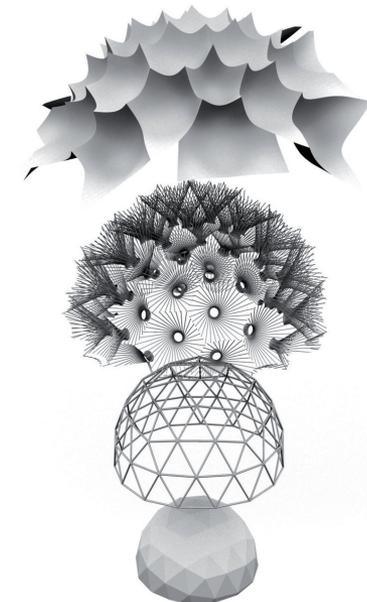
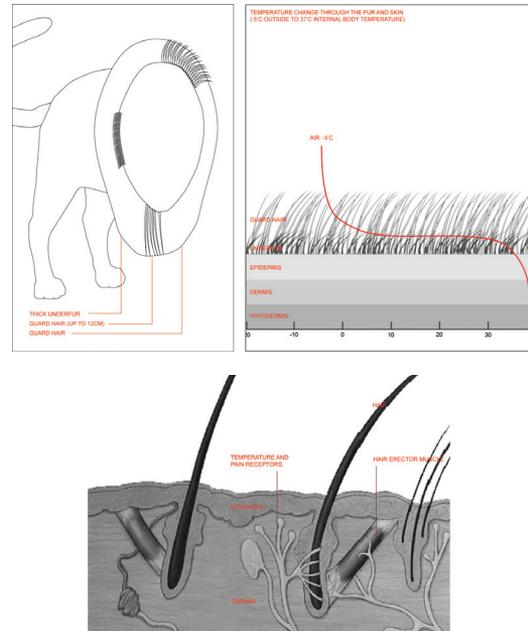
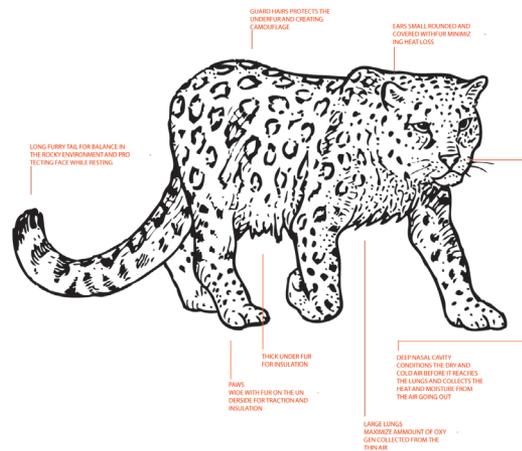


Panels diagrams

DAYTIME : sharper brilliance toward exterior.

NIGHTTIME : color glows more inward.





This pod intends to facilitate further research of the snow leopard.

The snow leopard is well-equipped for mountainous, broken terrain and cold, snowy climates. Its compact and round body, thick, dense fur and wide paws help it live easily in the snow. Likewise, the research pod is designed to primarily insulate, protecting researchers from extreme temperatures varying between -25°F to 60°F . Its compact and round shape is formed by a spherical structure covered with a morphing insulated layer. The whole system enables the building to expand and contract making the surface area larger and smaller according to the weather and season.

Similar to the skin and fur of the snow leopard, the

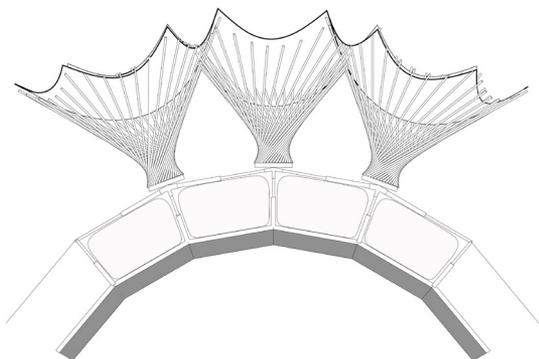
pod is constructed of several parts:

Inner Structure (Body): The inner static structure is a geodesic dome covered by highly insulating panels of NASA's Thermablock. This most inner layer of insulating panels protects the pod's interior and acts as main structure for the rest of the system to build upon it.

