Research Thesis as part of the Postgraduate Master in Biodigital Architecture

Effimia Giannopoulou

SIMPLE INVISIBLE

Director: Dr. Alberto T. Estévez

Master in Biodigital Architecture

ESARQ, Universitat Internacional de Catalunya

Barcelona, December 2009

Contents

Abstract

Mediante un acercamiento a textos clave de un amplio y a menudo fuentes contradictorias, esta tesis ofrece una completa introducción a los conceptos de genética, topología y sistemas artificiales en arquitectura, a través del uso de lo que se conoce como computación evolutiva. Con un intento de vincular y combinar el cuerpo biológico al cuerpo arquitectónico, re-planteando la hipótesis de las reglas de la naturaleza, e incluso artificiales, los proyectos utilizando las especulaciones y ficciones como proceso para des-alienar la subjetividades del post-capitalismo.

General Introduction

To change life is to change space, and to change space is to change life.
Architecture or revolution?[1]

In this essay I would like to give an extent description of the laboratory workshops that had been taken place in the U.I.C, during the period 12.1.09 to 26.6.09 for the Master's degree in Biodigital Architecture. The program aims to connect the relevance of biological paradigms with architectural design through generative genetic programs. It is opening a new dialogue between artificial life and architecture in the level of architectural reflection, process and tool development to generate novel forms. With the new technologies of computation new means of production leads to unconventional architectural formulations. The principals of genetics, using scientific methods (forming a hypothesis, testing it, coming to conclusion), may lead to new facts for design.

Biology is a science that studies living things and has given us data that substantiates the unity of life and a mechanism by which it diversifies, that progresses and develops concepts that allow as to understand the material world[2]. "To explain the complex visible by some simple invisible" [3]. The two greatest revolutions in biology, those in evolution and genetics, were driven by such insights. […] But neither natural selection nor DNA directly explains *how* individual forms are made or how they evolved. The key to understanding form is *development*, the process through which a single-celled egg gives rise to a complex, multi-billion-celled animal. […] And development is intimately connected to evolution, because it is through changes that changes in form arise[4]. And somewhere here arise the origin of complexity theory and the exchange between energy, information and matter.

---

[1] Crang M., Thrift N.J., 2000, *Thinking Space*, Routledge, London, page 172
[2] Mader S.S, 1998, Biology *6/E*, WCB/ McGraw-Hill, United States of America, page1

[3] Words by the physicist and Nobel laureate Jean Perrin
[4] Carroll S.B., 2007, *Endless Forms Most Beautiful,* Phoenix, Great Britain, preface

There are different lines of development of the concept of complexity in architecture: a gestalt-psychological line, a cybernetic line and a biological-algorithmic line[5].

To understand the new concept of universe with mechanistic terms is futile.
Robert Rosen (1991) built on the assumption that the explanatory powers of the mechanistic worldview cannot help understand the realm of living systems. One of several important clarifications he made was to define a system component as "a unit of organization; a part with a function, i.e., a definite relation between part and whole." From this and other starting concepts, he developed a "relational theory of systems" that attempts to explain the special properties of life. Specifically, he identified the "nonfractionability of components in an organism" as the fundamental difference between living systems and 'biological machines.' '[6]

So which could be the features of architecture that wish to express these characteristics of nature's intelligence? The ancient meaning of Architecture implies creation from the origins of nature, or the natural expression of originality; proceeding from the origins. And the origin of all things is found in nature and life itself.

In order to answer the question 'What is life?' some scientists have recently proposed that a general Living systems theory is required.[7] Cleland and Chyba wrote a chapter in Planets and Life: "In the absence of such a theory, we are in a position analogous to that of a 16th-century investigator trying to define 'water' in the absence of molecular theory." [...] "Without access to living things having a different historical origin, it is difficult and perhaps ultimately

---

[5] Gleiniger A., Vrachliotis G., 2008, *Complexity: design strategy and world view*, Birkhauser Verlag AG, Germany, page 72

[6] Rosen R., 1991, *Life Itself: A Comprehensive Inquiry into the Nature, Origin, and Fabrication of Life,* Columbia university Press,(first published 1934) New York, page 240

[7] Woodruff, Sullivan, Baross J, 2007, *Planets and Life: The Emerging Science of Astrobiology*. Cambridge University Press, Cambridge

impossible to formulate an adequately general theory of the nature of living systems".

Such general theory, arising out of the ecological and biological sciences, attempts to map general principles for how all living systems work. Instead of examining phenomena by attempting to break things down into component parts, a general living systems theory explores phenomena in terms of dynamic patterns of the relationships of organisms with their environment[8].

Life is also a property of ecosystems.
A systems view of life treats environmental fluxes and biological fluxes together as a ”reciprocity of influence."[9]

1. An aerial photo of microbial mats around the Grand Prismatic Spring of Yellowstone National Park[10]

The logic that derives from new digital tools aspires to manage complexity, but also the continuous changes in architectural practice. This way of thinking seems to be a stage of continual transitional perception of reality.

---

[8] Molly Young Brown, 2002, "Patterns, Flows, and Interrelationship". Retrieved from http://www.mollyyoungbrown.com/systems_article.htm.,27/6/09

[9] Bulletin of the Ecological Society of America, April 2002, *The Ecosystemic Life Hypothesis*, 28/8/09

[10] wiki/Life, 5/11/09

This reality has been described by philosophical theories and is detected in the form of digital architectural ideas and creations during the last years. To define a new paradigm of theoretical ideas that are informing the contemporary digital realm, it is useful to study the work of Gilles Deleuze and his philosophy which has been described as a "bio-philosophy". An approach can focuses on process rather than representation, on formation rather than form. There is a qualitative distinction, between a static (form-matter) and a dynamic (material-force) relation of understanding architecture.

Condense the estimated existence of the planet into a single year. If human beings first emerged 3 to 5 million years ago then compared the lifetime of the planet, we will have existed for about 1 hour and 50 minutes. If we then agree that human culture has existed for about 10,000 years, then we will have existed as a "cultured" species for approximately 13 seconds. To put it simply, human knowledge is minute and extremely limited in comparison to that of nature, and nature has "practiced" its ideas with astounding diversity and results. Such creative power and practical knowledge are almost incomprehensible. Given these facts, would it not behoove us to look with greater insight and inquisitiveness into the wonder, beauty and intelligence of nature as an experienced practitioner of architecture?[11]

To produce a history of technological innovation along the lines suggested by Deleuze and Guattari, will involve some conceptual breakthroughs, in particular, to get rid of the "hylomorphic schema" (form imposed on matter from the outside) and more importantly, to give a historical account of how this schema came to dominate our thought about the genesis of form. […] Military institutions, beginning with their eighteenth century contributions to the spread of mass production techniques, are one of the main sources of the current domination of the hylomorphic schema[12] .This will be further analyzed at chapter two.

---

[11] Tsui E., 1999, *Evolutionary architecture*: *nature as a basis for design,* John Wiley & Sons, Inc, United States of America, page 4

[12] DeLanda M., 1992, *War in the Age of Intelligent Machines,* Zone Books, New York

If Deleuze and Guattari are correct in saying that it is precisely this schema which makes the machinic phylum "invisible" or "unrecognizable," we may need much more than theoretical innovations to reconnect technological evolution to its old sources of inspiration and vitality. Reality itself, so homogenized after over two centuries of military uniformization, needs to be reinjected with heterogeneity; and our bodies, so deskilled after two centuries of military routinization, need to relearn the craft and skills needed to "hack" these heterogeneous elements into new combinations.[13]

But the unit-grid like Cartesian plane order of human expression is without benefit of nature's evolutionary process. The building is viewed like a static, machine-like, closed system with no exchange or response from the environment or other systems.

Architects are hopefully free or not free to get involved, and combine what ever this era is wearing. Architecture as a wide mechanism of dialogue may use any medium to embody itself, if it needs to adapt, transform meaning in them which are contemporary in the society.

Now with technology, everything seems like leading to a new era, that it is transitional and called Post – Human with global trade, bio – engineer, and mass tourism. Everything that has till now been learned is being re-learned. Experiments saw that there are no limits in imagination; ideas are infinite, as there are no limits in evolution of human intelligence. Maybe then, what wants architecture being in a sensitive situation is because of this totally new concept "new consciousness" [14]of space.
For this, it will be necessary to understand precisely what form is, how it arrives, and why the "form problem" has been so difficult to handle.

---

[13] DeLanda, M., 1998, *The Machinic Phylum*, Technomorphica. Edited by Joke Brower and Carla Hoekendikj, Rotterdam: V2 Organization , retrieved from http://framework.v2.nl/archive/archive/node/text/.xslt/nodenr-70071 5/10/09

[14] Referred to the "new consciousness" of space in Henri Lefebvre's Production of Space.

It was no wonder that futurism - the social movement most deeply sensitized to cataclysmic perturbations - was obsessed with complexes: delirious, infernal, and promiscuous. For the very ethics and physics of the futuristic program, conceived as an open, far-from-equilibrium system, responsive to and willing to amplify every destabilizing fluctuation in the environment, necessitated its multiple impregnation both in and by the social, material and affective systems that surrounded it. […] Yet futurism's profoundest gift to our century was its seemingly hubristic attempt to link the biosphere and the mechanosphere within a single dynamical system.[15]

2. Boccioni: Gli addii-Stati d'animo II, 1911[16]

[…] Posthumans lining the road to the future (which looks as if it exists, after all, even though Dada is against it), need the solace offered by the primal

[15] Kwinter, Sanford., 1992, *Landscapes of change: Boccioni's Stati d'Animo as a General Theory of Models*, Assemblage 19,
page 52-53
[16] Retrieved from http://www.scrivi.com/pubblicazioni 8/11/09

raw energy of Dada and its inhuman sources.[17]These cities[18] were concentrations of virtualities that offered the possibilities of creative reinvention of the world.[19]

Post human life is based on the alleged awareness of all living connections. […] The rational description of our post humanity would have it that the societal mechanisms that were of such concern to *thinkers* have been automated.[20] A posthuman is a human who has put nature (including herm own) between parentheses. Or convinced herm self that everything nonhuman is human and, therefore, human = nature. This used to be called "anthropomorphism," but lately it is known as a "user-friendly interface."[21]

This thesis is trying to find the relations to different dimensions within architecture. When time is no longer even a dimension of space,[22] and architecture is described as from a virtual event to a scientific molding of an image. A digital morphogenesis is unhistorical, emotionless and impartial, lacking a subject. From Deleuze borrows concepts which translated to architecture lend to the building new kind of surfaces, open to the surroundings and its information. This space-time organism is evolving every time information is rewritten. It's a creative evolution to Bergson. This instant becoming can only be described as magic, an illusion, perhaps with a misleading connotation. For a manifestation of an oneiric dimension, the abstract should meet its corporeity for the genesis of a novel abnormality, or oddness to Baudrillard.
For, facing a world that is unintelligible and problematic, our task is clear: we must make that world even more unintelligible, even more enigmatic.[23]

---

[17] Codrescu A., 2009, *The post human dada guide: Tsara and Lenin play chess*, Princeton University Press, United States of America, page 2

[18] From the same text, refer to the cities that the first dada lived (Zurich, Paris, New York, etc)
[19] Ibidem page 4
[20] Ibidem, page 5
[21] Ibidem, page 8
[22] Lefebvre H., 1905, The production of space, Anthropos, United kingdom, 2004, page 96

[23] Baudrillard J., 2000, *The Vital Illusion*, Columbia University Press, United States of America, page 83

1. Cells and Effects

Living things are organized

Living things acquire Materials and Energy

Living things respond

Living things reproduce and develop

Living things have adaptions[24]

Studio: Introduction to genetics and architectonical design.

Director: Pr. Alberto Estévez

Image: Snapshot from the project animation, by author

[24] Mader S.S, 1998, Biology *6/E*, WCB/ McGraw-Hill, United States of America, page 1

1.1. Introduction to Genetics

The goal is to engineer a new species of microorganism from scratch [25]

The evolution of life and intelligence on earth has finally reached the point where it is now deemed possible to engender something almost out of nothing. […] For the first time mankind is finally in possession of the power to change and transform the genetic constitution of biological species, which, without doubt, has profound implications for the future of life on earth.[26] This can bring forth a poetic re-enchantment of the world as Karl Chu mentions in the same text, or even threaten the future viability of all species. Architecture cannot be aside to all this.

It is not surprising that the origin of computation lies in an attempt to embody instrumental reason in an abstract machine along with the attendant drive to encode the logic of life and the world around us in all its manifestation[27]. Parallel to the development of computation is the discovery of the DNA code in the early part of the 20th century, the significance of which has only begun to be realised with the completion of the Human Genome Project. […] Computation and biogenetics […] will bring forth a new kind of bio-machinic mutation of organic and inorganic substances.[28]

A view of life

Living things have levels of organization from cells to ecosystems. Each level of organization has emergent properties that cannot be accounted for by a sum of the parts.[29]

---

[25] Venter, Craig, *Supermicrobe man*, Wired, No. 10.12 December 2002, page 191

[26] Genetic Architectures II: digital tools & organic forms, 2005, ESARQ/SITES books, Barcelona. page 159

[27] Idem

[28] Ibidem, page160

[29] Ibidem, page161

Biological forms are self-organized hierarchically, as systems within systems. They assemble themselves under the load of gravity and gather material and energy from their environment. An essential characteristic of self-organized forms in natural systems, both living and non living, is that small simple components assemble together to form larger structures that have emergent properties and behaviour due to the interactions between the parts making up the whole. One emergent property of human tissues, for example, is their mechanical behaviour. This mechanism is known as *linear stiffening*, and it is found even in single molecules and in DNA.[30]

The most common structural architecture in living systems, from water molecules to complex tissues and whole organisms is what we know as tensegrity, a term introduced by Fuller. From his experiments concluded that stability comes not from the strength of the individual elements but from the way forces are distributed around the structure as a whole.[31] A balance between parallel compressive and tensile forces leads to a self supporting property. For example, Tensegrity in the cytoskeleton might explain the self-supporting structural properties of cytoplasm in which the rigid parallel elements are not in direct contact. […] The cleavage furrow contractile ring is a temporary structure that exists for only about 10 minutes; it rapidly assembles and disassembles.[32]

---

[30] Overview from Weinstock M., On self –Organization: Stress driven form- finding in architecture, Genetic Architectures II: digital tools & organic forms, 2005, ESARQ/SITES books, Barcelona
[31] idem
[32] Hameroff R. S., 1987, *Ultimate Computing*, Elsevier Science publishers B.V. Tucson, Arizona, U.S.A., page 120

First and most importantly for all living systems, prestressed tensegrity structures are flexible enough to allow structures to have different forms. Second, they are efficient in terms of the amount of material used for the strength to achieve. […] The frequent occurrence of this structure is evidence of the existence of one of the common rules for natural self-organisation-the minimisation of energy and mass through continuous global tension and local compression.[33]

An intake of materials and energy is needed if an organism organization is to be maintained. The ultimate source of energy for life on earth is the sun […] Many organisms depend on behaviour to regulate their internal environment. To find energy they interact with their surroundings.[34] Individual organisms are not completely autonomous, but exist within higher level systems, which in turn are multiple and varied parallel systems that interact within populations, environments and ecologies.

Applications of genetic biological approaches

Today genetic engines are used in architecture and are derived from the mathematical equivalent of the Darwinian concept of natural selection or survival of the fittest (and the logic of cellular automata and Boolean networks). But if the fitness criteria are not modified by the distribution of variation in the population, or by interaction of individuals and populations, they are essentially external to the system and for that the type of organization that is produced is not self organized[35].

The new view of evolutionary biology develop new mathematical models that propose that the process within an environment, rather than the form is encoded in the genome, to explain why biological systems display far

---

[33] Genetic Architectures II: digital tools & organic forms, 2005, ESARQ/SITES books, Barcelona,, page 103

[34] Overview of page 3 in Mader S.S, 1998, Biology *6/E*, WCB/ McGraw-Hill, United States of America

[34] Genetic Architectures II: digital tools & organic forms, 2005, ESARQ/SITES books, Barcelona,, page 103, overview

more complexity than can be accounted for by direct coding in the genome. Phenotypes are more critical to self- organization evolutionary models than genotypes or genetic activity[36]. Based on genetic algorithms, networks (sub-systems inside system) are constructed and the learning algorithm stimulates phenotypes inside that environment.

But before going further more in our present biology and the design strategies of artificially constructed systems., it is necessary to show certain mathematical aspects of the morphology and the dynamical principles of organic and inorganic matter that manifest the harmony of the world, since everything is bound alike by physical and mathematical law, expressed by number and defined by natural order. And we should start by asking: What is that emerges, what does it emerges from, and how is emergence produced?[37]

Time adaption

The history of bio-architecture has started thousand years ago, when life was nomadic and shelter locomotive.
The vaulting houses made of animal skin and bones, or the desert-dwellings tensile tents "build" a sense of space through movement.

We will try to focus in this dynamic perspective and give attention to the relationships, to the interactions and the timely adaption to situation in order to find a fundamentally different architecture. The notion of architecture as an inflexible permanent static structure should be challenged in today's networked and fluid societies.

From the point of architecture, the study of living organisms could help to inspire and build an intelligence of space through movement and adaption.

---

[36] Steward I., 2003, *Self organization in evolution: A mathematic Perspective, Philosophical Transaction*, The royal Society of London, page 361

[37] Hensel M., Menges A., Weinstock M., *Emergence: Morphogenetic Design Strategies*, AD, Volume 74, No3, May/June 2004, Wiley-Academy, London, page 11

Learning an idea from a natural organism and then apply it, it's like taking the design principles, the genius of the natural world and gain knowledge from it. Biomimicry has greatly inspired technology on the software side, like computers that protect themselves. We are learning from gene regulation and biological development, genetic algorithms and evolutionary computers. But how does life make the most of things? How does life make things disappear into systems?

Two projects were proposed for the first studio of the master, as an introduction to genetics and architectonical design. The task of the studio was to develop the design of a skyscraper, taking advantage from new parametrical software. Using evolutionary computation as generative processes for morphogenesis to speculate inherent architectural future based on forms that occur in nature and develop the whole architectural process in three dimensions (design and manufacture). The computer numeric control (CNC) it is capable of automating a series of instructions sent from specific program and allows projecting, representing, stimulating and manufacturing elements, components and architectural projects by digital means.

Examination of available methods for modelling biological growth derived to architectonical strategies/methods to achieve advanced levels of functionality, performance and aesthetics. In this case, the biomorphic approach is referred as a non-representational form or pattern that resembles a living organism in shape or appearance. The investigation started from the behaviour of air cells and the plateau law, to change to a more biological concept of bone structure which focuses on the spongy bone of the femur.

