The aim of this research is the study and understanding of the chemical, biological and structural function of plants and animals and their appliance to architecture. To extrapolate and explore biological functions by observing cellular morphology for architectural and design purposes. There will be some conceptual prototypes developed with fragile and weak elements combined for strength, drawn in Rhino for additional development and in an attempt to entwine design and generative computation. Arthropods, shells, and urchins are put under investigation for the understanding of the function of each element in nature and try to apply it to architecture. As it is vital to collect those ideas for the potential of the biological and ecological shaping of architecture; its general morphology and of course the use of materials. Alongside with the exercises, and in the attempt to approach this contemporary performance of architecture, terms such as biomimetics, biomimecry, and forms developed in nature, adaptiogenesis, types of materials, ecology and morphogenesis and bottom up developmentare being analysed.

With this parallel development of computation and the discovery of the DNA code, the conjunction of computation and biogenetics, we are moving into the so called Post-Human Era,[1] the biogenetic revolution a symbiosis of organic and inorganic substances. A new form of architecture with its own autonomy and will to being is being potentially released but ensnared to the demands imposed by computation and the biogenetic revolution.

The study of natural elements, cellular forms and plant-growth has been long developed in design digital software. In 1968, the Hungarian biologist Aristid Lindenmayer[2] researched the growth patterns of different, simple multicellular organisms. The same year he began to develop a formal description of the development of such simple organisms, called the Lindenmayer system, L-system, a formal grammar. For L-system-based plant modelling, the rewriting rules capture, for example, the behaviour of individual modules over predetermined time intervals. L-systems have the capacity to give rise to a class of programming languages for specifying the models which make it possible to construct generic simulation software that is capable of modelling a large variety of plants at the architectural level, given their specifications in an L-system-based language. L-Systems thus enable architects to go beyond the empirical possibilities of the past and to directly and systematically appropriate the logic found in nature for their architectural design objectives. For this reason it is necessary to adapt L-systems as they algorithmically simulate the digital growth of plants.

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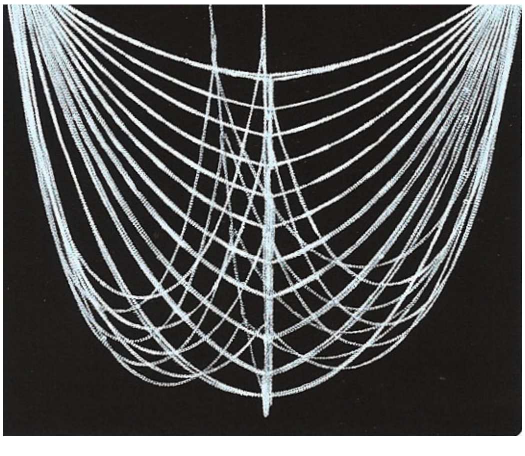
1 Chu, Karl, Genetic Architecture, article, http://futurefeeder.com/index.php/archives/2006/08/06/genetic-architecture/, 25/10/2008.

2 PRUSINKIEWICZ, Przemyslaw - LINDENMAYER Aristid, The algorithmic beauty of plants, Springer-Verlag, New York, 1996, Chapter 1.



example of the Frei Otto maeda workshop, 2003

form finding physical experiments,
Antoni Gaudí, 18??

One of the important key concepts for the study is biomimesis. Biomimetic has two roots, bios from the Greek word for life and mimesis, meaning to imitate[3]. Its appliance in science, engineering and design consists of searching natural systems in order to create new materials, structural forms and new environments based on biological principles. Biomimicry, having the same meaning, is a new discipline that studies nature's best ideas and then imitates these designs and processes to solve human problems. An innovation inspired by nature.

