

## **Selected study of architectural envelopes controlling sun radiation - the integration of nature into design**

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This article investigates light control devices in architecture and nature searching for possible improvements and inspirations in architectural design. The article will briefly evaluate sun breakers and louvers as well as comment on both the reaction of leaves and plants to sun radiation as well as the reaction of eyes to light. The appreciation of natural devices illustrating physical/mechanical characteristics extends to nature and its sensual richness. This study of nature identifies possible improvements in light control design and encourages the integration of plants into architectural envelopes enriching the overall experience.

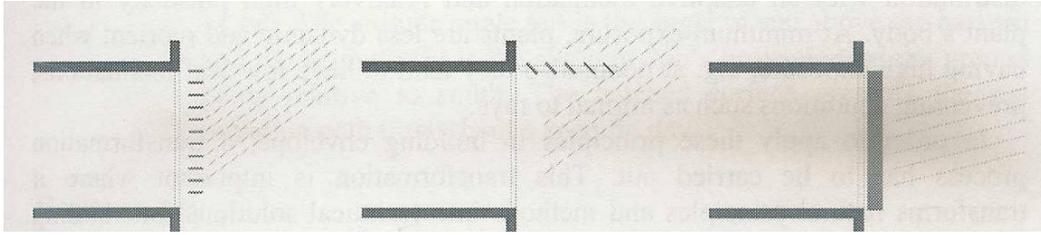
**Keywords: nature:** sun radiation and light control, architectural envelopes, nature.

The intention of this article is to do a basic review of architectural envelopes in terms of light control devices allowing for adjustment and adoption to changing weather and seasonal conditions and to compare them with selected objects that are not man-made but found in nature. The most popular and obvious of these is plant leaves, with their evident adaptation to seasonal and weather changes, and eyes, which regulate light. Could architectural envelopes do the same? How innovative have we been so far? What could we learn from nature and how could we implement nature into architecture? These questions are the core of this study.

### **Brief evaluation of *sun breakers* and *louvers***

Architectural envelopes are protecting and filtering layers, and efficient designs should develop devices that adapt to the sun's radiation – our basic source of light and energy. Sun-shading systems for architectural envelopes include '*sun breakers*' or '*brise-soleil*' – permanent and adjustable *louvers* designed to control the amount of the radiation while providing a visual contact with the exterior. Often *louvers* are incorporated into buildings to prevent the high-angle summer sun falling on to the façade and to allow low-angle winter sun to provide passive solar heating. Mostly *louvers* deal with horizontal and vertical extensions as well as added extra cladding, leaving some amount of penetrating light and protecting against radiation from glazed openings (Figure 1). The systems are design for extreme situations of solar radiation and not for the total exposure of solar radiation. Moreover, they do not adapt to changing conditions when it is cloudy or sunny during the day. All blades have the same angle of inclination when flipped. The vertical and horizontal *louvers* may be flipped to different angles but they are not three-dimensionally adaptable to track the sun's rays precisely throughout the day and through different seasons.

Is it possible to design more sophisticated devices? Products that are three dimensionally adaptable and track precisely the sun's rays throughout changing conditions. Could nature inspire better design? By just observing plants and leaves in particular, we discover that nature offers solutions that are more advanced in terms of responding to sunlight and tracking the sun effectively.

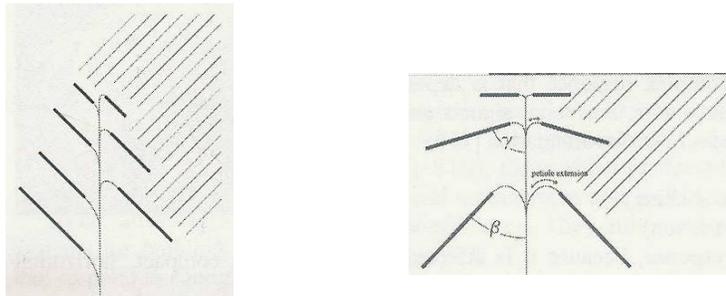


**Figure 1**  
**Simplified version of popular shade devices**  
 (the first and second image – horizontal *louvers* for high angles of radiation and the third image – vertical *louvers* for low angles of radiation)  
 (Badarnah 2008)

### Reaction of leaves and plants to sun radiation

Plants have developed specific mechanisms for peculiar climate and locations and react to changing weather and seasonal conditions. They can determine the amount of exposure to the sun for efficient performance. They have three basic reactions to light: *photosynthesis*, *phototropism* and *photoperiodism*.