1.2. Diagramming Growth and Form of Fluid Cells

Gaudi, he was certainly aware of the developing understanding of the natural connection linking structure and form with geometry. Gaudi is known to have been preoccupied with the apparent models of structural efficiency, aesthetics and composition found in the natural world […][38] and his principal design method was the use of physical gypsum plaster models.

Gaudi's interest in second order geometry-warped surfaces- has only become widely understood since his death in 1926 through the continuing efforts to complete his magnum opus, the Sagrada Familia Church in Barcelona[39]. He arrived to these forms in the end of his career, through descriptive geometry studies, and their rational geometry is in contrast with his earlier free form 'Pedrera'.

The hanging chain models are examples of material form- finding, which were continued in the work of Frei Otto. This interest in the geometry of forms produced by natural systems is represented into many physical experiments for the exploration of systems where stress produces the self organization of the material.

---

[38] Burry M, *Virtual Gaudi*, Leach N., Turnbull D., Williams C., 2004, *Digital Tectonics*, John Wiley & Sons, Italy, page 25

[39] Ibidem, page 23

3 Laboratory inside Sagrada Familia. Photo by author, March 2009

Observations of phase transitions in materials and the phenomena of irregularity that is characteristic of a phase transition suggest another interesting mathematical approach that might be successful in modelling the relation of order and randomness in the processes of natural systems, and might be useful to incorporate in stress-driven digital form finding[40].

The diagram is a visual representation of the way something works, rather than how it looks. It is an abstraction and a reduction of something. It is a mode of notation, but also a model of thought. For designers, the diagram constitutes a form of visual thinking – a 'thought-image'. The diagram provides a means of showing connections between disparate phenomena. It can make connections, organize, and maintain different types of information, including those varying in time.

To emphasize the relationship between growth and form, D'Arcy Thomson comments: Organic form itself is found, mathematically speaking, to be a function of time. [...] We might call the form of an organism an event in space-time, and not merely a configuration in space[41]. This concept is echoed by Hall´e, Oldeman and Tomlinson:
"The idea of the form implicitly contains also the history of such a form." [42]

Minimal Area

Surface tension is due to molecular force: to force, that is to say, arising from the action of one molecule upon another. […][43] But one simple explanation (or mode of statement) is that the molecules of the surface-layer are being

---

[40] Genetic Architectures II: digital tools & organic forms, 2005, ESARQ/SITES books, Barcelona,, page 105

[41] Thomson W. D' Arcy, 1917, *On Growth and Form,* 79 University of Chicago Press, edition:2- 1948, page 79

[42] Prusinkiewicz P, Lindenmayer A, 1996 *The Algorithmic Beauty of Plants,* Springer-Verlag, New York, preface

[43] Thomson W. D' Arcy, 1917, *On Growth and Form,* Cambridge University press, Cambridge, 1992, page 49

constantly attracted into the interior by such as are just a little more deeply situated; the surface shrinks as molecules keep quitting it for the interior, and this *surface-shrinkage* exhibits itself as a *surface-tension*. The process continues till it can go no farther, that is to say until the surface itself becomes a "minimal area". This is a sufficient description of the phenomenon in cases where a portion of liquid is subject to no other than its own molecular forces […][44] which governs the forms in the molecular range of a fluid surface.

Capillary surfaces

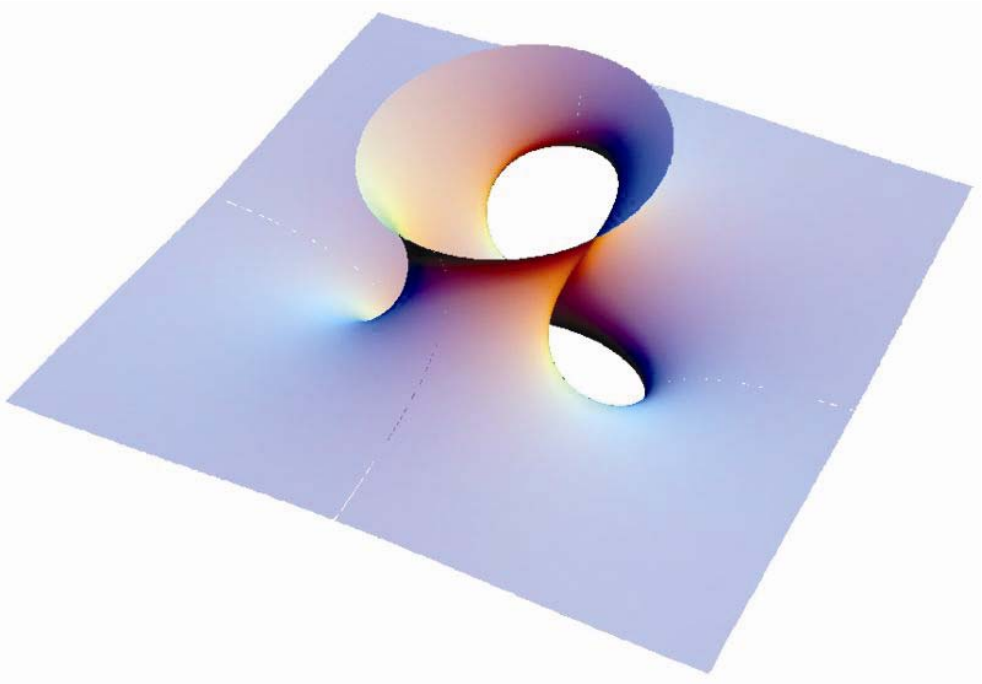
We know: as a fundamental law of "capillarity", that a liquid film in equilibrium assumes a form which gives it a minimal area under the conditions to which it is subject. These conditions include (1) the form of the boundary, if such exists, and (2) the pressure, if any, to which the film is subject; which pressure is closely related to the volume of air, or of liquid […] when we take up a soap film on a plane wire ring, the film is exposed to equal atmospheric pressure on both sides, and it obviously has its minimal area in the form of a plane[45].

The film is always contracting to the utmost, to arrive into equilibrium, and in the case of soap bubble the uniform contraction, has reduced the surface to the least possible area, lead to the spherical form.
The tension of the bubble, depending only on the surface condition, is independent of the thickness of the film[46] .
So the physical principal of a surface tension form is that the surface with the same mean curvature at all points is equivalent to a surface of minimal area for the volume enclosed.

The capillary surfaces of Plateau's form a beautiful example of the materialization of mathematical law. Theory leads to certain equations which determine the position of points in a system and these points we may then plot

[44] Ibidem, page 50
[45] Ibidem, page 51
[46]Ibidem, page 52, note 1

as curves on a co-ordinate diagram. Such a case is what Bacon calls "collective instance", bearing witness to the fact that one common law is obeyed by every point or particle of the system.[47]



4. A rendering of Costa's minimal surface[48]

Moreover, the sphere is the one which encloses the greatest volume with the least area surface; it is strictly and absolutely the surface of minimal area, and it is, ipso facto, the form which will be assumed by a unicellular organism (just as by a raindrop) if it be practically homogenous and if, like orbulina floating in the ocean, its surroundings be likewise homogeneous and its field of force symmetrical. [49]

---

[47] Thomson W. D' Arcy, 1917, *On Growth and Form,* Cambridge University press, Cambridge, 1992, page 60-61

[48] retrieved from http://en.wikipedia.org/wiki/File:Costa_minimal_surface.jpg 10/11/09

[49] Thomson W. D' Arcy, 1917, *On Growth and Form,* Cambridge University press, Cambridge, 1992, page 60-61

Double-bubble

In the plane, the analog of the double bubble consists of three circular arcs meeting in two points. It has been proved that the configuration of arcs meeting at equal angles has the minimum perimeter for enclosing two equal areas (Alfaro *et al.* 1993, Morgan 1995). It had been conjectured that two *equal* partial spheres sharing a boundary of a flat disk separate two volumes of air using a total surface area that is less than any other boundary[50].

Plateau's Rules describe the structure of soap films in foams. These rules were formulated in the 19th century by the Belgian physicist Joseph Plateau from his experimental observations. Plateau's rules state that:

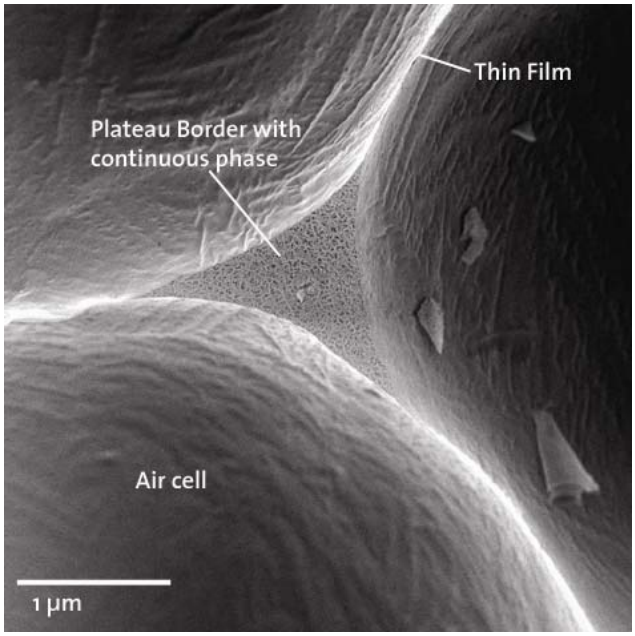
1. Soap films are made of entire smooth surfaces.
2. The average curvature of a portion of a soap film is always constant on any point on the same piece of soap film.
3. Soap films always meet in threes, and they do so at an angle of $\cos^{-1}(-1/2) = 120$ degrees forming an edge called a Plateau Border.
4. These Plateau Borders meet in fours at an angle of $\cos^{-1}(-1/3) \approx 109.47$ degrees (the tetrahedral angle) to form a vertex.

Configurations other than those of Plateau's Rules are unstable and the foam will quickly tend to rearrange itself to conform to these rules[51].

Innumerable new conditions will be introduced, in the shape of complicated tensions and pressures ,when one drop or bubble become associated with another, and when a system of intermediate films or partition-walls is developed between them.[52] In terms of *Energy*, the general principle which underlies the theory of surface-tension or capillarity, […] equilibrium, which is the condition of minimum potential energy in the system, will

[50] Wolfram, Double bubble, mathworld.wolfram.com
[51] wiki/plateau's laws
[52] Thomson W. D' Arcy, 1917, *On Growth and Form,* Cambridge University press, Cambridge, 1992, page 76

accordingly be obtained, caeteris paribus[53], by the utmost possible reduction of the surfaces in contact[54].

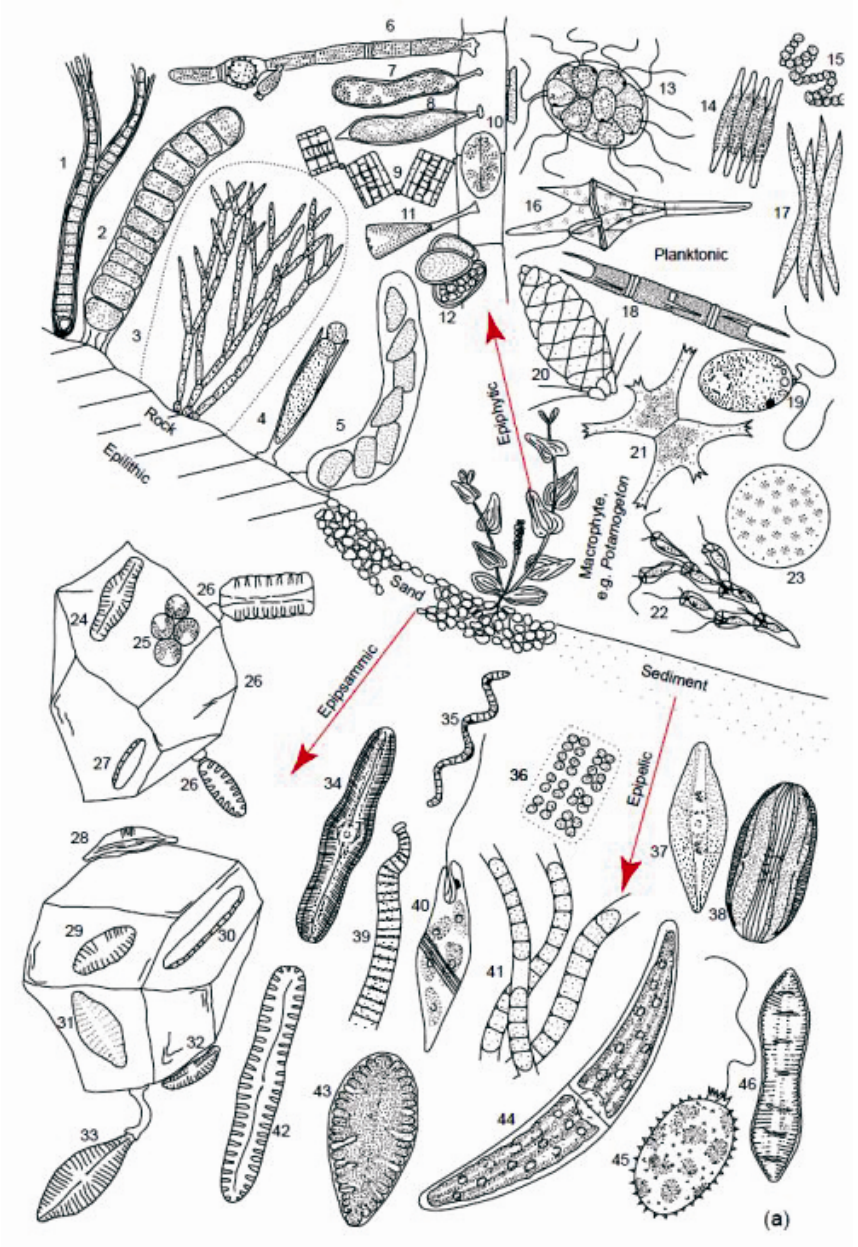


5. Cryo-SEM Picture of a Plateau Border[55]

Cases of asymmetrical deformation or displacement

If the sphere be the one surface of complete symmetry and therefore of independent equilibrium, it follows that in every cell which is otherwise conformed there must be some definite cause of its departure from sphericity. [...] Such a cause may be either external to, or may lie within, the cell itself[56].

[53] Cēterīs paribus is a Latin phrase, literally translated as "with other things the same," or "all other things being equal or held constant."
[54] Ibidem, page 88
[55] Retrieved from www.ilw.agrl.ethz.ch 15/3/09
[56] Thomson W. D' Arcy, 1917, *On Growth and Form,* Cambridge University press, Cambridge, 1992, page 77



6. Examples of the tremendous diversity in cell form of the microscopic planktonic algae in freshwater[57]

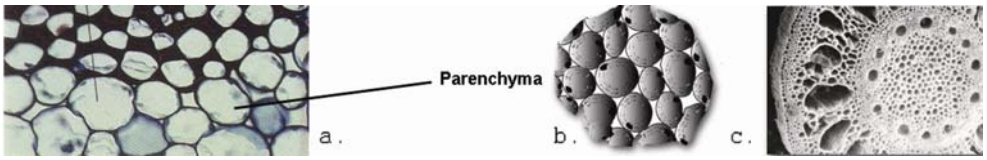
[57] Retrieved from answersingenesis.org, 12/10/09

1.3. A Dynamic Perspective of Cell Aggregations

From air cells to tissue branching - Hexagonal Symmetry

We have now passed from the solitary liquid cell to cell aggregates, which will lead ultimately to the study of more complex systems, like tissues were we need to consider also the effect of other forces. As it has been said, between soap-bubbles there is a continued balance of the capillary forces and the surfaces merge by a continuous curve. But in a tissue, the cell walls no longer meet as fluid films, however are stiffening into pellicles of solid contact, always obeying the principle of meeting by threes, at angles of 120°.

The same principles which account for the development of hexagonal symmetry hold true, as a matter of course, not only cells (in the biological sense), but of any bodies of uniform size and originally circular outline, close-packed in a plane; and hence the hexagonal pattern is of very common occurrence, under widely varying circumstances.[58]



7. a.b.Parenchyma cells of plant tissue, c.Aerenchyma[59]

Invisible forces

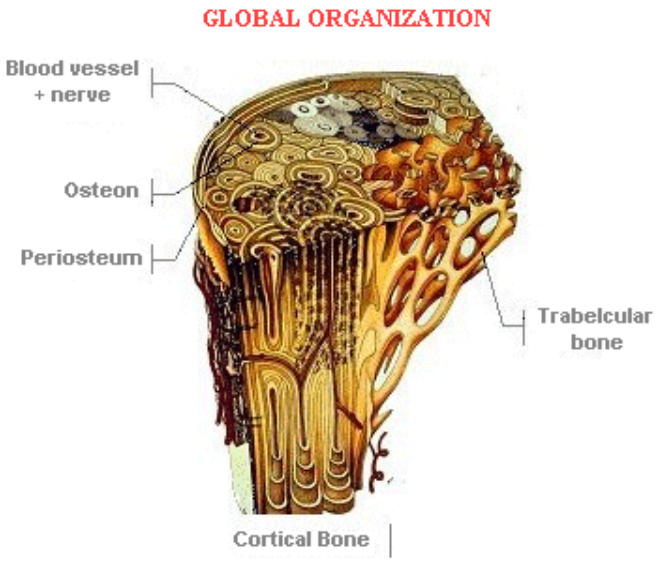
Space is a living, bending, and efficacious unity of invisible forces. These forces give birth to visible shape and structure. The curving elegance of a bone is formed from using the least material to achieve the most effective means of accommodating stress and strain. The cellular spacing and the density of bone matter change according to the presence of these two forces, and the nature of

[58] Thomson W. D' Arcy, 1917, *On Growth and Form,* Cambridge University press, Cambridge, 1992, page 103

[59] a. retrieved from www.uic.edu, b and c from www.tutorvista.com

function that it is called on to perform. These forces create the ultimate form and inner structure.