Biomimetic revolution can change our lives through the way we make materials, control energy, make medicines and store information. In each case, nature is model, measure, and mentor. We can manufacture in the same way nature does, using sun and other natural simple compounds to produce materials such as biogenetic fibres made of steel, inspired by woven spider-web, shatterproof ceramics drawn from sea-shell-pearl, and maybe solar cells copied from leaves. Biomimetic research has been concentrated on living seedpods and seeds incorporating them into environmental and genetic architecture. It is shatteringly impressive to see how it can all be translated and combined to architecture. In an effort to conceive the genesis of form in geological, biological and cultural structures, a concept is created; the machinic phylum, or technological lineage. The term 'machinic', the existence of processes that act on an initial set of merely coexisting, heterogeneous elements, and cause them to come together; "what we term machinic is precisely this synthesis of heterogeneities as such"[4]. And the term 'phylum' is the processes of self-organization. The machinic phylum is a crucial ingredient for the emergence of innovation at any level of reality is the "combinatorial productivity" of the elements. As the Hungarian physicist George Kampis has remarked, "the notion of immensity translates as irreducible variety of the component-types (…) This kind of immensity is an immediately complexity-related property for it is about variety and heterogeneity, and not simply as numerousness"[5]

Frei Otto's research[6] is specifically concentrated on nature for his architectural and engineering design, and has been directed by nature towards applications in construction. He is particularly interested in the natural processes of self-generation of forms, and in the structural behaviour of those forms. This resulted to him developing physical form-finding experiments, the first architect after Antoni Gaudí to do so. These form finding experiments are based on the processes that

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3 Etymology of the word made by the author.

4 See, DELEUZZE, Gille - GUATTARI, Félix – MASSUMI Brian, A Thousand Plateaus: Capitalism and Schizophrenia, The University of Minnesota Press, Minnesota, 1983, p. 330.

5 KAMPIS, George, Self-Modifying Systems in Biology and Cognitive Science. A New Framework for Dynamics, Information and Complexity, Pergamon Press, Oxford, 1991, p. 235.

6 See, HENSEL, Michael – MENGES, Achim – WEINSTOCK, Michael, Techniques and Technologies in morphogenetic design, AD_ Architectural Design, Vol.76, No.2, March/April 2006, Wiley-Academy, p. 20-24.

material systems are taking place during self-organization. According to the choice and definition of the conditions under which the form-finding process takes place an infinite range of possible forms can be projected. Those self-organizing processes in biology can be used in architecture[7].

Studying deeply into biological structures, we will observe that they consist only of one structural element. For example a skin filled with water and proliferated in a wide variety of ways. The skin is formed in a thin net out of fibres. Those fibres are the secret to understanding biological structures, and their phenomenal strength. Living structure is completely different to artificial technical structures that are shaped by simple geometries. The geometry structure of living nature is very complex. In living structure every element is different. Irregularity is important not only in biology but also in technology, it is a new concept that I being researched by scientists.

"It is necessary that we architects try to understand living nature, but not to copy it. This is one very important task for the future."[8] Since we are now proceeding towards a new practice of biology to design, various biological phenomena suggest new ways to solve numerous design challenges. Wilhelm Barthlott[9] of the Nees-Institute, University of Bonn, for example, studied how the lotus leaves manage to remain free of contaminants. He worked out how to replicate the geometric structure of the lotus skin and transform it into commercial products such as paint. The aim was to obtain a 'living' surface on a building façade which would 'keep working' when dried. There are dozens of self-cleaning products, which bear the Lotus-effect symbol such as glass, roofing tiles, and textiles.

The core idea is that nature is wiser than human. Animals, plants, and microbes are the consummate engineers. They know how to survive on Earth. The way a building skin can function with properties like those found in a leaf, an urchin shell, is by adopting a neural-like communication system. It could simultaneously provide the building with energy and sense dangerous pollution. If our world begins to function like the natural world, we could perhapsapproach a sustainable future. We ought not to consider nature only as the model, but more specific as the measure. Due to our unbridled vanity we are in great need of a judge for our innovations. "The environment is feeding from us and we are controlling it – mutual relationship"[10]