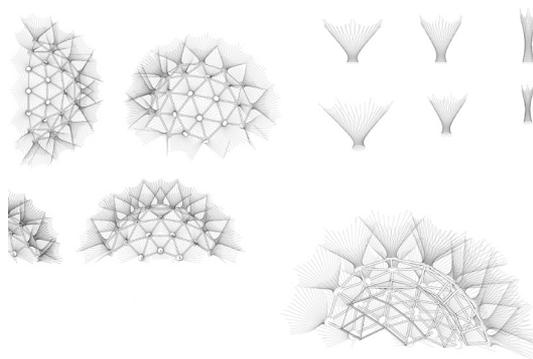
Telescopic Skeleton: A structure composed of telescopic rods is mounted on the inner body, forming a geodesic dome. This skeleton expands and contracts by inflatable cushions.

Rods: Each connection point in the dome has a round platform supporting a number of rods. These rods are connected at one end to the platform and at the other end to a corresponding rod from an adjacent platform. As the telescopic skeleton expands the

Top, membrane A. final waterproof membrane stretched over the end of the rods will unfold and its dark color will make the air pocket underneath heat up during a sunny day. Aesthetically the membranes' shape can be seen as a stylized picture of the mountain peaks in the surroundings the pod is intended to inhabit. Center, rods. Every connection point in the dome has a round platform hosting a number of rods. These rods are connected in one end to the platform and in the other end to a corresponding rod from an adjacent platform. As the telescopic skeleton expands the platforms will move apart and force the rods to flatten and open each cluster. Telescopic Skeleton A structure of telescopic rods is mounted on the inner body, forming a geodesic dome. This skeleton is expanded and contracted by inflatable cushions between it and the body of the building. Bottom, Inner Structure (Body) The inner static structure is based on a geodesic sphere covered by highly insulating panels of NASA's Thermablock. It functions as the last layer of insulating protection for the interior and as main structure for the rest of the system to build upon, much as the body of the snow leopard. The whole system works together to enable the building to expand and contract making the surface area larger and smaller according to the weather and season.



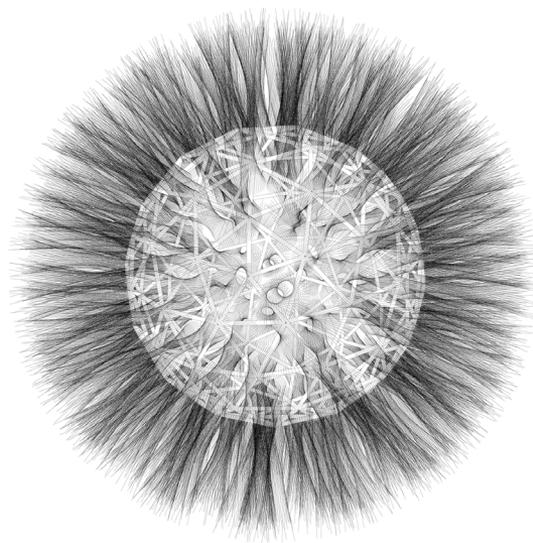
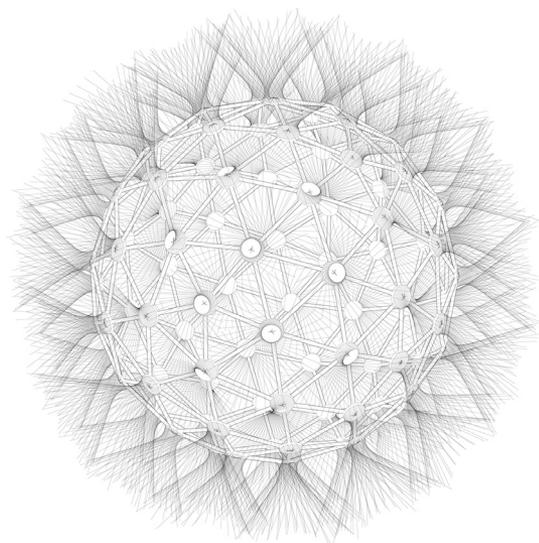
Detail section.



Rods on geodesic skeleton.



Closed state. Winter / night.



Open. Summer / day (winter size dashed).

platform moves apart and forces the rods to flatten and open each cluster.