Tissue structure, function and mechanically mediated tissue adaptation is first, from a mechanical standpoint, historically the most studied tissue and second due to one, the simpler behaviour of bone compared to soft tissues, that is, more is known about bone mechanics in relation to its structure. Bone is also a good starting point because it illustrates the principle of hierarchical structure function that is common to all biological tissues. In this section, we illustrate the anatomy and structure of bone tissue as the basis for studying tissue structure function and mechanically mediated tissue adaptation.[60]



8. Bone physiology [61]

[60] Text retrieved from www.engin.umich.edu/class/bme456/bonestructure/bonestructure 6/2/09
[61] Image retrieved from http://www.medes, 12/11/09

Cancellus bone architecture

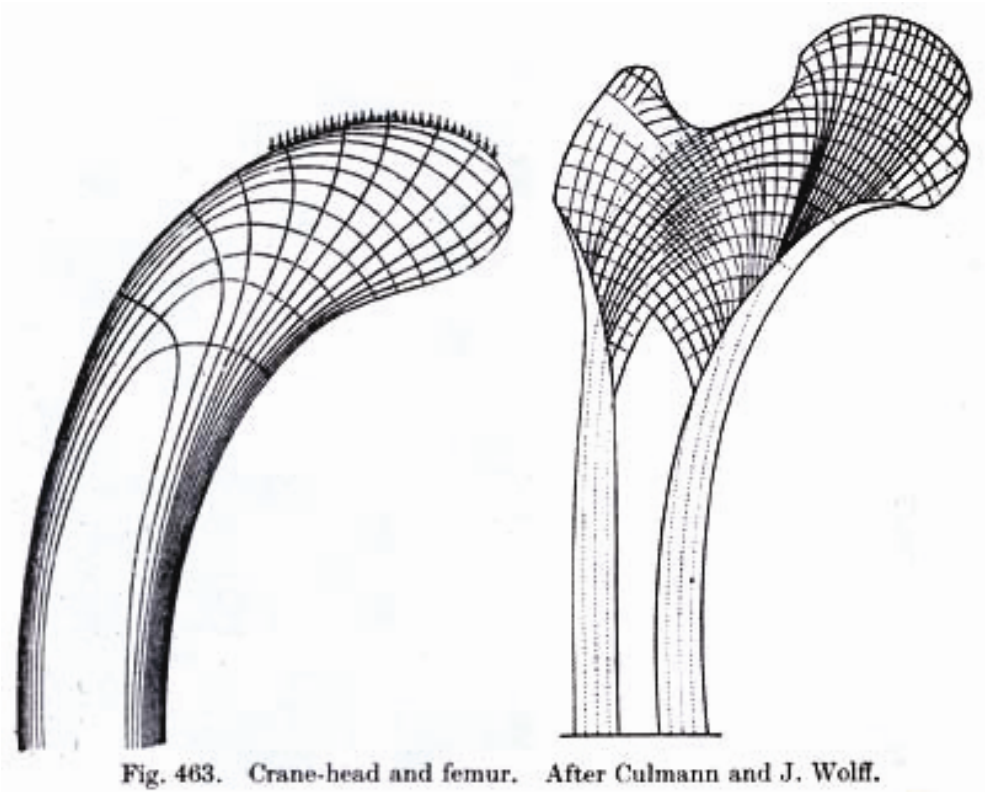
We assume, like Roux (1881), Wolf (1892) and many other authors since, that trabecular-bone architecture is formed, maintained and adapted by mechanical load.[62]

In the mechanical structure of the human bone, the vertical pressures impinge upon it to the cylindrical walls of the shaft. The hollow space is filled with organic marrow, vessels and tissues. And amidst these living tissues lies a fine lattice-work of little interlaced "trabeculae" of bone, forming the so-called "cancellous tissue". […] 1. The cancelli of such bones as assist in supporting the weight of the body are arranged either in the direction of that weight[…] In a mechanical point of view they may be regarded in nearly all these bones as a series of studs and braces. […][63] The arrangement of the bony trabeculae was nothing more nor less than a diagram of lines of stress, or directions of tension and compression, in the loaded structure, in precisely the manner and direction in which strength was required[64].

[62] Huiskes R., Mullender M., 1996, *Adaptive Bone Remodelling in Cyberspace: tricks and Treats*, Netherlands, page 305

[63] Thomson W. D' Arcy, 1917, *On Growth and Form,* Dover, New York, 1992, page 976

[64]ibidem, page 977

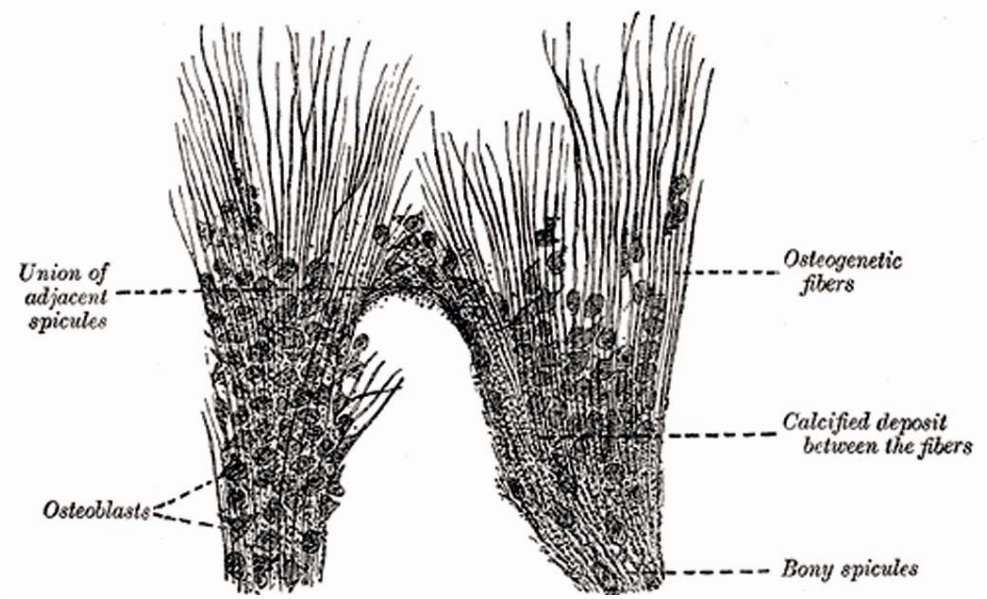


9. Thompson's diagram of the stress lines in a crane and a femur[65]

Trabecular morphogenesis paradigm

An osteoblast (from the Greek words for "bone" and "germ" or embryonic) is a mononucleate cell that is responsible for bone formation. Bone is a dynamic tissue that is constantly being reshaped by osteoblasts, which build bone, and osteoclasts, which resorb bone. Osteoblasts arise from osteoprogenitor cells located in the periosteum and the bone marrow. Osteoprogenitors are immature progenitor cells that express the master regulatory transcription factor[66].

[65] Image from Thomson W. D' Arcy, 1917, *On Growth and Form,* Cambridge University press, Cambridge, 1992, page 233
[66] Wikipedia, Osteoblast, 7/10/09

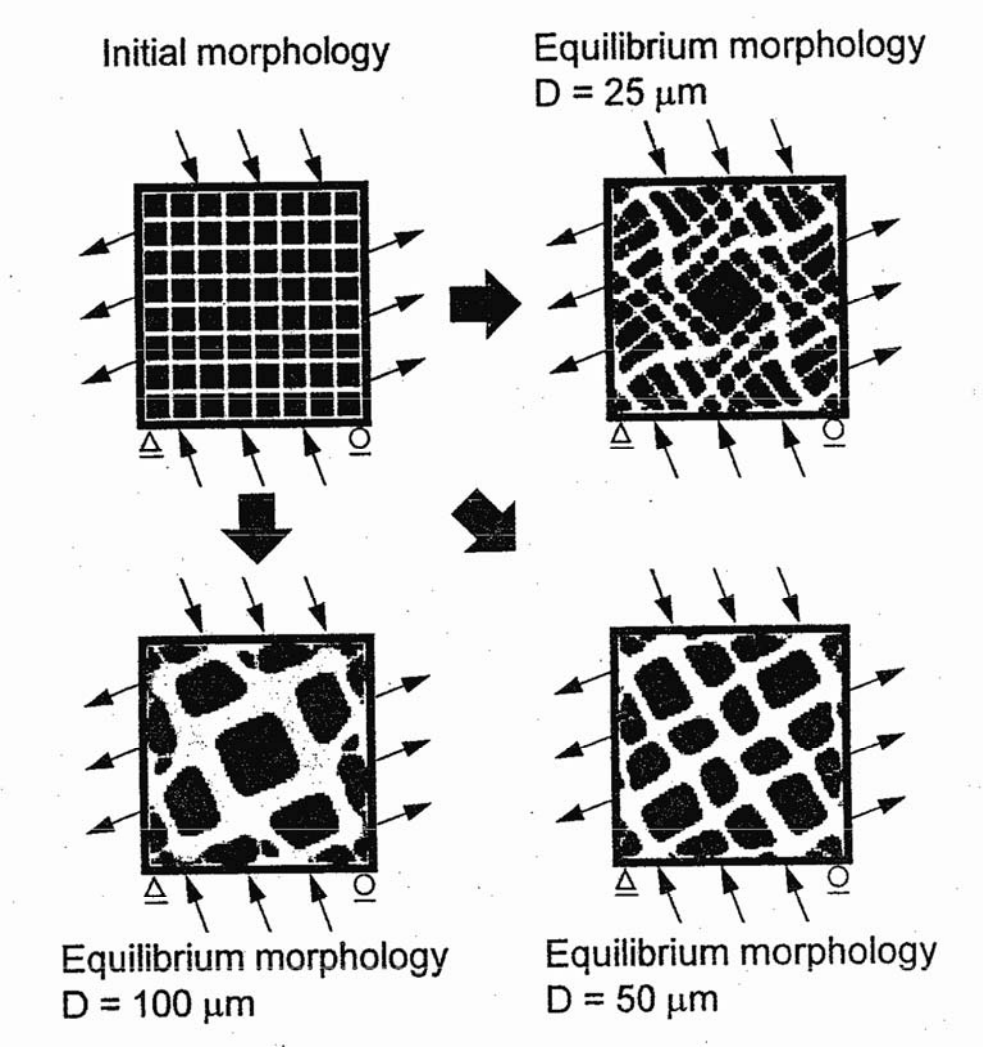


10. Part of the growing edge of the developing parietal bone of a fetal cat.[67]

In order to form and maintain an anisotropic architecture, the bone cells do not necessarily need information about the directionality of loading variables.[…] It was often proposed that cells must by necessity be informed about tensor loading quantities, such as stress or stain, in order to develop a functionally appropriate morphology. Apparently, this is not true. The structural anisotropy can emerge indirectly from the nature of the self-organizing process, depending only on the relationship between the external load and the local stress intensity.[68]

[67] Retrieved from http://www.answers.com/topic/osteoblast, 8/11/09

[68] Huiskes R., Mullender M., 1996, *Adaptive Bone Remodelling in Cyberspace: tricks and Treats*, Netherlands, page 306



11. Loads are applied to an arbitrary lattice structure for three different values of the osteocyte influence parameter D.[69]

[69] Idem

Lines of growth – St. Venants effect

But there is yet another and a very remarkable phenomenon which we may discern in the growth of a horn when it takes the form of a curve of double curvature, namely, an effect of torsional strain; and this it is which gives rise to the sinuous "lines of growth".[70] The new formed horny substance in the neighbourhood of the zone of active growth is plastic and capable of deformation. From the experiments of St Venants effect in the torsion of an elastic body, like a cylindrical (solid or hollow), a twist leaves each circular section unchanged, in dimension and in figure.

The branching of trabecular architecture in epiphyseal bone towards the articulating surfaces might be the expression of saint-Venants principle in the process of morphogenesis.[71]

[70] Thomson W. D' Arcy, 1917, *On Growth and Form,* Cambridge University press, Cambridge, 1992, page 210

[71] Huiskes R., Mullender M., 1996, *Adaptive Bone Remodelling in Cyberspace: tricks and Treats*, Netherlands, page 306

1.4. Project: Skyscraper

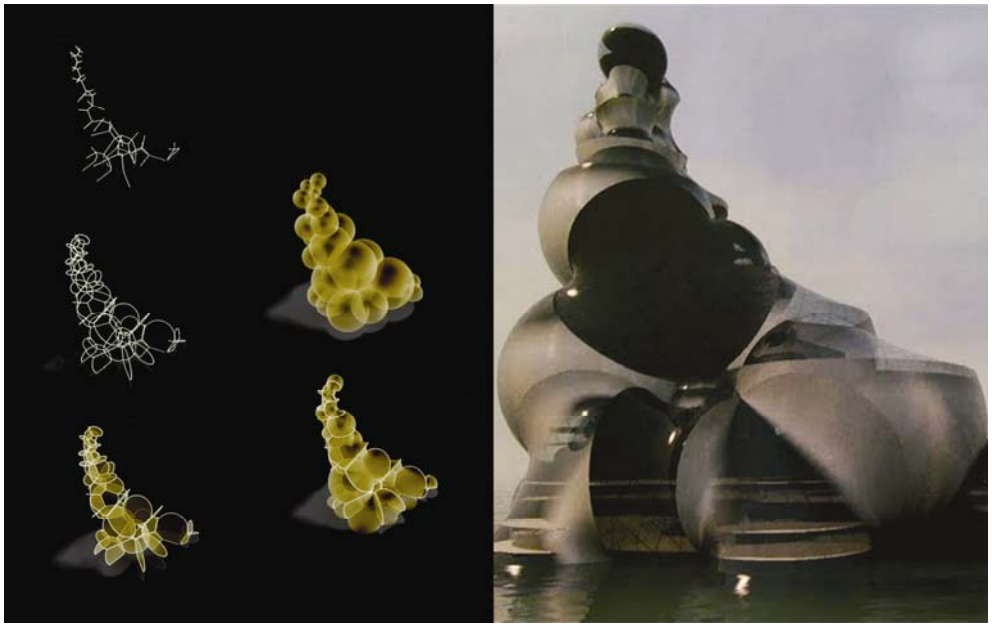
Even though the research for this project splits into two different subjects with their own final project proposals, there are some characteristics, for example, cell laws of structure, self-assembly and intersection, which are common ground. Hence, both proposals can be seen as in an extension.

Bubble Tower

The rules that come from the mathematical world to describe the physical phenomenon of dynamical formations of irregular bubble clusters are used in this project as system logic to arrange randomly (as inserted by themselves), various sphere-bubbles together for the creation of a bubble tower with a different logic of a skyscraper. The idea is that the building made of spheres, could float and the underwater bubbles will be transparent for a live view of the underwater world.

Starting from the logic that is derived from air-cells (soap, underwater, etc) we produce a bubble aggregation of many shapes and sizes. This strategy, to merge two or three bubbles to produce a chain similar to a molecular structure can be used as a way for building construction. As a method we take out the principal that when two or more bubbles merge, they adopt with the same way, which is sharing of the smallest possible area. At the point where they meet they sort themselves out so that only three bubble walls meet along a line, separated by angles of 120 degrees, according to the Plateau rules described previously. The structure says that:

- -only 4 walls can meet at a point.
- -bubbles always meet in three, in an angle of 120° degrees to form an edge (the Plateau Border).
- -the interfering light waves cause iridescent colouring



12. Diagram showing the bubble arrangement with the plateau borders, and final render. Digital image by Henriksen, Giannopoulou

-

Bone Tower – Emergence of trabecular architecture

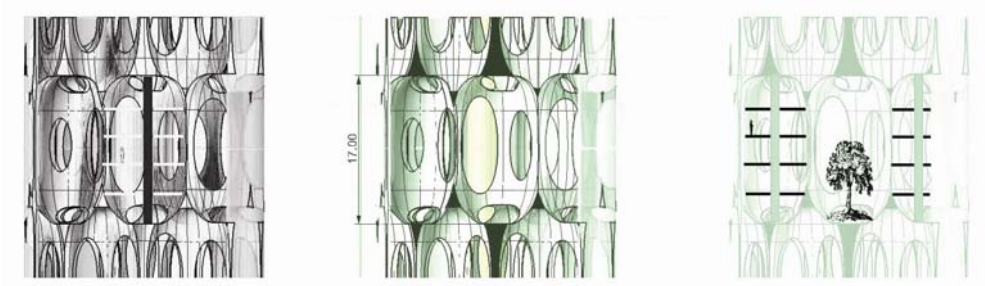
The question was how to generate a tower structure similar to the spongy formation of the femur that could be functional and harmonize with the coast's landscape of Barcelona.

Translating Wolff's paradigm of strain-adaptive bone remodelling into computer model implies specific loose propositions into strictly formalized rules.[72]

An establishment of an asymmetrical hexagonal grid represents the plane pattern of an abstract fluid. The cells assemble in a similar way, but it is like they are artificially inserted into the system by determining the number and the position of each cell. The hexagons and some pentagons are not symmetrical; similar to a system of diffusion currents, cells are in conflict one with another inside the artificial tissue, like before come to equilibrium. The polygons are smoothed to create inscribed curved lines, each in contact with other five or six curves in loose propositions. (Figure 14)

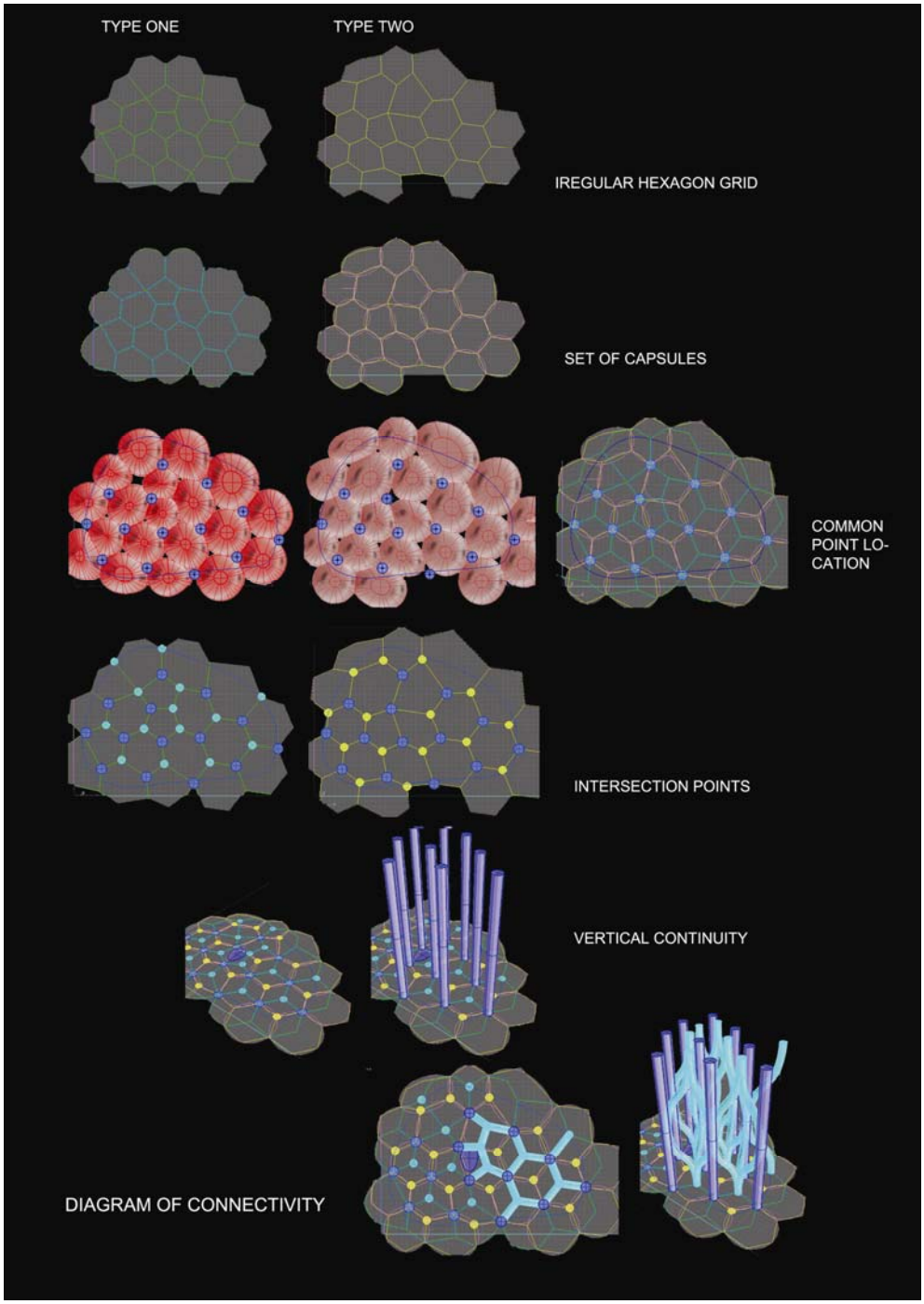
A regulatory model

The idea was to create two different layers of honeycomb capsule-cells to enfold diverse functions. Each cell is designed with seventeen meters height. The units are parametrically varied into a range of scales, orientations and densities to provide variant storage capacities, different paths of lighting or sound distribution and different transparency levels.