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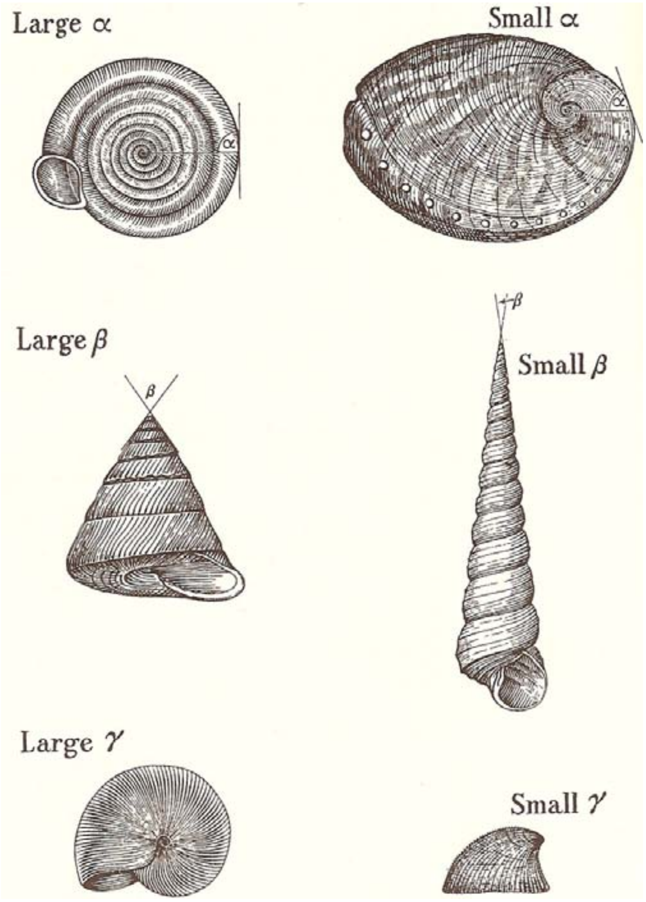
7 Abstracted from, HENSEL, Michael – MENGES, Achim – WEINSTOCK, Michael, Techniques and Technologies in morphogenetic design, AD_Architectural Design, Vol.76, No.2, March/April 2006, Wiley- Academy, p. 20.

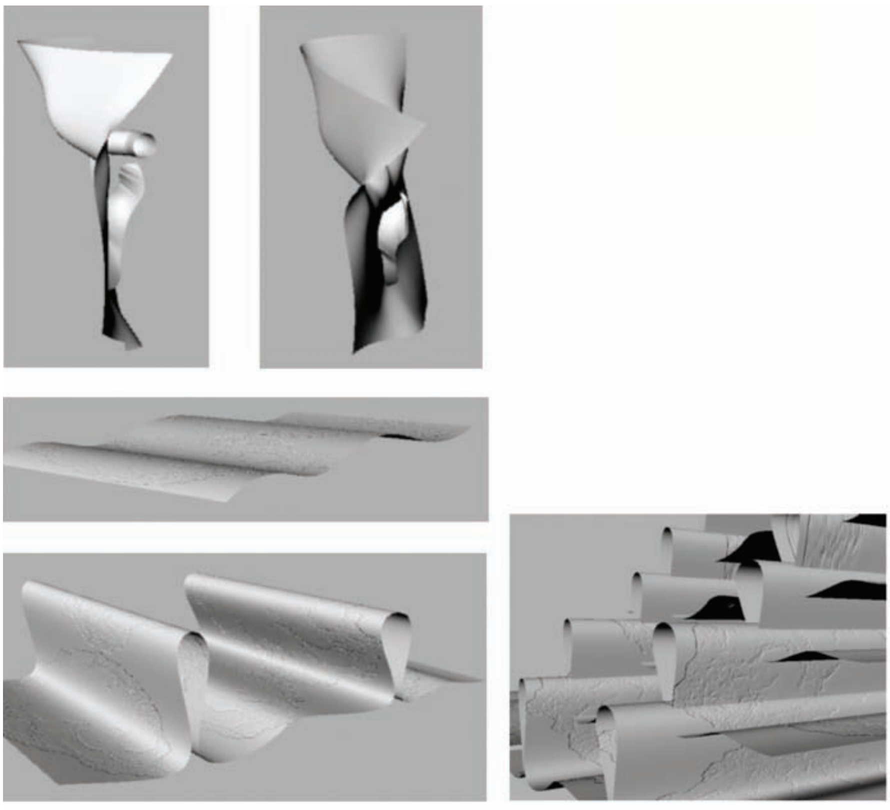
8 HENSEL, Michael – MENGES, Achim – WEINSTOCK, Michael, Emergence: Morphogenetic Design Strategies, AD_Architectural Design, Vol.74, No.3, May/June 2004, Wiley-Academy, p. 25.