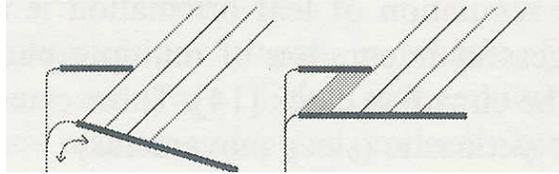
For the purpose of this study, *photoperiodism* is the most interesting response by plants to light. It is the physiological reaction to the length of day or night – which plants take as signals to flower and to grow. Other instances of *photoperiodism* in plants include the loss of leaves or the growth of stems or roots during certain seasons. A plant's directional growth – *phototropism* – is determined by the light source. Leaves exhibit positive *phototropism* – growth towards a light source, while roots usually exhibit negative *phototropism*. All life on earth depends on *photosynthesis* – the process of converting radiant energy from the sun into chemical energy. It would be excellent if we could draw on this nature/characteristic of plants in the creation of architectural envelopes – even simply to adjust the areas and angles of surfaces that are projected to the sun's rays according to different weather and seasonal changes.



**Figure 2**  
**The angle of incidence determines energy density (left)**  
**Lower leaves bend for maximum exposure (right)**  
 (Badarnah 2008)

Leaves have a significant relationship with the sun's radiation. They are influenced by sunlight and they react to the sun. Observations and studies of their organizational features like leaf distribution/position, orientation/inclination and dynamics show us

their significant role when controlling plants exposure to radiation. The angle of incidence determines energy density (Figure 2) and the effect of the inclination prevents self shading (Figure 3).



**Figure 3**  
**The effect of inclination preventing self shading**  
**Angle of incidence determines energy density (left)**  
**(Badarnah 2008)**

Leaves tend to vary their inclination in order to regulate sunlight interception in different climates. For example, in a hot and dry climate, leaves face east to ensure minimum interception at noon (Ezcurra 1991: 23-24).

Leaves tend to have a clear organization and distribution/position with an adaptive orientation/inclination and relatively high plasticity allowing for shifts from a vertical to a horizontal position at maximum exposure. Plants are less dynamic and reorient less at minimum exposure. For example, at noon, they tend to have low leaf orientation/inclinations preventing conditions such as normal to rays (Badarnah 2008: 87-96).

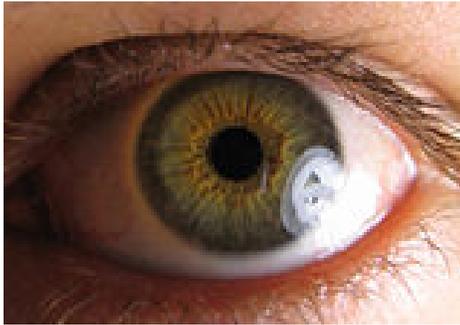
Plants' unique mechanisms for specific locations and climates determine the amount of exposure they have to sun radiation. Aristotle's (384 BC-322 BC) statement that "*nature does nothing without purpose or uselessly*" (online) concludes these norms but when it comes to application, Seneca's (c.4BC-AD 65) affirmation "*nature has given us the seeds of knowledge, not knowledge itself*" (Stone 2004: 66) encourages searching for better architectural resolutions. A shading system for building envelopes based on the unique geometry and structure of plant leaves providing the flexible adaptability to the sun's radiation path of each day of different seasons would be ideal.

Dynamics of leaves and plants like folding/unfolding and bending are generated due to their structure (Bar-Cohen 2006: 442-484). However, plants are not the only objects in nature reacting dynamically to light. Eyes also do so and we can study eyes to learn how to modify the amount of light passing architectural envelopes.