13. Schematic diagrams of functions. Digital image by Bennavides, Giannopoulou

[72] Huiskes R., Mullender M., 1996, *Adaptive Bone Remodelling in Cyberspace: tricks and Treats*, Netherlands, page 305



14. The two layers, with the capsules and the lines of vertical continuity. Digital image by author.

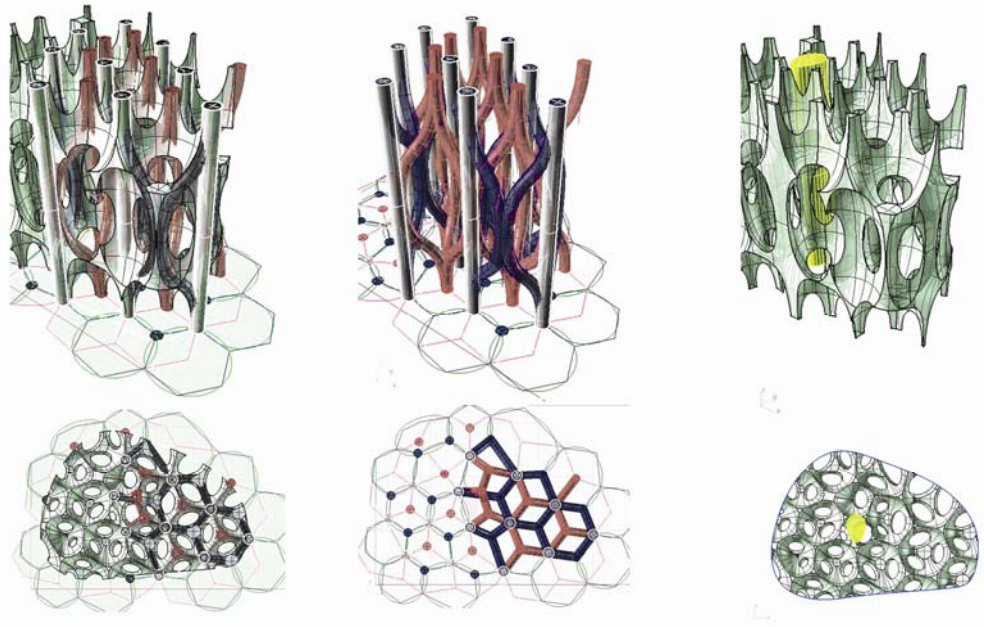
In that level of the composition a decision was taken for the genesis of the tower. The two different layers alternate additionally as they are arranged one top of the other multiple times to arrive at the height of 150 meters. The common points are the ones that allow this progress on space so that the evolution of the structure is like a series connection like a homogenous structure.

Unity and continuity of structure imply that the most efficient and strongest forms are those that have continuous surfaces contiguous to the entire space.[73] The circular plan minimizes the amount of exterior surface and creates a structure inherently stronger than other shapes.

Branching diagram

This demanded the establishment of a three dimensional diagram based on the intersections of the irregular hexagons and the geometry of the honeycomb-capsules (actor cells) that represent the osteoblasts of the bone tissue. It is used to orchestrate the whole composition. The curved pipes illustrate the vertical relations and connections between the cell enclosures on space and the columns specify the vertical continuity between the two layers. The points of contact in the diagram are being extended into lines representing surfaces of contact between the cells. (Figure 15)

[73] Tsui E., 1999, *Evolutionary architecture*: *nature as a basis for design,* John Wiley & Sons, Inc, United States of America, page 73



15. Diagrams of vertical continuity, perspective and top view. Digital image by Giannopoulou, Bennavides

Process of morphogenesis

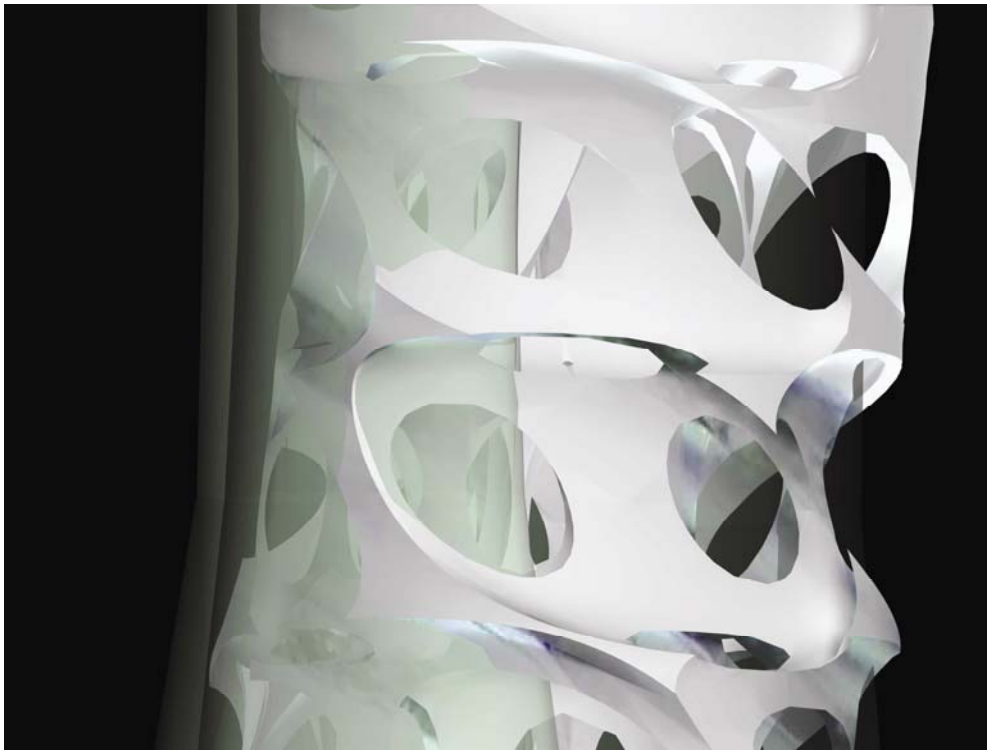
To apply parametric design tools to the entire synthesis is an intriguing phase of the process, because several conditions must be taken into account. External forces applied to the homogeneous structure. Similar experiments to the torsional strain effect were tested in different parts of the building body. The actual external shape of the cylinder remained the same, though the network of cell structure deformed into a dynamical sinuous, that end up in cases with similar characteristic of horn peaks. Like a living bone, very plastic to its structure, yields easily to any forces tending to its deformation. In parts an asymmetry occurs by the inequalities in thickness of different parts. There are the sense nodes or input data points on the meshwork that propel the rotation of the skeletal unit joints, and to which all the other nodes are related to.

16. Three dimensional top view showing the torsion effect in the capsules. Digital image by Giannopoulou, Bennavides.

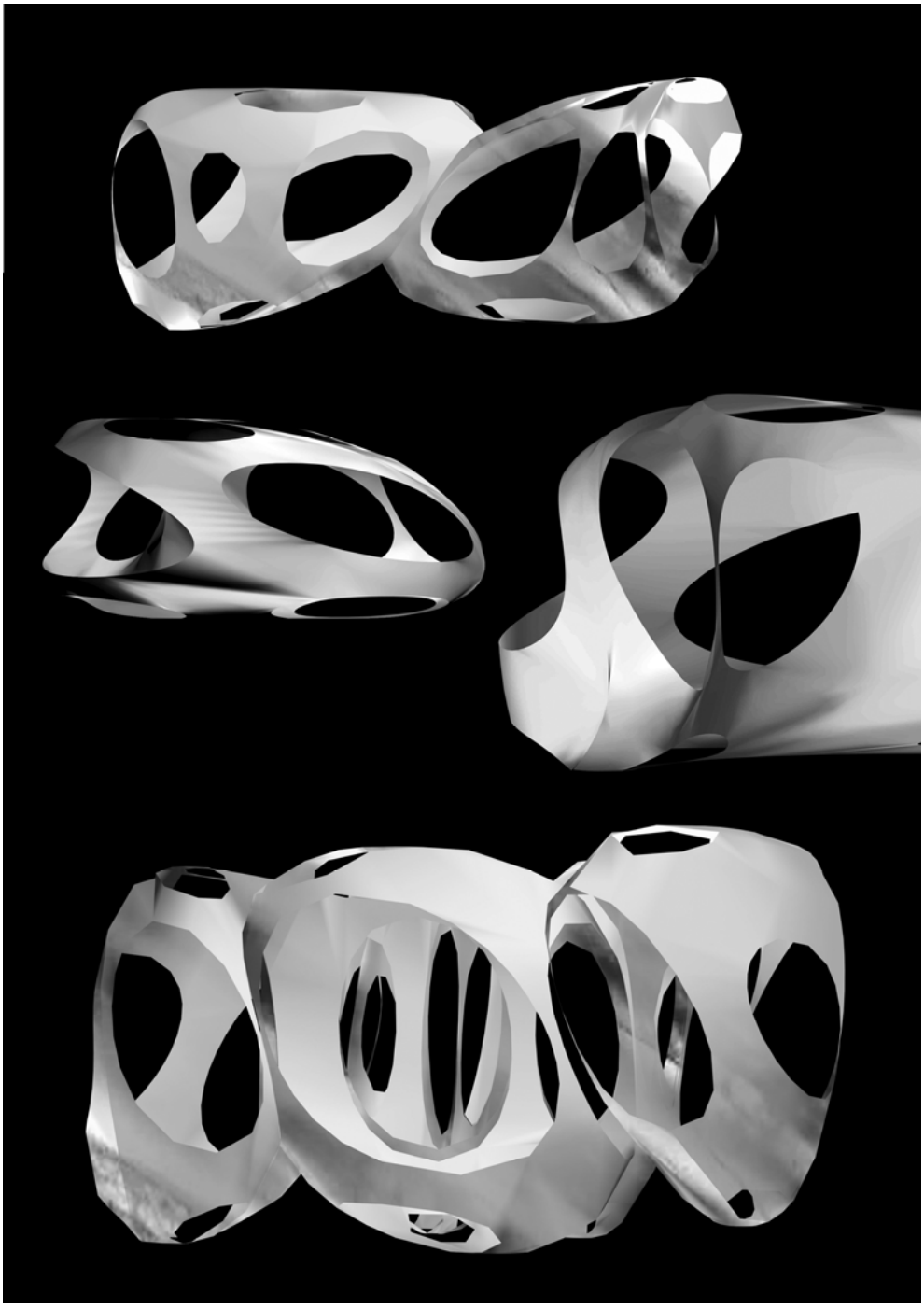
Invisible morphology

The boundaries between what is interior and what is exterior are blurred. For the final render, an image of a nerve fiber (400x) was applied as an abstract epitome of the hierarchical bone structure.

17. Different layers of tower indicating number and forms of capsules. Digital image by author.



18. Perspective view of tower. Digital image by Giannopoulou, Bennavides



19. Close view of capsules. Digital image by author

Conclusion

We can try to imagine what happens if we set the fluid in motion. If the impressed motion, be rotary, the first lines of demarcation are spiral curves followed by orthogonal intersections.[74]

The input to this regulatory model comprises the directions and magnitudes of the external loads applied to the volume of bone studied, and its output is architecture, represented by a density pattern […] When we changed the orientation of the external stress, the trabecular architecture adapted accordingly.[75]

The above assumption is taken from similar testing of stimulation of the cansellous tissue. From our experiments we arrived to the same conclusion.

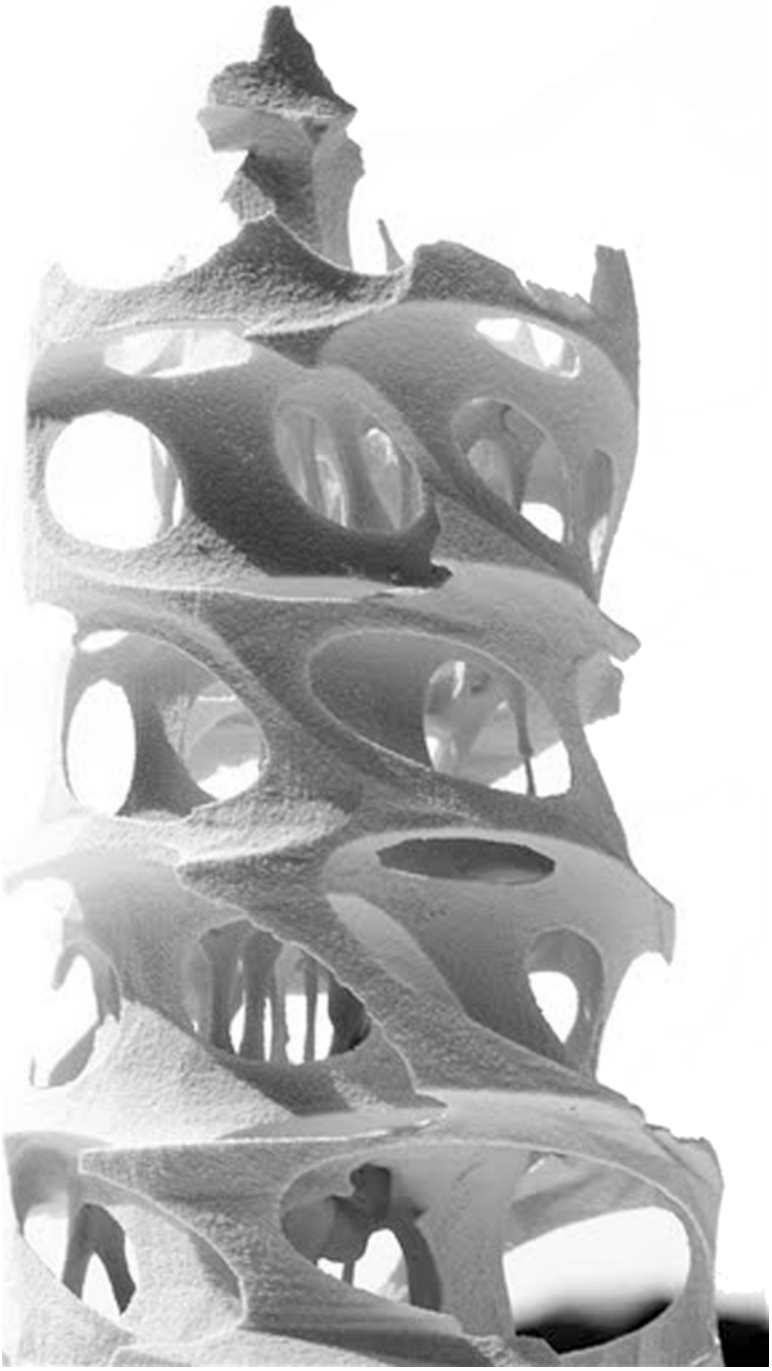
The initial proposal of the bubble tower is lucking of a biological reference. It is using mathematical laws for the structure of the building, but the final form doesn't have a natural orientation for a further analysis inside the living realm of organisms and their behaviour. It can be seen only as a first step of analysis of the natural world for inspiration. In the case of the Bone Tower properties of the physical material actively can determine the cell system morphology.

---

[74] Thomson W. D' Arcy, 1917, *On Growth and Form,* Cambridge University press, Cambridge, 1992, page 106

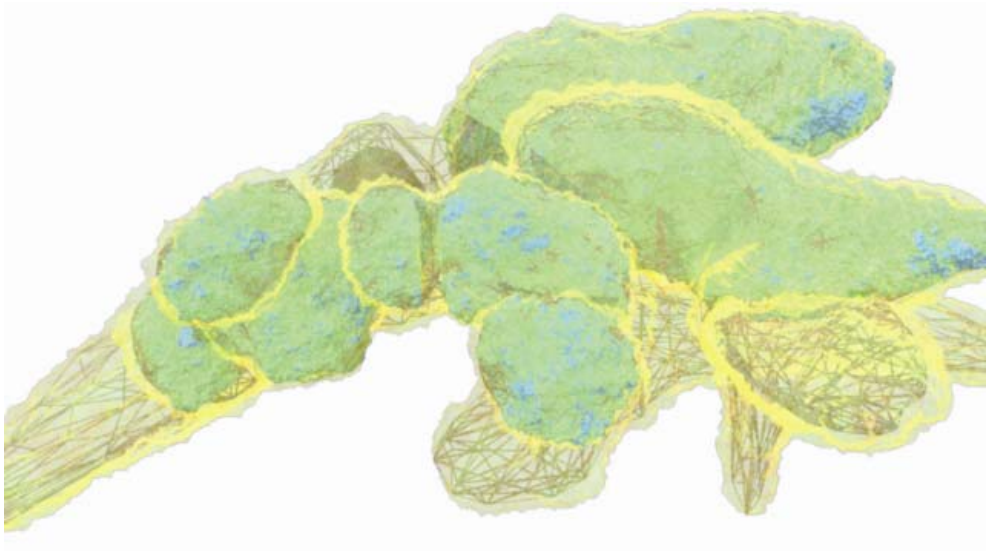
[75] Huiskes R., Mullender M., 1996, *Adaptive Bone Remodelling in Cyberspace: tricks and Treats*, Netherlands, page 308

20. Perspective view of tower. Digital image by author



21. View of real model laser printing.

2. Anexact Botanical Species



"The intricate relationship between surface articulation, structure, and affect".