9 LAI, S. C. S., Mimicking nature: Physical basis and artificial synthesis of the Lotus-effect, University of Leiden, The Nederlands, 2003, p. 1-31. http://members.ziggo.nl/scslai/lotus.pdf

10 BEESLEY Philip, Contemporary Techniques, New Strategies, International Architecture Symposium, SIMAE, ESARQ, Universitat International de Catalunya, 9-11 April 2008.

various gastropodsshowing the effect of the alteration of different angles.





exercise based onBoreothropon Acanthodes, production of the author.

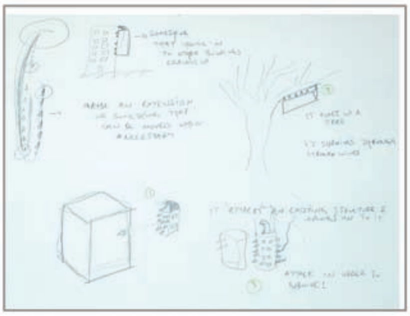
Spiral phyllotaxis is another type of geometry in nature. In spiral phyllotaxis there are two main families of spiral helices called parastichies. These may either be organized symmetrically or asymmetrically with respect to the number of counter-rotating spirals[11].

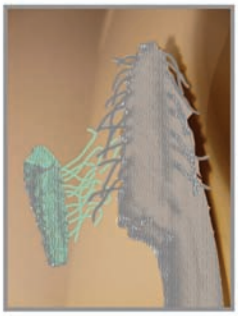
The design process can now be a part of the generative process of architecture. Various plant characteristics can be modelled, like spiral phyllotaxis. It comes from the Greek word *φύλλο* and *τάξης*, it is the arrangement of repeated plant units and the pattern of their repetition within the same alignment, for example the seed or scales or the orientation and exposure of leaves towards environmental input such as sunlight. A very important feature to architecture as it can be useful for energy-generating photovoltaic, and for photosynthetic elements. The latter could populate the building and take a specific role in its overall orientation to multiple input sources. Such as sun path, prevailing wind directions. Hair and thorns on plants often organized in phyllotactic distribution fulfil various functions. An interesting one is the hair around the stomata of leaves. They modulate airflow so that too much water is not lost through the combination of evaporation and transpiration. There are many natural systems that have a cylindrical morphology, and display a robust and flexible structural performance. The latter is provided mainly within the skin without any internal ribs or columns, as seen in various gastropods always having different enveloping angles. It is remarkable how such tiny features on shells manage to modulate very strong forces, and that these features and their functions do not scale. This is important to investigate; by producing same-size features to achieve the performance observed in nature, and to determine appropriate sizes for other features to modulate chosen conditions over required ranges.

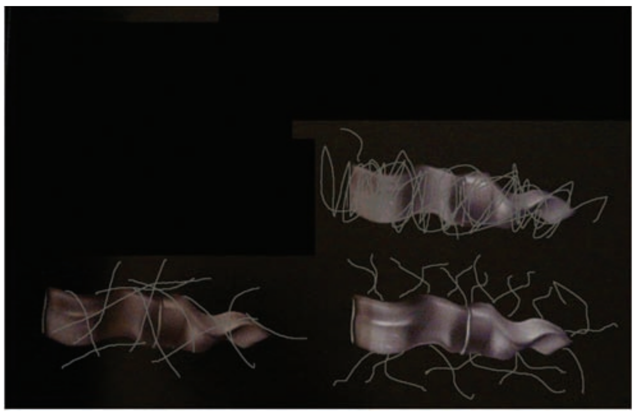
Spiral helices occur in dynamic configurations at all scales in the physical world. Helices are immediately visible in geophysical systems such as the atmospheres or oceans. Their use in architecture could be surprisingly rich. In living forms spiral helices are found in, for example, the Boreothropon Acanthodes, a seashell found in the Philippines. Its exoskeleton consists mainly of calcium carbonate and the nacre; the inner part is built from hexagonal platelets of aragonite[12]. The surface of the shell has been constructed from a number of layers over the years and the spikes seem to have dried out while folding. The shell, like the creature within it grows in size without changing its shape, this is because the many structures that display the logarithmic spiral increase, or accumulate, rather than grow[13].