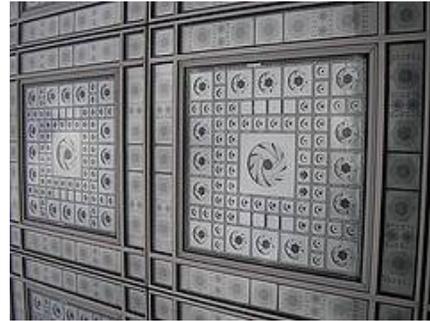
### **Dynamic reaction of eyes to light – improving sun breakers – the modern moucharabieh/mashrabiya**

Light enters the eye through the pupil. The iris (the area surrounding the pupil) regulates the amount of light by controlling the size of the pupil (Figure 4). The pupil gets wider in the dark but narrower in light. The shape of the eye is related to the optical characteristics of the lens and this varies. The shape and sizes of the pupil also varies. The reasons for the variation in shapes are complex. Based on this observation, most photographic lenses can be modified to admit more light and give

higher resolution. A camera lens will often incorporate an aperture adjustment mechanism, to regulate the amount of light that may pass.

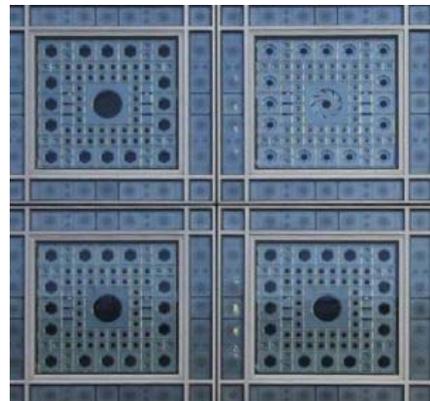


**Figure 4**  
Light enters the eyes through the pupil  
(Pupil online 2008)



**Figure 5**  
IMA façade details – Moucharabieh  
(Moucharabieh online 2008)

Jean Nouvel, through his architecture of the Arab World Institute in Paris (1987) and IMA (the Institut du Monde Arabe) has presented us with interesting examples of how the same techniques the eyes uses to control light can be adapted for architecture. The theme of light is reflected in the southern façade (Figure 6). A metallic structure on the front acts as a sun breaker or 'brise-soleil' (Figure 5 & 6). The elements resembles *moucharabiehs* or *mashrabiya* – latticework found on openings in Arabian countries.



**Figure 6**  
The Arab World Institute, Paris  
Façade of automated sun breakers  
(Nouvel & Arab World Institute online 2008)

As well as being a sun breaker, the feature offers privacy to occupants who can obtain a good view without being seen. Predominantly wooden screens with openable windows give shade and protection from the hot summer sun while allowing the cool air from narrow streets to flow through. They allow a significant amount of air to move in the room without causing discomfort. The designs of the latticework are usually with larger openings in the higher parts and with smaller opening in the lower parts, therefore causing the draft to be fast above the head and slow lower down.

Jean Nouvel invented an automated system that operates like the eye's pupil, or a camera shutter. The design's symbolic polygon elements unfold to regulate light entering into the building. The moving geometric motifs have been mounted like diaphragms and adjust to different light conditions.

The automatic aluminium sun breakers control light entering the interior of this building (Nouvel online). They can be graduated to allow varying amounts of light into the building, depending on the weather conditions of the day. A computer monitors the external sunlight and temperature. Motorized diaphragms automatically open or close as needed. Inside the museum, light and shadow are integral parts of the design (Figure 7).

Interiors created in this manner have filtered light and are climate-controlled – representing the natural approach. Enhancing this is the pattern on the surfaces created by the entering light and resembling shadows of leaves and gaps between them (Figure 7).



**Figure 7**  
**The Arab World Institute, Paris**  
**Interiors – patterns on surfaces**  
**(Nouvel online 2008)**



**Figure 8**  
**Gaps between leaves and shadows of them**  
**(author collection 2008)**

The comparison, as shown in the images (Figure 7 & 8), forces us to ask: could plants do this job? Do we have to imitate plants or could we apply them to get what we want?