Studio: Genome structures and architectural design

Directors: Prof. Matías del Campo – Prof. Sandra Manninger

Image: Studio project by author

2.1. Introduction to Botanical Topologies

The significant value for architecture lies in our capacity to speculate upon biological mimesis as a new paradigm for both material and programmatic behaviour. In other words, world history has entered into a radical phase where the very destiny of life as we know it can now be altered by reconfiguring the 'computation logics' of natural selection.[76] Evan Douglis call up that: one of the challenges of our era is that as we enter through this new phase of morphogenetic expansion we unleash a range of material and programmatic opportunities capable of altering the very destiny of architecture.[77]

A new design culture emerges from the contemporary scientific approaches of Botany. The research in the field of floral morphologies, as point of departure and investigation for architectural conditions based on inherent floral qualities, is like looking into the natural world to seek for life attributes. That method of speculation to spatial conditions needs a scientific approach similar to the one used in contemporary Botany. Computer Programming and algorithms are of the new basic tools that are used by scientists to stimulate and mimic nature and invisible natural processes for the creation of architectonical entities. With L-systems[78], for example, botanical growth mechanisms can be stimulated and described from the modelling perspective, but also a relation to physiological processes, observed in nature can be found, and involves various methods of general mathematics.

A visual comparison of models with real structures is an important component of model validation. […] Self-similarity relates plant structures to the geometry of fractals.[79]

---

[76] *Genetic Architectures II: digital tools & organic forms*, 2005, ESARQ/SITES books, Barcelona, page 127.

[77] Ibidem, page 130.

[78] Or Parallel Rewriting Systems, after the biologist Aristid Lindernmayer who invented it.

[79] Prusinkiewicz P, Lindenmayer A, 1996 *The Algorithmic Beauty of Plants,* Springer-Verlag, New York, preface, iv.

This design culture is seeking to find a technical language, with specific terminology and grammar, based on this branch of biology. The analysis of growth, reproduction, metabolism, development, diseases, ecology and evolution can inspire solutions for spatial problems and designs from the product development to larger scale tasks and for new families of material systems.

Inside this environment the studio is interested to reach beyond any floral form imitations. The task is to deepen onto the surfaces with a different approach from the smooth, seamless and faultless forms usually created by the computer designers, and to find a surface geometry with an outer and inner logic and with an aspect to the relationship between the whole to part and opposite. The exploration of the countless possible, in depth articulations of the surface, could offer novel insights into possibilities of spatial differentiation, structure and form, for architectural conditions. The architectural prototypes should include spatial conditions imminent in Botany: Lamina, Leaves, Ovary, Peristome, pits, plicate, reticulate, petal, sepal, and whorl. For this assignment, a variety of parametrical and topological software were the design tools. By establishing a material for the evaluating and understanding the importance of this aspect, in relation to a possible manufacturing process we could reconsider the initial geometry.

To design a Pavilion, in Park Güell, in Barcelona for butterflies is from its own very inspirational. Discursive research was made to understand the specific botanical issues of this studio culture. As an evolution of a previous approach of floral forms which globally influenced 19th century culture under the art nouvo style, it is likely to reconsider the creation processes. In a biomorphic approach, form is generated in terms of form. But as a fraction of biomimicry research, it is deeply rooted in science.

2.2. Systematics in Botany

Species classification

Faced with the enormous number of living things on earth, scientists realized long ago that we need a way of classifying and naming individual species. Although the ancient Greek philosopher Aristotle devised a primitive classification system over two thousand years ago, it wasn't until the 1700s that a Swedish biologist, Carolus Linnaeus, developed a systematic method of naming species[80] that is still used today. A species name consists of two Latin words, as in Homo sapiens for human. The scientific name of an organism consists of its genus and a specific epithet. The complete binomial name indicates the species.[81] The biological definition of specie rests on the recognition that distinctive characteristics[82] are passed on from parents to offspring. Subspecies occur for species which have a wide geographic range and designated by a three-part name.

An organism is generally classified on the basis of phylogeny - evolutionary relationship to other species. In this context, specie is a taxonomic category below the rank of genus. Species in the same genus share a more recent common ancestor than do species in other taxa. Taxa {Greek. Tasso, arrange, classify} are groups of organisms that fill a particular category of classification.[83]

In his book "Systema Naturae",[84] published on 1735, Linnaeus simply used flower part differences to assign plants to these categories: species, genus, order, and class. Today, we make use of at list seven obligatory categories, each subdivided into three additional categories, which makes more than thirty

---

[80] the binomial system

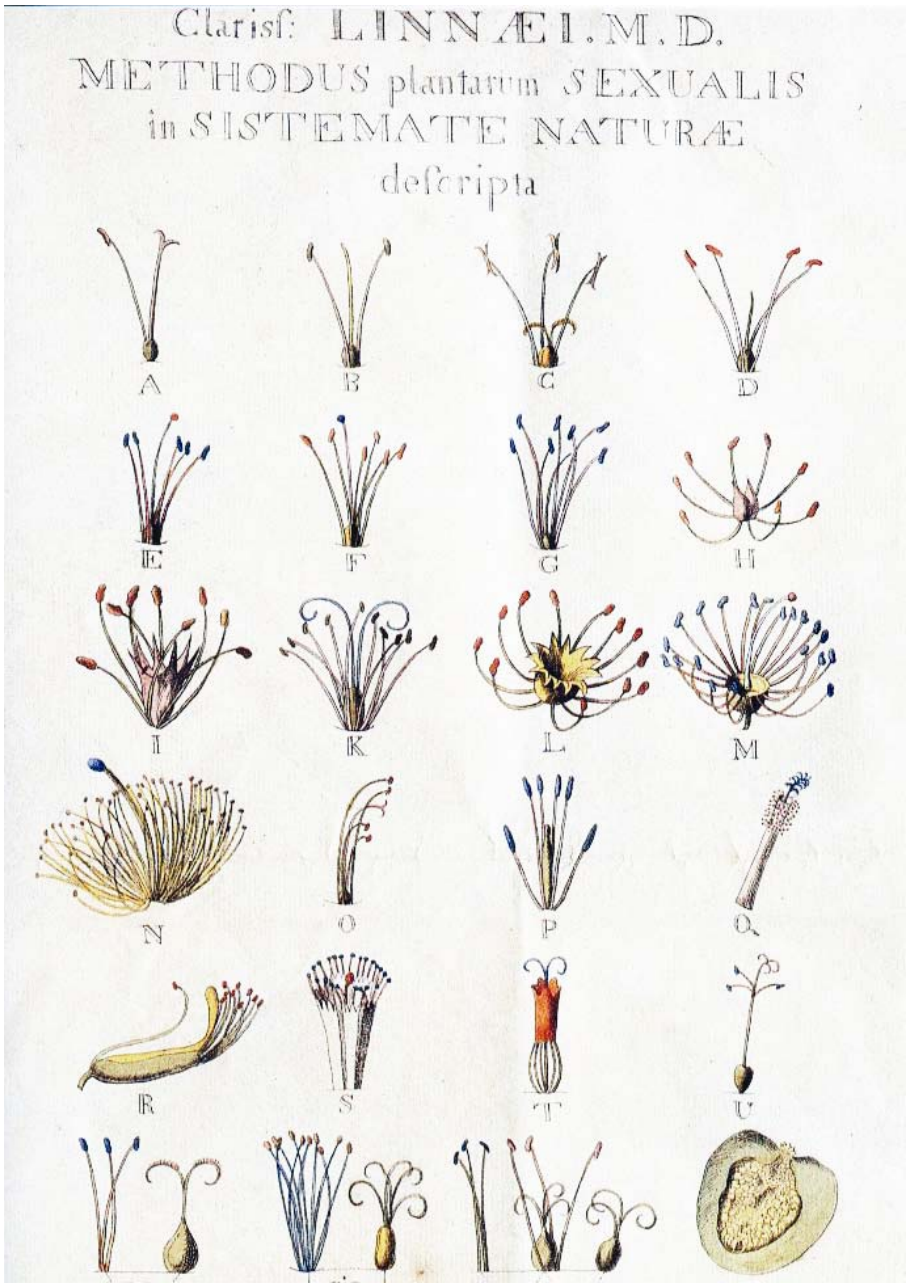
[81] Mader S.S, 1998, Biology *6/E*, WCB/ McGraw-Hill, United States of America, page 493

[82] structural differences like shape, size, colour, etc

[83] Ibidem, page 494

[84] "Systema naturae per regna tria naturae, secundum classes, ordines, genera, species, cum characteribus, differentiis, synonymis, locis",wiki,7/11/09

categories of classification, in a hierarchy. Taxonomy and classification are part of a broader field of systematics[85], which goal is to determine phylogeny,[86] or evolutionary history of a group of organisms.



22. Graphic illustration of Linnaeus's so-called "sexual system", drawn by Georg Dionysius Ehret in 1736. The title says "Linnaeus's sexual method of plants, described in the book *Systema naturae*." Natural History Museum (London).[87]

[85] Greek systema, an orderly arrangement
[86] Greek phyle, tribe, Latin genitus, producing
[87] http://commons.wikimedia.org/wiki/File:Syst-sex.jpg, 7/11/09

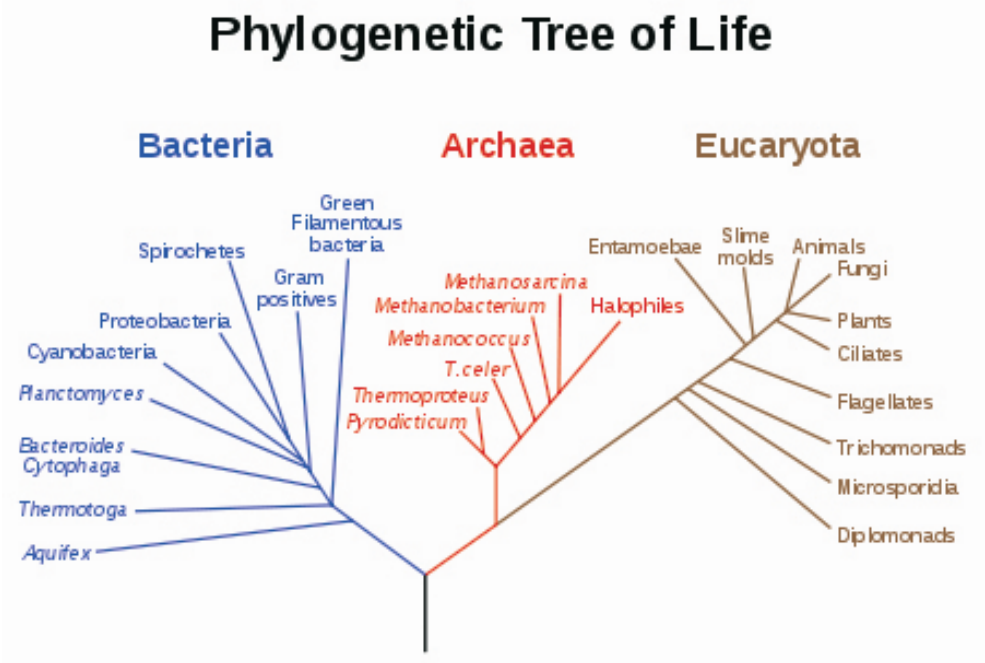
Spatial-temporal differentiation - Relations between species

The botanologists are now working on the production of new specimens and cladistic[88] analysis of species.
Since the 1960s a trend called cladistics has emerged, arranging taxa in an evolutionary or phylogenetic tree[89], a diagram that indicates common ancestors and lines of descent (lineages)[90], and in which a primitive or derived character need to be determined. Charles Darwin (1859) produced one of the first illustrations and crucially popularized the notion of an evolutionary "tree" in his seminal book “The Origin of Species”. Over a century later, evolutionary biologists still use tree diagrams to depict evolution because the floral analogy effectively conveys the concept that speciation occurs through the adaptive and random splitting of lineages. Over time, species classification has become less static and more dynamic.[91]

A phylogenetic tree or evolutionary tree is a tree showing the evolutionary relationships among various biological species or other entities that are known to have a common ancestor. In a phylogenetic tree, each node with descendants represents the most recent common ancestor of the descendants, and the edge lengths in some trees correspond to time estimates. Each node is called a taxonomic unit. Internal nodes are generally called hypothetical taxonomic units (HTUs), as they cannot be directly observed.[92]

---

[88] the Greek klados= branch
[89] wiki/Life, 5/11/09
[90] Mader S.S, 1998, Biology *6/E*, WCB/ McGraw-Hill, United States of America, page 496
[16] wiki/phylogenetic tree, 5/11/09
[90] idem



23. A speculatively rooted tree for RNA genes[93]

Phylogenetic trees among a nontrivial number of input sequences are constructed using computational phylogenetics methods. Cladistic analysis forms as the basis for most modern systems of biological classification seek to group organisms by evolutionary relationships; in contrast to a more traditional tend which rely on key characters (morphology)[94]. A cladogram is a tree formed using cladistic methods. This type of tree only represents a branching pattern, i.e., its branch lengths do not represent time.

[93] idem
[94] wiki/cladistics, 6/11/09

2.3. Structure of Inflorescence: Cell Based Compounds

Modelling inflorescence

We are in agreement with Troll (1964), who defines the inflorescence as "the shoot system which serves for the formation of flowers and which is modified accordingly". The forms of the flower-bearing branching systems and their position in the overall structure of the plant not only determine the external appearance of the flowering plants to a great extent, but also at the same time provide important criteria for their relationships.[95]

The following discussion focuses on the modelling of compound flowering structures or inflorescence. In some cases an entire shoot system can be considered an inflorescence, in others only some of the branches bear flowers and are inflorescences. Inflorescence architecture is an elaboration of branching structures in general[96]. The regular arrangement of lateral organs (leaves on a stem, scales on a cone axis, florets in a composite flower head) is an important aspect of plant form, known as *phyllotaxis. […]* The area of phyllotaxis is dominated by intriguing mathematical relationships. One of them is the "remarkable fact that the numbers of spirals which can be traced through a phyllotactic pattern are predominantly integers of the Fibonacci sequence"[97]

Besides a purely morphological terminology, attempts have been made to construct a "typological" terminology, expressing the "essential" features of flowering structures.[98] At each developmental stage the inflorescence contains a sequence of flowers of different ages.[99] The flowers newly created by the apex are delayed in their development with respect to the older ones situated at the

---

[95] Weberling R., translation Pankhurst J. R., 1992, *Morphology of flowers inflorescences*, Cambridge University Press, Cambridge, page 201

[96] Prusinkiewicz P, Lindenmayer A, 1996 *The Algorithmic Beauty of Plants,* Springer-Verlag, New York, page 71

[97] Ibiden, page 99

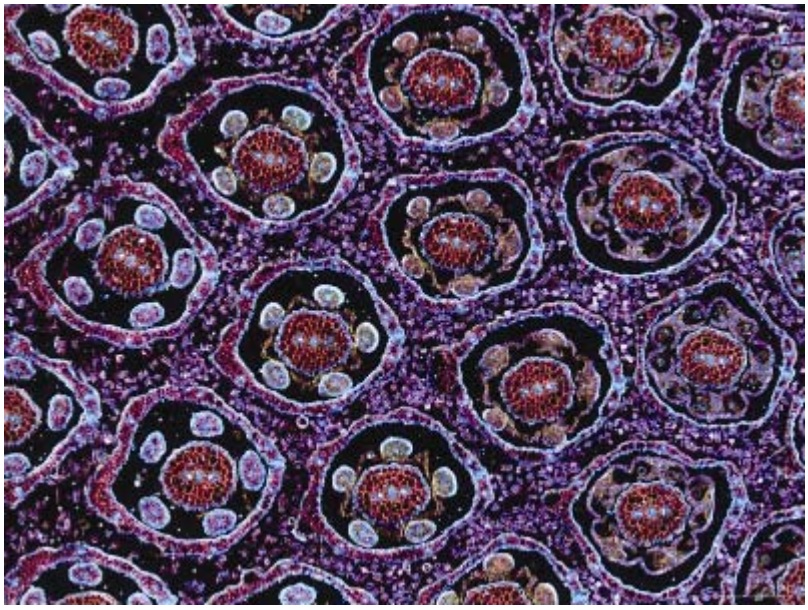
[98] idem

[99] ibidem, page 72

stem base […] their graded differences of age lead to an exquisite gradation of size and form; the time-interval between one and another, or the "space-time relation" between them all, gives a peculiar quality – we may call it phase-beauty – to the whole[100].

Pseudanthium inflorescence

The family Asteraceae or Compositae (known as the aster, daisy, or sunflower family) is the largest family. The name 'Asteraceae' is derived from the type genus Aster, while 'Compositae', an older but still valid name, means composite and refers to the characteristic inflorescence. An inflorescence is a group or cluster of flowers arranged on a plant stem that is composed of a main branch or a complicated arrangement of branches,[…]a special type of pseudanthium. A pseudanthium or flower head is a special type of inflorescence, in which several flowers are grouped together to form a flower-like structure found in only a few other angiosperm families[101].



24. Dandelion Flower Head, Crepis Species, Showing Inflorescence Structures
By Harold Taylor[102]

[100]Thomson W. D' Arcy, 1917, *On Growth and Form,* Dover, New York, 1992, page 194

[101] Retrieved from http://www.absoluteastronomy.com/topics/Asteraceae#encyclopedia, 5/10/09
[102] Retrieved from allposters.com, 14/9/09

Material component: an entity defined by form

In Botany tissues are cell-based compounds creating cavitations, inflections and cladistic of space conditions by the use of void, more than by the use of mass. Air is used more than material. This implies possible solutions for a minimum material surface composition in building architecture.
The roots of component-based (cell-based) surface technique lie in complexity theory. Huge numbers of components have "to work interactively to produce large fields of infected material", as Jason Payne says[103].