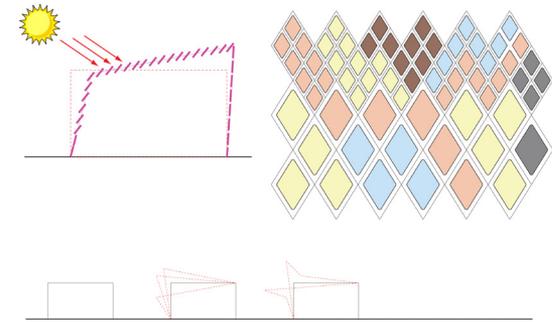
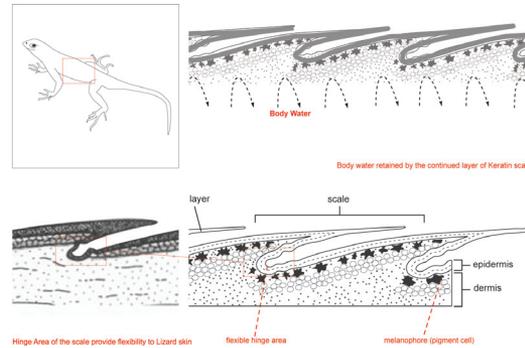
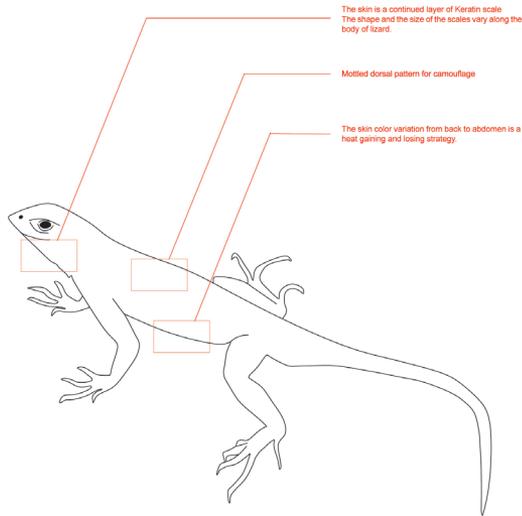
Membrane: A final waterproof membrane stretched over the end of the rods unfolds once the structure expands; its dark color makes the air pocket underneath heat up during a sunny day.

Aesthetically, the shape of the pod's membrane can be seen as a stylized representation of peaks like the surrounding Himalayan mountains.

SIDE-BLOTCHED LIZARD (*Uta stansburiana*)

Yuan Yuan & Juan San Pedro

S.C.A.L.E.S. (*smart, continuous, active, layered, environmental, system*) is a project that takes inspiration from the characteristics of the Side-

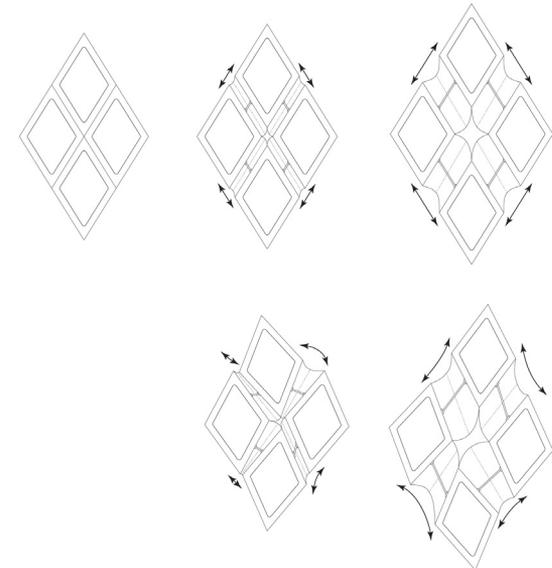


blotched Lizard (*Uta stansburiana*). The team created a residence for the desert climate which mimics the behaviors and translated physiological characteristics of the lizard's skin.

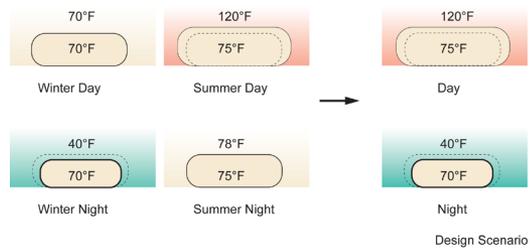
The scales of the lizard are not separate, but rather, a continuous epidermal sheet. The sheet forms each overlapping scale, which are connected by hinges of thinner keratin material. The scales vary in shape according to the degree of movement the body part experiences. The body parts of the lizard that experience more movement have smaller sized scales than other, less mobile parts. The skin color pattern is typically a dark color on the back of the lizard for sunlight absorption and a light color on the abdomen for reflecting heat from the ground. In addition to the skin characteristics, the behaviors

of the lizard contribute to its thermoregulation. The lizard adjusts its body position perpendicular to the sunlight for heat absorption or parallel to the sunlight while curling its toes to avoid heat gain. It hides in the shade to cool when overheated.