The skin begins to unwrap revolving itself while experimenting, in order to make use of the shell's

[11] See, THOMPSON, D'Arcy, On Growth and Form, Cambridge University Press, Cambridge, 1961,chapter vi, p. 100-175.
[12] Observations made by the author.
[13] See, THOMPSON, D'Arcy, On Growth and Form, Cambridge University Press, Cambridge, 1961, p. 100-175.







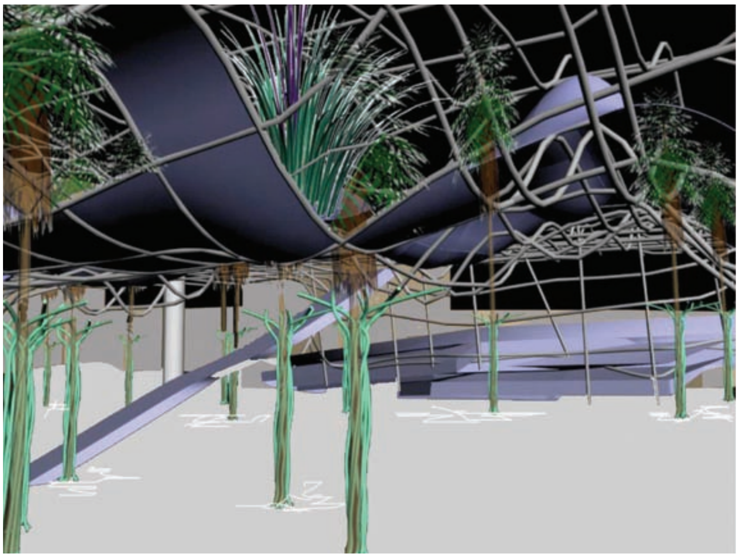
sketches and collages for the investigation of the spikes of the arthropods functions in architecture. This new skin breathes creating a phenotype with new properties. It folds forming void spaces that allow the airflow and then flattens back. There are many instances in engineering where variable stiffness materials and structures would be beneficial; for example, in applications where it would be beneficial to alter the shape of a rigid structure, or an element of structure, and then restiffen it[14]. Potential architectural applications are structures that could be reconfirmed for change of load or condition and portable structures that could be soft to transportation, rigid in deployment and soft again for relocation.

Morpho-ecologies

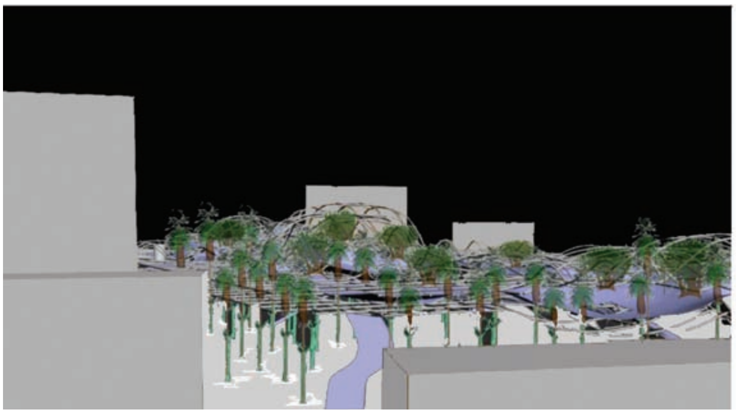
The complexity of urban-use cycles and material life cycles increases within an uncontrolled acceleration. Therefore we need to be conscious of the built environment, ecologically and topologically with the adequate structural provisions; Ecologically, because it affects all the integration between human groups and their physical and social environments, and topologically because it consists of the connections between all the material elements in an environment. In this way ecology, topology and structure are profoundly interweaved. Through such an integral approach architectural design begins to construct a change in the micro-environmental system, promoting in this way modulations of the whole ecosystem, so that the architectural environment can cooperate with the natural one. Such complex environments continue to evolve through adaptation, a process known as adaptiogenesis.