Most classical theories of form are limited by a major shortcoming: they are unable to account for the emergence, or genesis, of forms without recourse to metaphysical models. One of these classical theories- perhaps the paradigmatic one- is the so-called hylomorphic model. According to this model an independently constituted and fixed form is understood to be combined or impressed with a quantity of hyle, or matter, itself conceived as a fundamentally inert, homogeneous substance. Once brought together, these two abstract elements are said to form a thing. […] The classical grid system does not, strictly speaking, limit one to static models of form, but it does limit one to linear models of movement or change.[104] […] Complexion ultimately involves physiological disposition.[105] Entire, well-formed and functional bodies, homogeneous from self –similar assemblies of parts cannot possibly address all of the issues involved in a whole building.

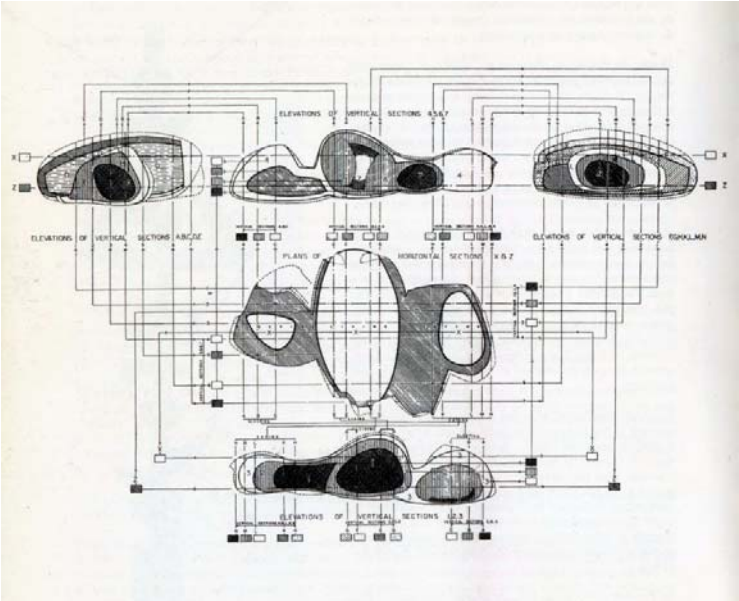
The computational botanist Przemyslav Prusinkiewicz work with L-systems, rule-based systems designed to create branching morphologies, in order to re-write the featureless branch, or line, with a simple shape.. This entails simply removing or overwriting the line with a bounded area or volume. Doing this over and over creates the artificial approximation of a growing plant.

---

[103] Meredith M., 2008, *From Control To Design: parametric/algorithmic architecture,* Verb monograph, Actar, Barcelona, page 239

[104] Sanford Kwinter, 1992, , Landscapes of change: Boccioni's Stati d'animo as a General Theory of Models, in Assemblage 19, MIT Press Cambridge, page 53
[105] Ibidem, page 238

Seeing the transfer of locational logic with the addition of dimensional information allows us to imagine similar transfers with increasingly "architectural" material as we build systems up from the abstract, diagrammatic armatures. Matter drives organization as physics draws the diagram[106].



25. Drawings of Friedrich Kiesler's endless house[107]

26. The "continuous tension" is a concept that Friedrich Kiesler established at 1947-1951 with the endless house, a living organism with highly sensate nervous system, aiming to create flowing harmonic rooms in various dimensions, without boundaries between floors, walls, and ceiling, like an endless space free from edges and borders, he substituted columns and beams by a concrete shell

---

[106] Meredith M., 2008, *From Control To Design: parametric/algorithmic architecture,* Verb monograph, Actar, Barcelona, page 237

[107] Retrieved from http://375gr.wordpress.com/tag/inestable/, 14/10/09

2.4. Variation of Forms - Differentiation

Non- Euclidian objects

The notion of topology has particular potentiality in architect as the emphasis shifts away from particular forms of expression to relations that exist between and within an existing site and the proposed program. These interdependences then become the structuring, organizing principle for the generation and transformation of form[108]. In the opening essay of the volume[109], editor Giuseppa Di Cristina describes what she terms the "topological tendency in architecture": Architectural topology means the dynamic variation of form facilitated by computer-based technologies, computer-assisted design and animation software. The topologizing of architectural form according to dynamic and complex configurations leads architectural design to a renewed and often spectacular plasticity, in the wake of the baroque and of organic expressionism.

The topological, or Deform movement represents a deliberate shift from Derrida's discourse to that of Deleuze. Its intention is to incorporate, rather than exaggerate difference. This involves a policy of "gratification" rather than conflict and seeks to develop systems to incorporate various elements in an architecture intended to be inclusive and organic. The requirement is thus for a geometry which is elastic in its ability to contort and deform in a process of continual transformation.[110]

Topology is concerned with those elements that remain constant as the entire system undergoes change, or those relations that remain constant under transformations and deformations. Through the use of what is known as "anexact" geometry computers are able to model forms previously prohibited in

---

[108] Kolarevic B., 2003, Architecture in the digital age: design and manufacturing, Grafos SA, Spain, page 13

[109] Giuseppe di Cristina (ed.), *Architecture and Science* London: Wiley-Academy, 2001

[110] **Abstract** Michael Chapman reviews Giuseppe di Cristina (ed.), *Architecture and Science* for the *Nexus Network Journal,* vol. 4, no. 2 (Spring 2002).

traditional architectural practice. Anexact geometry involves non-developable forms, or forms that cannot be flattened. As a result, and in contrast to Euclidean geometric forms, it is impossible to describe such forms in the form of an algebraic equation. Lynn describes abstract geometries as those that "can be determined with precision yet cannot be reduced to average points or dimensions.[111]"

Interactive surfaces

CAD systems have taken on a role beyond the mere generation of production drawings; they now fundamentally affect the forms and environments that architects create. The ability to represent topological relationships in digital environment has a direct influence on the ways in which architects can now think of buildings: "Topological structure corresponds to quantitative difference and, hence, to service; topological form corresponds to qualitative difference, and hence, to surface." (Novak, 1998, p.27)[112]A recent example of application of surface modelling techniques to the generation of new building forms is the Kunsthaus Graz by Peter Cook and Colin Fournier. But the project not only explores the dynamic responses to the surrounding environment, but also its interaction with it. A low-resolution computer-controlled façade display projects events inside the building to the outside. Projects such as Novak's *paracube,* in which parametric relationships between surfaces in 4-D space were used to define a 3-D spaceframe structure, also illustrate how concepts such as multidimensional or trans-Euclidean space can be explored and investigated with digital technology.[113]

---

[111] Szalapaj P., 2005, *Contemporary architecture and the Digital design Process,* Elsevier, Oxford, page 108

[112] idem

[113] Szalapaj P., 2005, *Contemporary architecture and the Digital design Process,* Elsevier, Oxford, page 106

2.5. Project: Pavilion

Taraxacum inflorescence

There is an explicit connection between butterflies and flowers. Specific flowers can only pollinate, reproduced by butterflies. A house for butterflies should contain elements that attract butterflies. Usually they are attracted by vivid colours. Because these animals can not hover they need a surface to relax. The program includes a house for butterflies and a public space for visitors. The design strategy seeks to establish differential thermal environmental conditions to allow the adjustment of various families of species. This is achieved by the organization of environments of independent cell-enclosures, inspired from the inflorescence of the selected flower. The flower head, or pseudanthium is a special type of inflorescence, where several flowers are grouped together to form a flower-like structure.

27. 800px-Dandelion_seed[114]

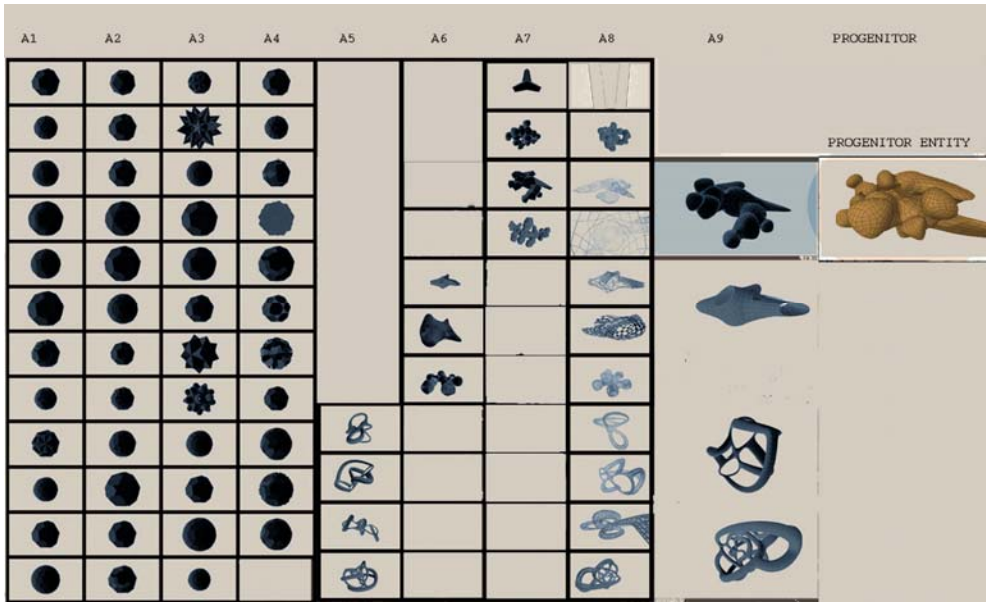
Scientific name: Taraxacum Officialle
Scientific classification: Kingdom; Plantae
Division; Magnoliophyta
Class; Magnoliophyta
Order; Asterales
Family; Aster (Asteraceae, formely Compositae)

Taraxacum Inflorescence is heads ligulate, solitary, scapose; phyllaries many, outer ovate to lanceolate, generally reflexed, inner erect, linear; receptacle convex, naked. Etymology: Greek: ancient name.[115] The growth pattern of the inflorescence system is a capitulum's flower head, a much contracted raceme where the single flowers are born on an enlarged stem with radial actinomorphic symmetry.

[114] Retrieved from http://commons.wikimedia.org/wiki/File:Dandelion_seed.jpg
[115]Retrieved from http://ucjeps.berkeley.edu/cgibin/get_JM_treatment.pl?Taraxacum%20officinale

Digital cladogram

The proposed process begins with the formation of a progenitor entity which serves as the starting point for the scrutinizing of the various approaches to botanical entities. The polygonal modelling tool is most widely used to create control surfaces for subdivision schemes. The faces of the model are geometrically well-defined, something that allows self–intersection and manifold meshes. It is used to model a new form, in early design phase of the conceptual design. For this task, we create a cladogram which works as a map of possible generations inspired by the growth pattern of the flower's inflorescence. A mixture of different tactics is examined upon simple geometries, with the use of topological modelling tools for the creation of an array of different objects, from which one is selected (the progenitor), for the efficiency of its form, the possible relativeness with the environment and its achievable functional properties. All these objects were collected in the cladogram to illustrate promising applications of the different specimen. The cladogram makes possible to illustrate the genetic relations between these different entities, helps to evaluate the certain one between a varieties, and to estimate likely crossbreeding among the created entities.

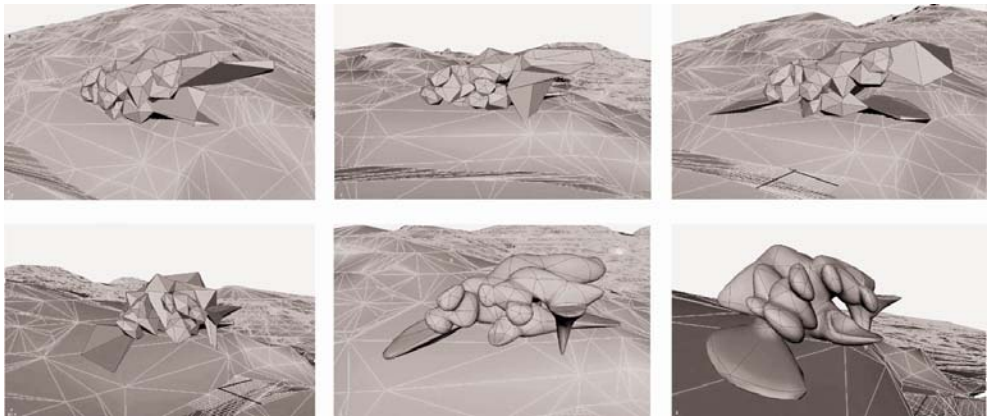


28. Digital Cladogram: Generations and the progenitor entity (smooth version). Digital image by Montás, Giannopoulou, Anton

Progenitor entity

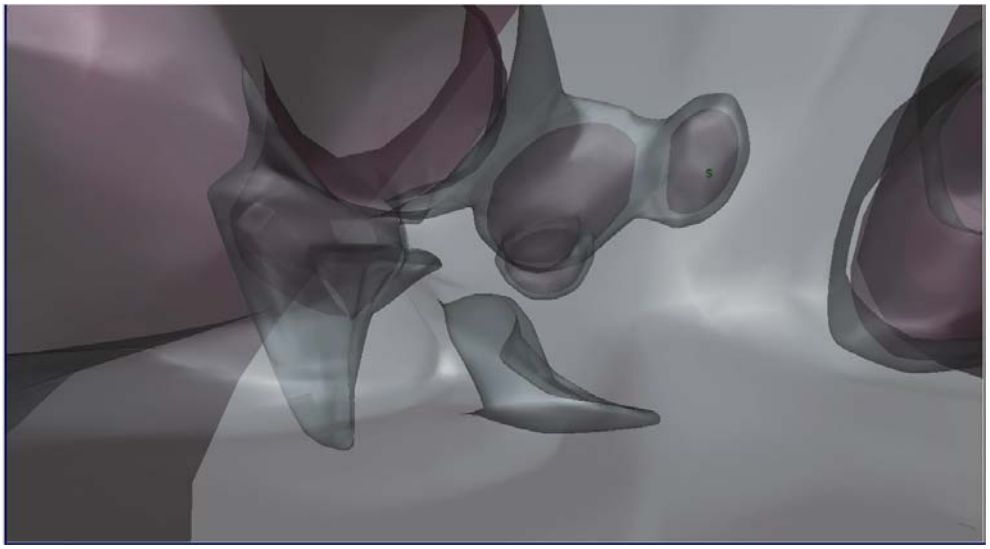
The progenitor's form, as a polygonal entity, has similar topological qualities to the inflorescence. From an enlarged stem, single smaller flowers grow in contact with a large stem. But, in this case, other aspects are taken in consideration. A very important intention was to embed the progenitor entity to the specific site. The proposed location, besides the panoramic view that offers, had limitations considering the size and its position on the top of a cliff. These parameters were taken in advance for the organization of the space and for the generation of the final form. Extrusions of form create exterior decks, some of which in attempt to adapt to the cliff are transformed to roots and other just suspend on air. The organization keeps the initial spatial conditions of an enlarged stem with multiple smaller flowers growing from it. Just only some of them have been de-formed in a process of continual transformations to give plasticity and malleability to architectural form.

29. Perspective of progenitor embedded in the landscape. Digital image by Montás, Giannopoulou, Anton



30. Perspectives of final geometry in polygonal and smooth version of the developed progenitor. Digital images by Montás, Giannopoulou, Anton

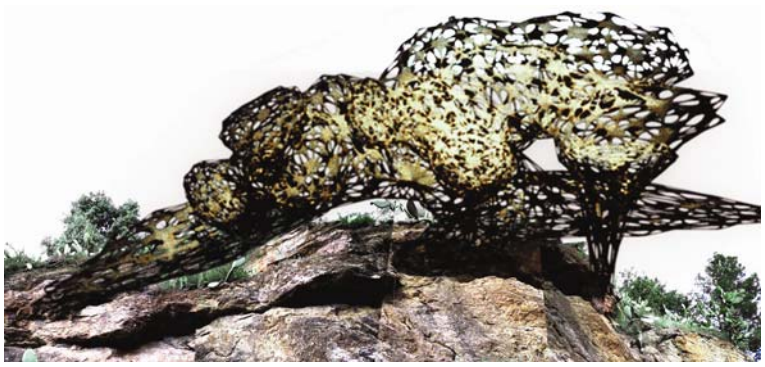
When the mesh tools are applied to the polygonal geometry, the population of the smaller flowers are not any more in contact with the main body, but form independent cell ovaries, translated architectonically to butterfly space. A double layer skin is created. The semi-transparency allows visual contact between the exterior and interior environments. The particularly powerful form of B-splines , referred as NURBS,(non-uniform rational B-splines) are defined by control points and allow interactive display and manipulations of the parametric equations of surface.



31. Interior view of cell ovaries. Maya render by author

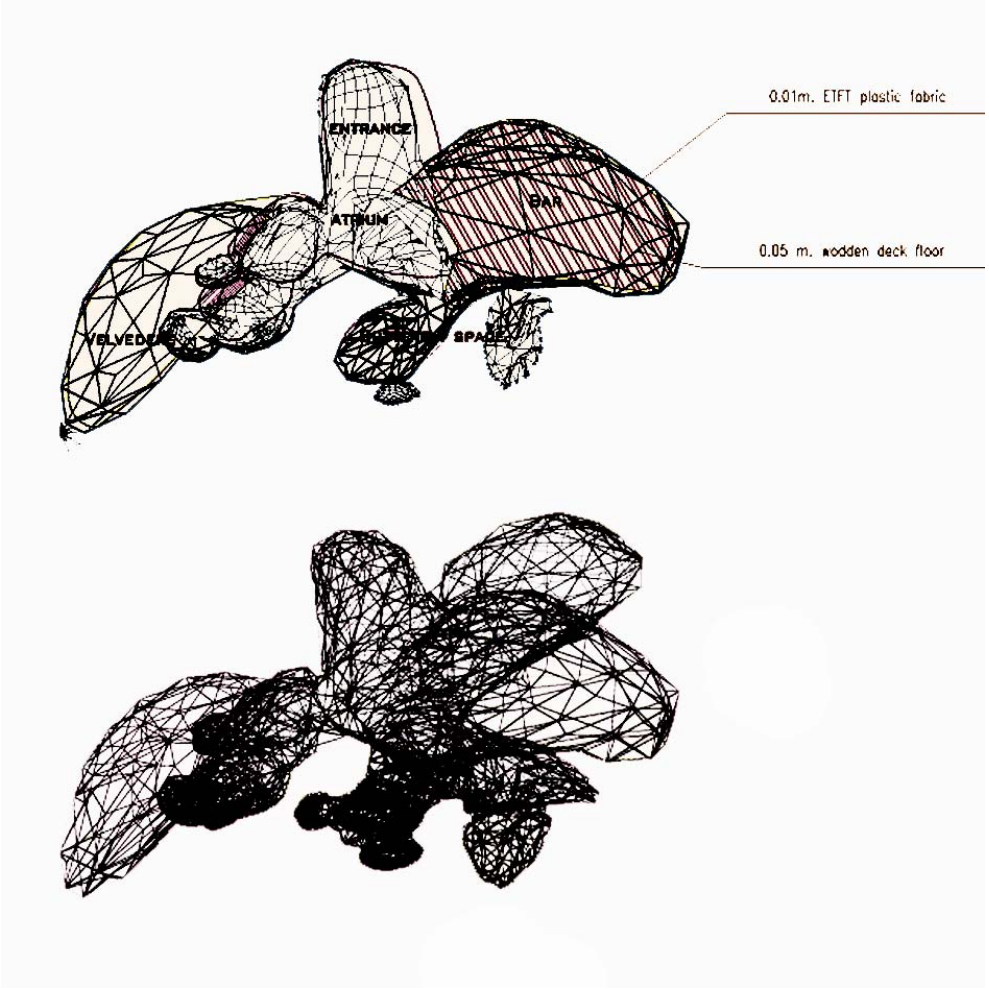
Material properties – Differentiation

Different textures and materials are examined for an exploration onto a surface articulation. A wide variety of combinational remeshing operations are applied to the polygonal manifold, for a research of a possible surface articulation, or structural organization system together with the material. These operations work with algorithms without changing the topology of the mesh. Triangulizations create semi-regular regions, and a wire frame "pipe" modelling tool is applied. The final net-structure is continuous and can be physically fabricated with the chosen material (bamboo) and it is focused on minimising the supporting elements.