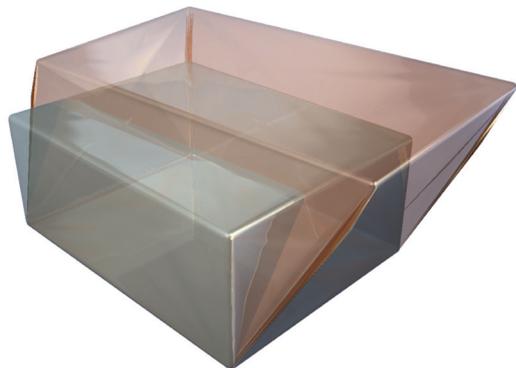
Similar to the lizard in the desert the main concern of the design is the comfortable existence of the residents during hot, arid days and cold nights. The site of the residence is in Palm Springs, California and is designed to perform within the maximum experienced temperatures within a 24-hour period. The physiological aspect of the lizard skin informs the walls of the house. While the behavioral aspects of the lizard is translated into the building's 'smart' sun tracking system and is actuated by the hydraulic system.



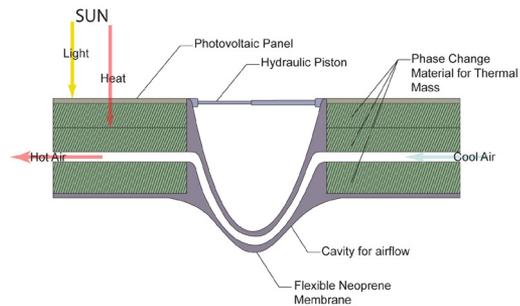
Skin Panel Movement Diagram.



Design Scenario. Relationship Between Temperature and Building Size.



Night and Day Change of Building Size.



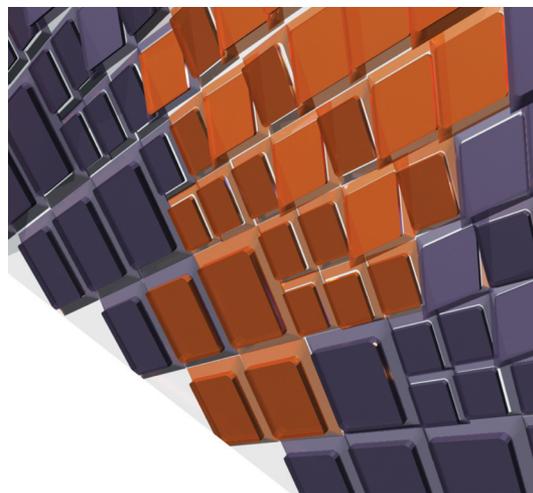
Skin Section.



Roof and South Façade Dark Color for Heat Gain.



East and West Facades Light Color for Sunlight Reflection.



The walls of the residence are comprised of colored photovoltaic panelized surfaces that have hydraulic pistons and a flexible neoprene membrane between each panel. The membrane permits the expansion and rotation of the wall panels, the increase of the surface area and the optimization of the panels' angularity towards the sun. The panels contain two layers of phase change material (PCM) and a flexible air passage sandwiched between them. This allows air to flow between the thermal mass and absorb heat or be cooled down depending on the time of the day. The different sizes of the panels indicate which parts of the skin move more frequently. The movement of the walls also causes a variation in the spaces of the residence. The hydraulic system and sun tracking are powered by the electricity collected

by the photovoltaic cells. The panels are colored according to cardinal direction and the sun path. The roof and south side of the residence are comprised of darker colored photovoltaic cells and the east and west sides have lighter colors. This color scheme allows for the south side and the roof to absorb an abundant amount of heat and light, while the east and west sides reflect heat and light preventing the residence from overheating.

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Links:

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- <http://www.extra.rdg.ac.uk/eng/BIONIS/>
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