Adaptation is based on evolutionary modifications and is the process of the continuous adjustment of a system to its environment. This phenomenon was applied as an experiment in the exercise of the arthropods. In arthropods, their exoskeleton is accomplished by the cross-linking of the protein chains in the exocuticle, a process called sclerotization. Thus, the arthropod exoskeleton is divided into numerous sclerites, joined by unsclerotized, membranous regions. An attempt to differate the use and shape of spikes and endoskeleton, and instead of treating them as independent substances, try to unite them and reinforce them. This is another approach to the attempt of understanding the use and manipulation of the spikes in relation with the structure itself, with other structures to come along and of course with the adaptation of the environment. Therefore the spikes start to create a nest towards the surrounding environment. And maybe detect it. The main element for a performative, complex environment is material system , which is the process of structure. Through its organizational logic affects the final complex environment with just one single structural component. This is what biomimicry does; as a new science it studies nature's models and then emulates these forms, process, systems, and strategies to solve human problems – sustainably.

[14] See, HENSEL, Michael – MENGES, Achim – WEINSTOCK, Michael, Emergence: Morphogenetic Design Strategies, AD_ Architectural Design, Vol.74, No.3, May/June ,2004, Wiley-Academy, p. 42-86.



3D perspectives of the exrecise in Plaça Lesseps



As it is a new way of viewing and valuing nature, biomimicry introduces an era based not on what we can extract from the natural world, but also what we can learn from it as after 3.8 billion years of evolution. It differs from other bio-approaches as biomimics consult organisms and are inspired by a chemical reaction or an ecosystem principle such as nutrient cycling15. This is the real value of biomimicry, all what surrounds us in nature is the secret to survival.

For example, during a human design challenge the innovator begins with identifying the function under consideration and reviews how various organisms or ecosystems are achieving that function. The competion of the experment was made for the reformation of Plaça Lesseps, in barcelona, Spain. The aim was to create a 'green bridge', a passage for the pedestrians in the middle of the city. The way to achieve that, was to place dozens of trees of various types in a mesh that grows and is being moulded according to the growth of each plant. As the city's main issue for the well being of human is vegetation, this floating membrane that hosts species of plantation and birds is suspended. The analysis of the net created by the spikes s used for this synthesis by detecting the surrounding environment and control the growing of plants and trees when necessary. The desired result would be the interaction of this form within the city in an attempt to communicate with it. There could be passages and circulation routes in many forms, above ground, on the ground and underground, communicating and creating a net.

These evolutionary modifications involve generative feedback between the digital and the physical form finding, the structural analysis and the ecological testing techniques, in order to develop morphogenesis from the bottom up development. The bottom-up development appears where the design of components has the priority over the design of the whole. The evolution of material design leads to structural morphologies, which leads to the emergence of an ecosystem.

Geometry and Fibre material Hierarchies

Biology makes use of remarkably few materials, with successful results, as the importance is not a matter of what they are but of the way in which they are put together. D' Arcy Thompson[16] in his study of a wing of a dragonfly he observed the following: it consists of a complicated system of veins which are averagely parallel to one other and make a hexagonal meshwork of 'cells'. The latter are intercalated between pairs of ribs into angles of 120°, creating this way co-equal tensions. This geometrical and hierarchical organization of the fibre architecture is significant.

Similar interest is found in the Tipuana Tipou, the seed of the maple tree. The Maple disperses the seed with the help of the wind because the seeds are aerodynamic, or shaped for

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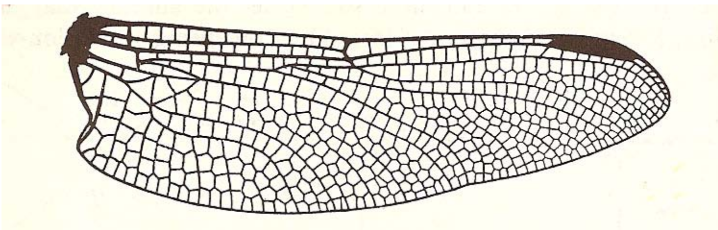
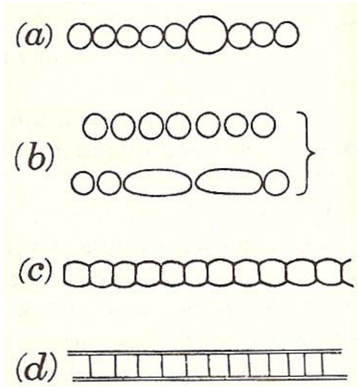
15 http://www.biomimicryinstitute.org , 2/9/2008.