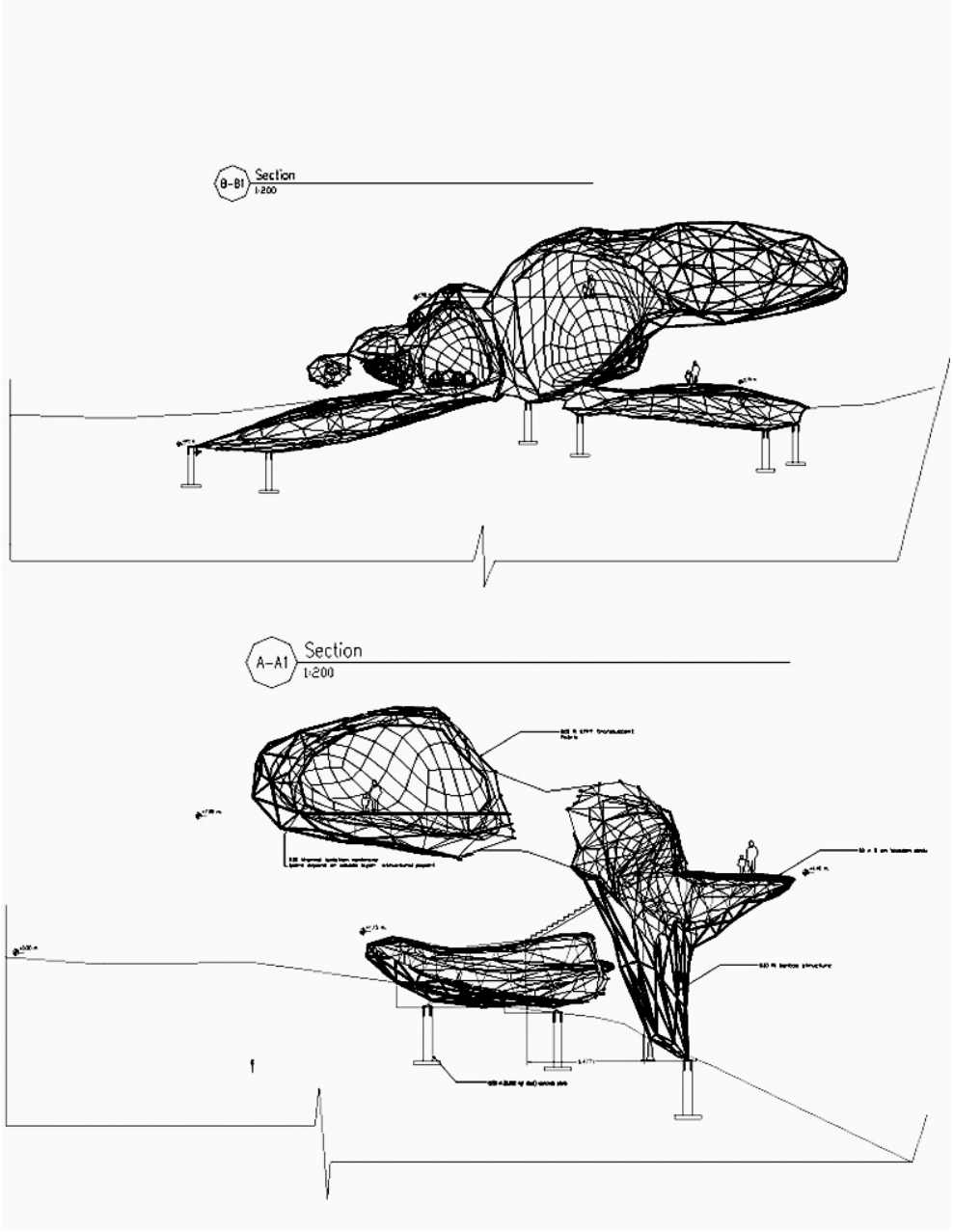


32. Perspective view of surface network. Image colaze by author

The basic form of the developed progenitor is finally enhanced with a highly ornamented structure and the fabric structure is been defined in order to create a translucent free-form body that could withstand the weather and, at the same time, satisfy the needs of a butterfly house. If the ground is to Deleuze one action which affects the surroundings, then the material surface of a new type has to be open to the environment and its information, like a space-time organism, so to be affected from it.



33. Top views of structural network. Digital image by Montás, Giannopoulou, Anton



34. Sections and structural supporting. Digital image by Montás, Giannopoulou, Anton

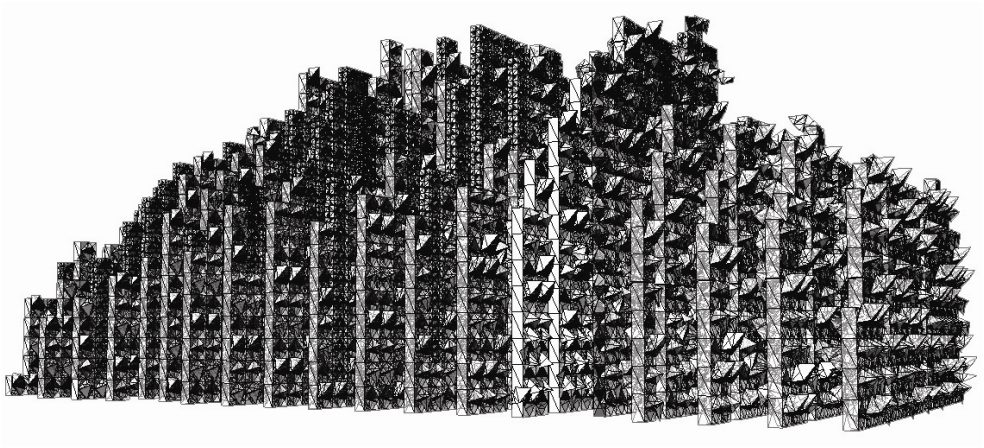
35. Perspective model on site. Digital colaze by Montás, Giannopoulou, Anton

Conclusion

The currently popular Deleusian view that there is no distinction between process and product (Krauss, 1993) is having a major influence on those wanting to create new forms of architecture. Novak warns of the dangers of omitting technological considerations from such views: "How can the response to a technological, informational, computational virtuality just be that we make stranger forms in conventional space, and arm these forms with more controlled rhetoric?" (Novak, 1998, p.21) If we are to escape from superficial form combined with talking architecture, then just as in other architectural movements, contemporary digital design practice needs to connect the real to the virtual, the content to the style, the function to the expression.[116]

[116] Szalapaj P., 2005, *Contemporary architecture and the Digital design Process,* Elsevier, Oxford, page 108

3. Abstract Vertebrates



Studio: Genetic architectonical design II

Director: Karl S. Chu

Image: Studio project by author

3.1. Introduction to Metaphysics

"… πάντων γὰρ ὅσα πλείω μέρη ἔχει καὶ μὴ ἔστιν οἷον σωρὸς τὸ πᾶν ἀλλ᾽ ἔστι τι τὸ ὅλον παρὰ τὰ μόρια …"

"… the totality is not, as it were, a mere heap, but the whole is something besides the parts …"

Aristotle, Metaphysics

Hypothesis – Building being in itself, becoming, realising itself

Is it possible to expand the meaning of "the building" to a building that does not contain foreign elements (program), a building with reference to itself and self conscious? Is it possible to emerge from its own? This is a continuous hypothesis with an intellectual program, an esoteric problem, about the will of being. We could say that architecture is the construction of possible worlds. And then, we ask what a world is? The life of a bee is a world. Every body has its own world. The jungle, which has high degree of autonomy, can be a possible world. World is the construction of life forms and to qualify world is with life. Life and the organization of life constitute possible words. So we come with the next questions what is life, what makes life and what is the origin of living organisms[117].

Until now there is no scientific consensus as to how life originated and all proposed theories are highly speculative[118]. Some of the earliest theories of life were materialist, holding that all that exists is matter, and that all life is merely a complex form or arrangement of matter. […] Democritus (460 B.C.), the disciple of Leucippus, thought that the essential characteristic of life is having a

[117] Notes by author from the lecture of Karl Chu, 11/5/09
[118]retrieved from Wiki/ Life 6/11/09

soul (*psychê*).[119] According to the theory of Hylomorphism (originated with Aristotle (322BC)) all things are a combination of matter and form. According to him, all things in the material universe have both matter and form. And the form of a living thing is its soul.

Jung discovered that there is an internal world, just as large as the external world. [He] developed the idea that the nearly chaotic variety of dream images visited on humans tend to gravitate around certain stable nodes which form key and universal images, much of interlinked complex systems tend settle dawn upon 'attractors' to use modern terminology.[120] In the classical Jungian framework, the tail-biting Uroborus is the symbolic depiction of the self. The completeness of the circle is the self-containment of self, a containment that is at the same time made of one thing and made of competing parts.[121] It is used in the cybernetic context as an emblem for feedback loop, is a mythical beast-the beast of self.

The self is a mere ground state, an auto-conspired form, out of which the more complicated ego can later distinguish itself, should its complexity allow that Every self is a tautology: self-evident, self-referential, self-centered and self created. Gregory Bateson said a vivisystem is "a slowly self-healing tautology".[122]

A systemic definition of life is that living things are self-organizing and autopoietic (self-producing) and to Kauffman, must involve the concept of autonomy.

How does this quality of autonomy arise? Clearly the system must be open to its environment; there must be a throughput of matter, energy, and–crucially-information. But more is needed. [The same] has coined the term autonomous agents to characterize a program of research aimed at explaining how a system can have "a life of its own"[123]. It is true that defining life as "an emergent

---

[119] idem

[120] Kelly K., 1994, *Out of Control: the rise of a neo-biological civilization*, Basic Books, Cambridge, page 124

[121] Idem

[122] Idem

[123] Barrow D. J., Davies P.C.W., Harper L.C., Jr., 2004, *Science and Ultimate Reality: Quantum Theory, Cosmology, and Complexity*, Cambridge University Press, Cambridge, page 23

property contingent upon the organization of inanimate parts but not reducible to them" (the best that science can do right now), comes very close to sounding like a metaphysical doctrine.[124]

Life results when anything is organized according to laws only now being uncovered; it follows rules as strict as those that light obeys[125]. [First] this organization must, by law, produce the unpredictable and novel. Secondly, the result of organization must replicate at every opportunity, giving it a sense of urgency and desire. And thirdly, the result can easily loop around to protect its own existence, and thus it acquires an emergent agenda. […] This doctrine is radical because it entails a revised notion of what laws of nature mean: irregularity, circular logic, tautology, surprise.[126]

The genesis of the genetic idea

Life is constructed on the genetic code. Hence genetic architecture is the construction of genetic codes. "Gene" can be seen as a unit of information not only biological but also as an idea.

The word "gene" was coined in 1909 by Danish botanist Wilhelm Johannsen for the fundamental physical and functional unit of heredity. The word gene was derived from Hugo De Vries' term pangen, itself a derivative of the word pangenesis, which Darwin (1868) had coined. [127]Bateson took this to introduce the term "genetic", a system of propagation of genetic information (genes).

William Bateson, a proponent of Mendel's work, coined the word *genetics* in 1905. The adjective *genetic*, derived from the Greek word *genesis* - *γένεσις*, "origin" and that from the word *genno* - *γεννώ*, "to give birth", predates the noun and was first used in a biological sense in 1860.[128] The meaning of both terms,

---

[124] Kelly K., 1994, *Out of Control: the rise of a neo-biological civilization*, Basic Books, Cambrigde, page 108-109

[125] Ibidem, page 109

[126] idem

[127] The word pangenesis is made from the Greek words *pan* (a prefix meaning "whole," "encompassing") and *genesis* ("birth") or *genos* ("origin") retrieved from http://www.newworldencyclopedia.org/entry/Gene, 5/10/09

[128] idem

genetic and gene, are sufficiently abstract and general enough to be used as concepts that have logical implications for architecture without being anchored too explicitly to biology.[129] If gene is an idea, a minimum unit of information, then it can be closer related to a logical idea than a bio-logical one.

A rediscovery process - Emergence from the past

Design is about conceptualization, imagination, and interpretation […] an indefinite process of genesis, emergence, or formation of something to be executed but which starting point, origin, or process is often uncertain. […] In Greek the word design is σχέδιο (pron. Schedio), which is derived from the root σχεδόν (pron. schedon) which means nearly, almost, about, or approximately. [130]

To Re-design could mean to take one idea and to form a new image with a conceptual content that from its nature is endless, abstract and fragmentary. A further back origin of the word can be linked indirectly to a loss of possession and a search into an oblivious state of memory[131]. So it's mostly connected with the past and with memories.
The act of remembering and the act of perceiving both detect a pattern in a very large choice of possible patterns. When we remember we re-create the act of original perception; that is, we relocate the pattern by a process similar to the one we used to perceive the pattern originally[132]. Thought is not arborescent, and the brain is not a rooted or ramified matter. […] Many people have a tree growing in their heads, but the brain itself is much more a grass than a tree.[133]

---

[129] *Genetic Architectures II: digital tools & organic forms*, 2005, ESARQ/SITES books, Barcelona, page170
[130] Terzidis K., 2006, *Algorithmic architecture*, Elsevier Ltd., Oxford, page 1

[131] Ibidem, page 2
[132] Kelly K., 1994, *Out of Control: the rise of a neo-biological civilization*, Basic Books, Cambridge, page 18

[133] Deleuze G., Guattari F., 1987, *A Thousand Plateaus: capitalism and schizophrenia*, University of Minneapolis Press, United States of America, page 15

From the pre-Socratic assumption that nothing comes out of nothing and nothing disappears into nothing, change is just a transformation from one state into another; the appearance or disappearance of parts is only phenomenal; nothing is added, or subtracted. Therefore, if something emerges, appears, or claims to be new, then it must be nothing but an illusion […] According to this logic, design as a mental process of creation can be seen as bounded by the limits of preservation[134] and is going back in time, where primitive archetypes are awaiting to be discovered.

Genetic architecture contains memories, fragments of time and has assembled over hundreds of thousands, to millions of years, like the DNA's internal code. This memory gives form to the specie. Form is not coming from outside, it's only biological or information. That's how new architectural species can come from scratch where the whole morphology is different from its parts.

The language of genes

The investigation focus on formal system logic for the creation of conditions within architectural 'logos' as the language. It draws upon the non-deterministic nature of the generative forces behind the design process. Consisting of an operation through notational maps it engages the complexity of organizational space into three-fold phases: codification of the syntactical elements, construction of the generative principles and mapping analysis of the final results.

When the point of departure is abstract and autogenous, then the language should be manifold, collective and non-linear. 'Words' obtain meaning simultaneously through their interrelation, meaning as significance, as the constructive difference.
The creative processes within the organism are *word-like* processes. Something does speak through every part of the organism -- and certainly through DNA along with all the rest. […] Neither grammatical nor logical rules determine the

[134] Terzidis K., 2006, *Algorithmic architecture*, Elsevier Ltd., Oxford, page 5

speech in which they are found. Rather, they only tell us something about *how* we speak. […] In the ongoing conversation between word and text, part and whole -- and contrary to the Central Dogma -- we find the context of the organism *informing* the genetic text at least as much as the genes can be said to inform the organism. This is the underlying truth that science historian Lily Kay trades on when she writes: "once the genetic, cellular, organismic, and environmental complexities of DNA's context-dependence are taken into account", we might find that genetic messages "read less like an instruction manual and more like poetry, in all their exquisite polysemy 'multiplicity of meaning', ambiguity, and biological nuances" (2000, pp. xviii-xix)[135] The content is double: intrinsic (for its own, esoteric, de facto, substantial), that comes from outside and extrinsic (exoteric, sensitive to environment, external, foreign).

[135] Holdrege C., Talbott S., 2008, Beyond biotechnology: the barren promise of genetic engineering, University press of Kentacky, Kentacky, page 104-105

3.2. System Logic

We are, without exaggeration, on the verge of a possible world that we cannot even begin to imagine except through the emerging paradigms of artificial world.[136]

The internal logic of a clock as it measures off time by a complication parade of movements is the archetype of a sequential system. Most mechanical systems follow the clock.[137] As opposed to a clock work or a stream engine, computation is inherent constructive: it is a formal system that enables symbolic structures to build further symbolic structures in a consistent way[138].