### **Plants integrated into architectural envelopes**

There is a long tradition of incorporating plants into architectural envelopes. Specially designed structures like *trellises* and *pergolas* have been constructed for controlling the amount of permeated light and temperature in changing seasons. *Trellises* are usually made from interwoven pieces of wood, bamboo or metal to support plants. There are many types of *trellises* for different plants such as ivy, grapevines, peas and for other support based growing plants. The term *trellis* also refers to a structure, usually made from interwoven wood pieces, attached to exterior walls of a building or the roof and the term *pergola* may also be used.

*Pergolas* are architectural features on which climbers grow, to make a passage that is cool, shaded and moderately dry in a shower. A *pergola* forms a shaded walk or

passageway of pillars that support crossbeams and a sturdy open lattice, upon which plants are trained. As a type of gazebo, it may be a protection for an open terrace. *Pergolas* may link buildings or pavilions and may extend from a building's door to an open garden feature or may be entirely free-standing just providing shelter and shade to a length of walkway.

Modern *pergola* designs tend to favour many different materials and are becoming more affordable and increasing in popularity by exploring different forms and sizes/scales. They epitomise firm structures luxuriantly planted.



**Figure 9**  
**University of Warsaw, Library Gardens**  
**Inner and outer views of trellis**  
**(author collection 2008)**

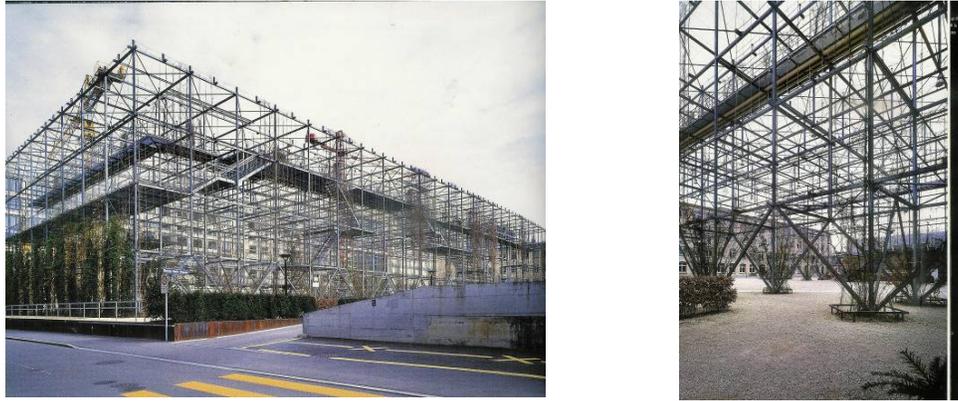
Plants and light are parts of our natural environment that appeal to us and stimulate our senses and reactions – a way of behaving that is instinctive which has not been learned but that is born with. Going back to roots helps us to relax and not try to hide anything or pretend. It has a great meaning when it comes to architecture as a whole – not just light regulating envelopes. The real nature of architecture is shown by the manner in which people feel, react and behave when exposed to it and interact within it (Figure 9). Horace's (65 BC-8 BC) quotation, "*You may drive out nature with a pitchfork, but she will keep coming back,*" (Stone 2004: 66) may refer to our human nature as well as the physical context.

Examples illustrated below show the challenging thinking being done in terms of playing with parameters and scale, defeating time of growth and ecological engineering, and of integrating plants into architectural envelopes.

### **Growing big – the “park- house”**

In 2002, the MFO Park designed by Swiss firm Burckhard + Partner and a landscape architect Raderschall was opened. It is positioned in complex urban mosaic in Zurich. The so-called *park-house* (Figure 9) demonstrates possibilities for enriching public spaces formed by leaves and plants arranged to form a rigid lattice. The traditional wood trellis has been replaced by metal frames and steel cables stretched along a grid. The *park-house* is a three-story structure. Visitors circulate through different levels and suspended platforms. They are able to enjoy different leaves and branches, and the theatrical scenario of nature. The plant structure consists of varieties of climbing

plants and ivies that are able to survive the local climate. They were selected and arranged according to speed of growth, resistance to exposure, ornamental impact, fragrance and colour. Different varieties of plants were chosen to fill differently orientated façades. To introduce a dense cover of plants in a short period of time, a variety of quick growing plants, vines and wisteria were brought in (Lambertini 2007: 138-160).