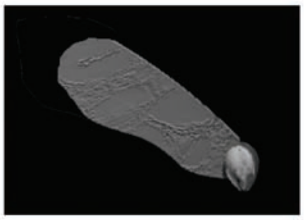
16 THOMPSON, D'Arcy, On Growth and Form, Cambridge University Press, Cambridge, 1961, p. 98.

a dragonfly's wing.



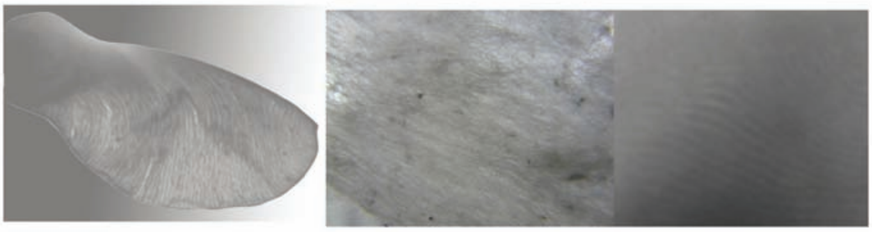
filamnets, or chains of cells
in various algae.



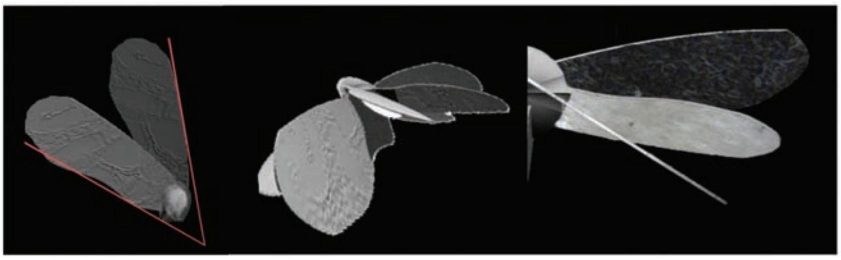


tipuana tipou
The seed of the maple tree.

The Maple disperses its seeds with the help of the wind. Because the seeds are Aerodynamic, or shaped for traveling in the wind, the wind will pick up the Maple seeds and carry them to suitable land. They will then drop and sprout a new Maple tree.



photographic analysis of the texture of seed - cotton - skin

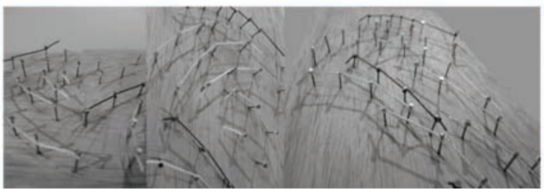


digital modeling for the analysis of the movement of the seed while falling

as the seed falls begins a circular rotation about its center of mass. The rotation actually inscribes a cone around the axis of fall. if from a single fruit many blades were extracting.

The fibres of the blade are now running in all directions.

The fibres are set free to dominate the place



conceptual physical model of the despersing of fibres in space travelling in the wind, the wind will pick up the maple seeds and carry them to suitable land. They will then drop and sprout a new maple tree. As the seed falls it begins a circular rotation about its centre of mass. The rotation actually inscribes a cone around the axis of the fall. If we could extract the fibres of the blade, they would be set free to dominate the place. Some physical experiments were made for use of material with similar cell condensity and geometry.