**Figure 9**  
**MFO park-house, Zurich**  
**(Lambertini 2007)**

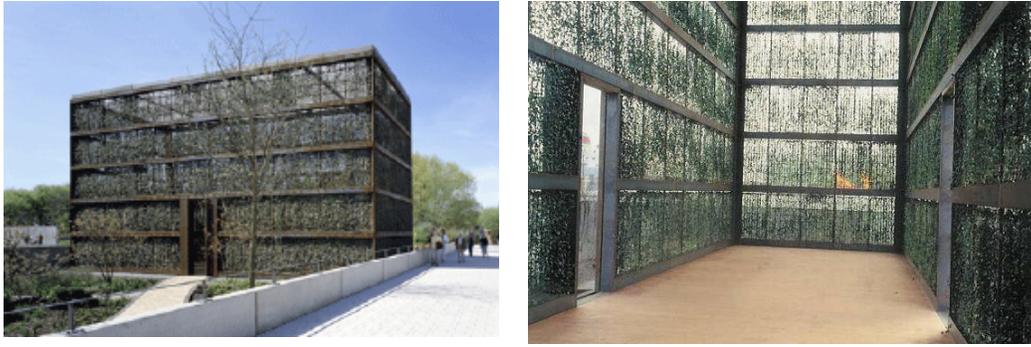
The space is the perfect location for public events, plays, concerts and different types of installations. A sequence of evergreen plant layers envelope throughout the seasons and day/night changes. It gives a very unique and sparkling atmosphere. The link between interior and exterior is spectacular.

The MFO in Zurich has not only functional and emotional value, the design also teaches us how to integrate the natural with man-made objects. It takes time but it can be done.

### **Speeding the filling of the façade – the “multiple trellis”**

In 2003, for IGA (International Horticulture Exposition) in Rostock, Germany, an exceptional project was built by Atelier Kempe Thill Architects. The construction is a kind of a pavilion/building/space and is a modern interpretation of the *trellis*. The simple steel frame of columns and beams has been filled with ivies, pre-grown on metal panels in glasshouses. Normally, it takes years to grow and cover a wall with ivies but the smart panel system allowed for big green screening without a temporal limitation (Lambertini 2007: 68-93).

A steel frame provides five rows of soil-filled channels. Ivies grow from them, are nourished and irrigated by a computer-controlled system. The project is an interesting interpretation of the French garden where nature adopts the forms that man desires, and the rationality of Dutch agriculture. The space is conceived as all-enveloping vegetation. This vegetation threshold is a simple idea with a powerful sensation of garden techniques (Reyes 2007: 66-75).



**Figure 10**  
**The Dutch exhibition for the IGA, Rostock**  
**(Lambertini 2007)**

Rather than isolate, the ivies delimit the space, allowing the natural ventilation of the space. This is an intriguing interaction between inside and outside spaces. The movement of the ivy leaves and their shadows make the space intriguing and fascinating. The ivy façade gives it a unique character providing semi-transparency bringing a filtered and soft light inside.

The architectural envelop serves to modulate light. The impression of interior is created in a composition of light, half-shadow, and shadow. This is a simple and clear representation of the best of nature. The plants have been incorporated to architecture. The physical beauty and spiritual value of plants have contained on the site. This application has brought additional dimension to something that is known. They ordinary ivies are not ordinary anymore. This is a celebration of season, weather and time.

### **Incorporating the best of nature and man-made**

The architecture of Quai Branly Museum (2006) has an unexpected character and the most advanced techniques have been applied to achieve this. The windows are very large and although transparent are printed with patterns and huge images. What is solid seems to disappear giving the impression that the museum is a façade-less shelter with no identifiable boundaries or solid definition.



**Figure 11**  
**Details of real plants and light garden, Quai Branly, Paris**  
**(author collection 2008)**

When designing this museum, Jean Nouvel cooperated with botanist Patrick Blanc and played with many secret objects, following his statement that “...in ancient times the garden was the place of best-kept secrets” (Nouvel online). Blanc is the inventor

of the concept of a vertical garden. He patented his flexible system where the plants are placed directly into pockets made of felt. Layers of felt somehow copy/imitate clumps of mosses that grow on damp soil, or wood or stone and cliffs and they are used to support the roots of many plants. A nutrient solution containing dissolved mineral necessary for plant growth are distributed/provided by a network of pipes controlled by valves. The felt is soaked by capillary action. This nutrient solution descends along the wall by gravity. The plants harvest the nutrients required and excess water is collected by a gutter at the bottom of the wall, and re-injected into the network of pipes. It is a closed circuit. Plants are carefully selected depending on available light and for their ability to grow on this type of environment.

Blanc's achievement evokes the concept of an ecological engineer and the use of local species has become the real target – at least outdoors (Lambertin 2007: 168-179). He has been working on his individual commission (Centre Commercial Quatre, Paris and Marche des Halles, Avignon, France) and with architects paying a lot of attention to the environment – like Edouard Francois (Parking Des Ternes, Paris and Cheminee Vegetale La Defence, France) and two Pritzker Prize winners Jean Nouvel (Fondation Cartier and Quai Branley Museum, Paris ) and Renzo Piano (Genoa Aquarium, Italy).

The Quai Branly Museum dissolves in depth of the structure and site. Dematerialization encounters the expression of unnecessary objects and the museum dissolves in the depth of the structure and site. What is solid disappears from your view. Tall, randomly placed pillars are mistaken for trees or totems. Illusion creates the background for art and objects. The necessary functions retain but leave our view and our consciousness, vanishing before the sacred objects. What seems to be impossible to achieve is happening here. A vertical carpet of plants and wildly eccentric luminescence garden of artificial lights are there.

The poetry of the space is sacred but the architectural language is not strange. Gentle interpretations of the known materials and objects dissolve the fear of unknown.



**Figure 12**  
**Variety of shutters and louvers, Quai Branly, Paris**  
**(author collection 2008)**

Jean Nouvel uses new techniques and materials that have been never more important than the actual purpose though. His architecture has etherised appearance.



**Figure 13**  
**Variety of louvers, printed screens and vertical garden, Quai Branly, Paris**  
**(author collection 2008)**

Jean Nouvel's research is always based on specificity. He does not repeat the same vocabulary in his architectural envelopes. He researches good reasons to do one thing in a specific place with specific people to create something unique in natural way. Every work has to ask a question in these dimensions.

### **Recapitulation**

Exposure to sun and how we bring light into are the major questions of architecture - questions about sunlight that is given to us at a certain place and time and how it stimulates our activities and restricts them, how much we rely on materials and technology when bringing the light into architectural spaces. Light brings the meaning to our lives, moods, feeling of presence, well-being, harmony and beauty. Passion is the creation of architectural envelopes that produce this kind of effect may bring us closer to nature.

From the composition and "presence" of nature and the effect of light, this poetics of architecture enables to recapitulate what really matters in the process of screening spaces.

It is important to consider that each place needs a geographical and environmental continuity and is in a stage, part of the natural environment. Projects that begin with the idea of modification rather than disconnecting from the context have more change to communicate well with human beings and the world. A project full of simplicity, delicacy and depth, which maintains the spirit of the location and the desire of people encompass all in natural way.

There is the desire to analyze and understand nature but this should not prevent us from expressing and inventing something. Cloning and repetition of the same architectural ideas across the world shrink the world. We have to evolve to create differences, not for the sake of it but differences as signs of deeper understanding, interpretation and integration of nature and human beings. It is

necessary to emphasize the integration of the physical and spiritual experience when creating architectural envelopes.

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