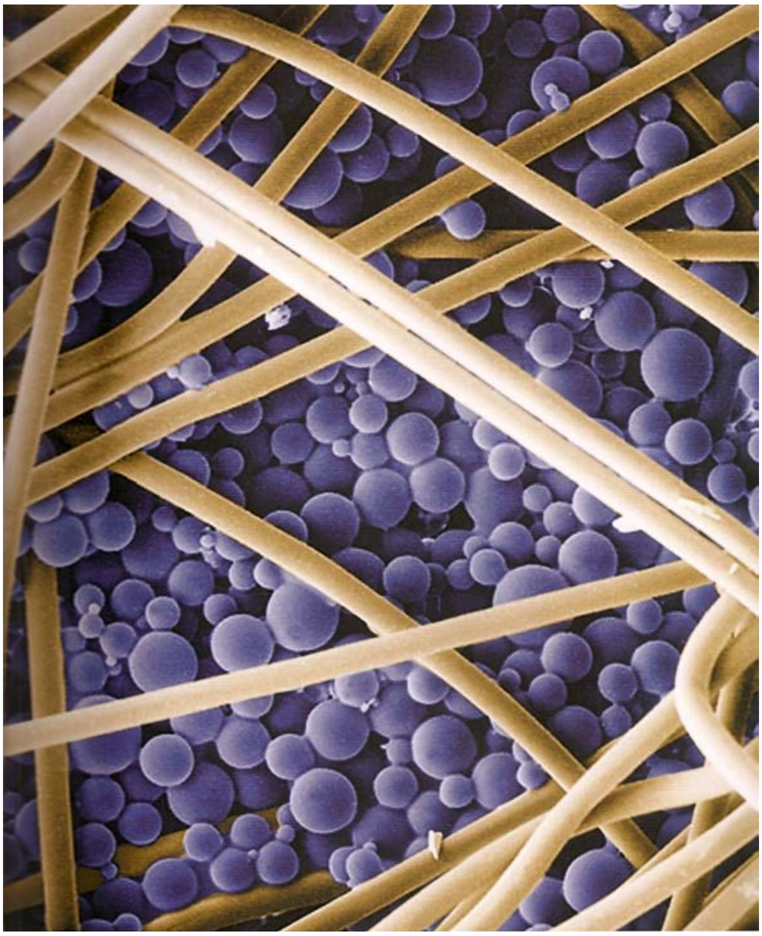
Consequently we cannot distinguish between material and structure. All natural material systems consist of cooperation both local and global, in order to achieve adaptation and efficiency. Many biological material systems achieve movement without muscles. Movement and force are generated by a unique interaction of materials, structures, energy sources and sensors. Plants, lacking a central nervous system and mammalian brains, make growth movements to orientate themselves to the sun or to correct their inclination. Evolutionary algorithms permit adaptiogenesis, and furthermore, lead the performance of evolutionary process from which derives complex emergent structure. The developed prototype software design tools consist of a synergy between architecture, artificial intelligence, artificial life, engineering and material science. Evolutionary adaptation can be successfully modelled in computational processes and is useful in design strategies for the development of architecture.

The development in smart materials and responsive buildings are of an extreme interest in biology and biomimetics. Whilst there have been a number of interesting architectural applications of advanced materials in architecture, it is early to say that intelligent buildings exist.

Conclusion

The self-organization processes can provide important lessons for architects by observing the growth of living organisms. Biologists and computational scientists have collaborated in order to make it possible to evolve plants digitally that are "grown" according to environmental input. This environmentally sensitive growth delivered through a method and toolset in architecture can yield remarkable results as in the design preferences as well as in structural and material properties.

To derive architectural strategies and methods for differentiated performances informed by environmentally specific conditions and, thus, to achieve advanced levels of functionality. It is interesting to examine the modelling biological growth informed by a hosting environment. The modelling of plant growth and its development is predominantly based on mathematical geometry. Such models can involve a large number of parameters in calibrated descriptive models of specific plants. Simulations produce numerical output, which can be complemented by rendered images and animations for the purpose of easily comprehensible visualization.



microcapsules that contain a phase-change material (PCM)coating fabric fibres.

The use of computational models has several benefits. They provide quantitive understanding of developmental mechanisms. They also provide new analytical and generative sensibility to architectural design, as they may facilitate the coexistence between systems and environments, in terms of their behavioural characteristics and capacities. Interestingly, standard software such as 3D studio, Cinema 4D and Maya have incorporated hair simulation in relation to airflow; in such a way that specific properties of hair and airflow can be determined, giving value to architectural design.

Plants grow wherever conditions are beneficial, and so elements of the built environment can be distributed accordingly through similar processes, in order to incorporate ecological organization. The distribution of these buildings to a given environment should depend on their particular interaction with the environment. Ecology is the study, which goes through the relation of the individual organism to populations, up to communities of species, ecosystems and the biosphere.