Language, elements, rules

Architecture may be defined as the art that goes back to the origins-to nature itself. The root meaning of the word is derived from the Greek, 'Archi', meaning 'first', or 'original' (law); and 'tect', meaning the ability to put things together (construction). In Genetic architecture the laws (rules) plus construction (letters) are translated into computation as software plus hardware. A Formal system is based on elements (letters) and rules (grammar). Its units are not signified (endowed with meaning) but are distinctive (having differential value).
The term "monad" is used to define the minimum unit of self-replicating system. Its monad is one bit. A bit is usually understood as the binary unit of information at the most irreducible level. The classical bit can be either 0 or 1.
[In Wheeler's[famous 'it from bit' dictum, the 'it' [is] referring to a physical object such as an atom, and the 'bit' being the information that relates to it. In it from bit, the universe is fundamentally an information-processing system from which the appearance of matter emerges at a higher level of reality.[139]

---

[136] Chu Karl, 1995, *Modal space*, A.D. volume 65, issues 7-12, page 69

[137] Kelly K., 1994, *Out of Control: the rise of a neo-biological civilization*, Basic Books, Cambrigde, page 21

[138] *Genetic Architectures II: digital tools & organic forms*, 2005, ESARQ/SITES books, Barcelona, page 173

[139] Barrow D. J., Davies P.C.W., Harper L.C., Jr., 2004, *Science and Ultimate Reality: Quantum Theory, Cosmology, and Complexity*, Cambridge University Press, Cambridge, page 10

The language proposes a spatialization, an arrangement in space, and a path to be created. This is a precondition of the building that should be located on a path and have paths inside.
If the language cannot control these paths towards and within a building, then that only signifies that language is enmeshed in these structures that it is "on the way". "On the move towards language' (Heidegger), on the way reaching itself. The way is not a method that must be clear. The method is a technique, a procedure in order to gain control of the way, in order to make it viable.[140] On one sort of a code one can arrive at when attempting to analysize the elements of articulation of a certain "language": a code capable of serving as a metalanguage for it, and for other more synthetic codes as well.[141]

Three principles: a general law of evolution

Monadology[142] is one of the earliest attempts in sketching out a system of principles that generalizes the nature of the world from an abstract point of view… [Monadology] is the earliest endeavour to propose what is now known as an open source architecture based on the principles of philosophical genetics: the principle of generative condensation, the principle of combinatorial expansion, and the principle of conservation of information[143]. The Monadology is a metaphysical treatise that describes each monad as a metaphysical, immaterial point.[144]

The principle of combinatorial expansion is essentially about part/hole relationships where the increase in magnitude of the whole is a function of the multiplication of the parts. In this respect, there are two kinds of aggregation

---

[140] Derrida J, *Where the desire may live* from Leach N., 1997, *Rethinking Architecture: a reader in cultural theory*, Routledge, New York, ,page 320

[141] Eco U., *Function and Sign,* from Leach N., 1997, *Rethinking Architecture: a reader in cultural theory*, Routledge, New York, ,page 192

[142] Monadology is the work of Gottfried Wilhelm Leibniz, written at 1898

[143] *Genetic Architectures II: digital tools & organic forms*, 2005, ESARQ/SITES books, Barcelona, page 170

[144] Oosterhuis K., 2006, Game Set and Match II: On computer games, advanced geometries and digital technologies, Episode Publishers, Rotterdam

with regard to combinational expansion: the first is a heap or a grouping with no internal connection; the second is an organized clustering of units having a regulatory network of some kind. An interconnected aggregation of computing monads is a set of entities that continuously regenerates itself by transformation pathways; the matrix that provides connectivity is irreducible. [145]

A monadic ensemble can be either one of these two kinds of aggregation or a combination of both. A point to note is that monads are patterns that supervene on other patterns. Each monad is a fractal system and the clustering of monads thereby lead to the emergent patterns of organization. These patterns, in turn, supervene onto other patterns in order to arrive at the autogenetic construction of a monadic ensemble or possible world: proto-species of genetic architecture. Such a possible world can be a complex object or building, evolutionary games, interactive virtual environments, etc. [...] Clearly, there is nothing more fundamental to the construction of possible worlds than the principle of the conservation of information.[146]

Matter, energy, information control

A system is anything that talks to itself and in the real world provides a home for control mechanisms. To Kevin Kelly, we can speak about three regime of automatic control. First, control of energy, second, control of material and third, control of information. Each regime of control is boosted by deepening loops of feedback and information flow. With genetic engineering and tools for electronic libraries, we are now in the third stage of the control revolution and we generate more information than we can control.[147] The shift from energy to information is now conceptualised as the capacity for algorithmic compression relative to the amount of random information present within any system.[148] The

---

[145] *Genetic Architectures II: digital tools & organic forms*, 2005, ESARQ/SITES books, Barcelona, page 175-176

[146] Ibidem, page 176

[147] Kelly K., 1994, *Out of Control: the rise of a neo-biological civilization*, Basic Books, Cambrigde, An abstract from page 125

[148] Chu Karl, 1995, *Modal space*, A.D. volume 65, issues 7-12

story of automatation is the story of a *one-way* shift from humans control to automatic control. The gift is an irreversible transfer from ourselves to the second selves[149].

[149] Kelly K., 1994, *Out of Control: the rise of a neo-biological civilization*, Basic Books, Cambridge, An abstract from page 126

3.3. Computing vice Intuition

A genetic system can be responsible for the formation of the architectonical body. But for an aesthetic relevance it needs imagination. To create geometrical noise, like a random alphabet, in a way it is necessary to insert intelligence, because the system is dump[150]. A system is anything that talks in itself. All living systems and organisms ultimately reduce to a bunch of regulators - chemical pathways and neuron circuits - having conversations as dumb as "I want, I want, I want; no, you can't, you can't, you can't"[151]. The computer is not a brain[152]. To Terzidis, we shouldn't consider it as an extension of the mind. The computer is the other of the human mind, not its mirror. During the creative process we experience an estrangement from ourselves. Something that comes from our minds, but we don't know, and separates us from the computer. To what extend the mind is working like a machine based on rules and the opposite, been unexpected is still a question?

Machine intelligence might be best described as that of mindless connections […] it does not think critically about how it connects. The present limits of connectionism are staggeringly complex, and the directness with which multiple entities can be related challenges human sensibility. […] the failures in artificial intelligence suggest a need to develop a systematic human intuition about the connective medium rather than attempting to build critically into the machine. Even in the most scientific applications of computer simulations it is argued that first an intuition must be developed in order to recognize the nonlinear behaviour of computer stimulation.[153]

---

[150]Chu K., form the lecture at U.I.C, May'09

[151] Kelly K., 1994, *Out of Control: the rise of a neo-biological civilization*, Basic Books, Cambridge, page 125

[152] Lynn G., 1999, *Animate Form*, Princeton Architectural Press, United States of America, page 19

[153] idem

3.4. For the Autonomy of Architecture

…are anything but anarchic chaos.[154]

Implicit within the concept of genetics is the idea of replication of heritable units based on some rule inherent within the genetic code and embedded within the mechanism for replication is a generative function; the self-referential logic of recursion. Recursion is a function or rule that repeatedly calls itself or its preceding stage by applying the same rule successfully, thereby generating a self-referential propagation of a sequence or a series of transformation. It is this logic encoded within an internal principal, which constitutes the autonomy of the generative that lies on the heart of computation[155]. This generative autonomy is forming a *viral*[156] *theory* of architecture that it is symbiotic in nature.
A symbiotic will to power of computation, resulting in a non- anthropomorphic xenoarchitecture, as anticipated by Karl Chu.[157]

Genetic architecture is based on genetic code: a two-fold logic of recursion and self-replication founded upon the principles of computation[158]. On one of Turing's last published papers, before his death in 1954, had studied the riddle of "morphogenesis"- the capacity of all forms to develop ever more baroque bodies out of impossibly simple beginnings.[159] Turing's work on

---

[154] Derrida J, *Where the desire may live* from Leach N., 1997, *Rethinking Architecture: a reader in cultural theory*, Routledge, New York, ,page 329

[155] *Genetic Architectures II: digital tools & organic forms*, 2005, ESARQ/SITES books, Barcelona, page 170

[156] Viruses are most often considered replicators rather than forms of life. They have been described as "organisms at the edge of life"… Virus self-assembly within host cells has implications for the study of the origin of life, as it may support the hypothesis that life could have started as self-assembling organic molecules.(wiki/Life, 16/11/09)

[157] Oosterhuis K., 2006, Game Set and Match II: On computer games, advanced geometries and digital technologies, Episode Publishers, Rotterdam, page 522

[158] Chu K., genetic architecture of possible worlds, retrieved from http://www.rethinking-academic.org/scientificpapers/GeneticArchitecture-PossibleWorlds-KC.pdf, 22/6/09

[159] Johnson S., 2001 *Emergence: The Connected Lives of ants, brains, Cities, and software,* Scribner, United States of America, page 14

morphogenesis had sketched out a mathematical model wherein simple agents following simple rules could generate amazingly complex structures.[160]
The morphogenetic approach in contrast to the morphodynamic systems approach is rooted in the idea of an internal logic principle that generates architectural form and organization. It is 'an investment of the will of architecture', according to Chu, or in Peter Eisenman's terms of the interiority of architecture, which is lucking in the morphodynamical approach[161]. The morphogenetic approach is based on the logic of an internal principle or code that generates morphology, seeks to establish the autonomy of architecture.[162]

The attempt to return architecture to what architecture, since the very eve of its origin, should have signed[163] (point de folie-maintenant) is how Derrida refers to the *folies* of Bernard Tschumi. That is to locate architecture in another place where, it's essential impetus, it will no longer obey external imperatives - economic, aesthetic, epiphanic or techno-utilitarian means- but it will be non representational, non- mimetic, and referring only to itself.

---

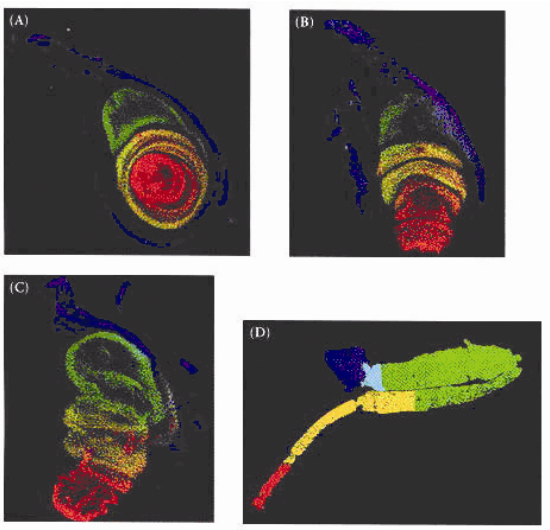
[160] Ibidem, page 15
[161] Oosterhuis K., 2006, Game Set and Match II: On computer games, advanced geometries and digital technologies, Episode Publishers, Rotterdam, page 527

[162] Chu K., genetic architecture of possible worlds, retrieved from http://www.rethinking-academic.org/scientificpapers/GeneticArchitecture-PossibleWorlds-KC.pdf, 22/6/09
[163] Derrida J, *Where the desire may live* from Leach N., 1997, *Rethinking Architecture: a reader in cultural theory*, Routledge, New York, ,page 329

3.5. Maps – From Genes to Building- Body Geometry

General logic of embryo-geography

In his book, *Mapping the Next Millennium: The Discovery of New Geographies*, Stephen Hall described how Map-making is one of the first stages of scientific exploration. […] Animal embryos are themselves little worlds, whose future topology is marked out by the actions of the tool kit genes. Hall provided the apt metaphor of understanding the "geography" of the egg as a central quest of biology, and we shall make new kinds of maps to do so.[164] Tool kit genes are just pieces of genetic material. The discovery of the genetic tool kit did more than identify genes for body-building. It gave us a whole new way of looking at development.[165] To identify what particular structures are produced by cells in different regions and the techniques that were developed in early embryos led to the construction of maps, the so-called fate maps.



36.Figure shows the expression of three genes involved in determining the proximal-distal axis of the fly leg[166].

---

[164] Carroll S.B., 2007, *Endless Forms Most Beautiful,* Phoenix, Great Britain, page 83-84

[165] Ibidem, page 84

[166] Retrieved from Gilbert S. Developmental Biology 6/E, http://www.ncbi.nlm.nih.gov/bookshelf/br.fcgi?book=dbio&part=A4302&rendertype=figure&id=A4325, 7/10/09

Tool kit - Gene actions

In terms of geography analogy, fate maps reveal that cells "know" their specific position on the globe defined by their longitude, latitude, altitude (if projecting out of the body) and depth (within layers of the body), as well as a "national" identity (nerve cells, liver cells). They "learn" that from the collective work of the tool kit genes.
And there is a sensible logic to the order of the tool kit gene actions such that positions in the embryo are defined on a progressively finer scale. […] The key idea is to picture embryos as globes upon which coordinates are progressively determined and refined in several steps[167].

Invisible unfolding - Complex architecture from simple patterns

The geometry of the embryo's coordinate system, with its parallel and intersecting lines of longitude and latitude, imposes some spatial order on how the program of tool kit genes unfolds.[…] The population of cells that make up the major subdivisions of embryos, or the position of developing organs or other specialized structures, are often first marked as simple geometrical shapes-bands, stripes, lines, spots, dots, or curves-of tool kit gene expression.[…] Indeed this stripes and other shapes are much more than aesthetically pleasing pictures of the tool kit genes in action as embryos develop; they reflect the basic operations through which the complex architecture of animals is progressively built up from geometrically simple patterns.[168]

From the same text we take that the general logic of the tool kit action is in organizing, subdividing, specifying and sculpting parts, to mark out the geography of the development building body. It's a complex process which can be seen as the product of many simpler individual and invisible in ordinary light, operations, and events unfolding within it. This action take place only in particular space and time of the development and the on/off patterns reflect the order and logic of the making of architecture.

---

[167] Carroll S.B., 2007, *Endless Forms Most Beautiful,* Phoenix, Great Britain, page 90
[168] Idem, page 90-91

The spectacle of development

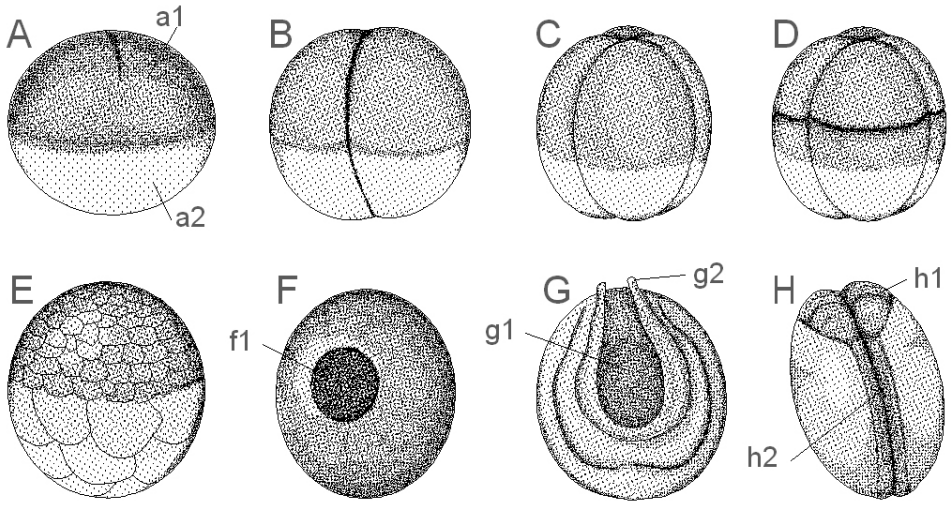
There is an order to the sequence of steps when invisible genes make visible forms. And the chain of parallel and successive operations is what builds complexity. Longitudes and latitudes axes are defined and refined as stripes of transient subdivisions (turn on patterns) which mark the boundaries between segments and the site of construction, where other structures can take place in respect to them. Serve both as physical boundaries (such as edge of the wing) and as reference points or landmarks around which further subdivisions are organized.
The coordinate system within growing appendage is sufficiently refined to assign the position and identity of rows, clusters, and even some individual cells[169].

Differentiation may occur of serially repeated parts with the activation of particular genes, which control specific longitudes along the main body axes.
For the formation of the basic design of a body plan all vertebrate pass through a stage of development which they appear similar. That is when a major body axis is established, the generation of tissue layers are defined and also the brain, a neural tube is evident. Clusters of genes create a "code".
The same logic of making a series of initially similar modules and then making them different from one another applies to another prominent feature of vertebrates, the making and differentiation of the segmental organization of the body plan.[170]

Once the basic body plan is laid out, positions begin to be marked where the organs and appendages will grow, and the construction begins. Joints arise in zones and tool kit prefigures the expression of different parts. Separations of digits occur due to the death of the tissue. All limbs are different forms of the same structure.

---

[169] Ibidem, page 96
[170] Ibidem, page 100



37.Frog development indicating the general logic of embryo geography [171]

[171] Retrieved from www.cas.bellarmine.edu, 15/11/09

3.6. Order on a Scale

One of the most striking truths about animal body patterns is their regularity at all scales, from the overall body plan to the fine details of an individual structure or body part.[172] The spacing of many individual elements in a larger array is often accomplished by a process dubbed " lateral inhibition" [173](regular spacing pattern).

Cells do the same in generating order on a fine scale. The general mechanism is for cells that are to become certain types of structures to create a local zone of inhibition around themselves. […] The net effect is a regular pattern. […] All of these patterns are generated locally by cell interactions, not specified by global coordinates.[174]

"To explain the complicated visible by some simple invisible", words by physicist Jean Perrin describe a common principle of explanatory systems. But, in our case, is a way to examine the mechanisms of natural design and understand form in terms of development by going one step further and see[175] the "simple invisible" genes become visible forms. The revealed logic of this order which exist in the sequence of steps, from the making of the basic body plan to the fine detailing of individual body parts, makes sense as in the construction of a building. To build complexity needs a chain of parallel and successive operations and a topology of possible movements of the body as a sphere map.

Switches, circuits and networks

The general function of a genetic switch is to transform existing patterns of gene activity into a new pattern of gene activity. Their function is regulatory and consist the dark matter of the genome which control where and when genes are used in development and draw the patterns of gene expression. They

---

[172] Ibidem, page 104
[173] Ibidem, page 104-105
[174] Ibidem page 105
[175] We can see the patterns with powerful technologies that light up the RNA or protein products

are the ones that encode the instructions. The physical integrity of switches is very important to normal development. […] Mutations occur due to broken switches that turn on too kit genes in wrong positions within the body. […] There are an astronomical number of potential combinations of signature sequences in switches,[176] and the combinational logic of the switches can reveal mechanisms for making patterns by adding, subtracting or changing just a few bases in the switch. This is how evolution is shaped by changes in switches.

The developmental steps executed by individual switches and proteins are connected to those of other genes and proteins. Larger sets of interconnected switches and proteins form local "circuits" that are part of still larger "networks" that govern the development of complex structures. Animal architecture is a product of genetic regulatory network architecture. Each switch is a decision point, one node in the genetic circuitry.

Genome sequencing has shown us that mice and humans have nearly identical numbers and kinds of genes (about 25,000 each). It's the switches that enable the same tool kit genes to be used differently in different animals.
Because individual switches are independent information-processing units, evolutionary changes in one switch of a tool kit gene or in a switch controlled by a tool kit protein can alter the development of one structure or pattern without altering other structures or patterns.[177]

We know from chaos theory that many deterministic systems are exquisitely sensitive to initial conditions-one small difference will send it off into chaos. But when you start out from complete randomness, and you see these things assemble towards something that is a lot more structured than you had any reason to believe could be there. This is anti-chaos…The system is sensitive to the initial conditions, but it is usually attracted to order[178].

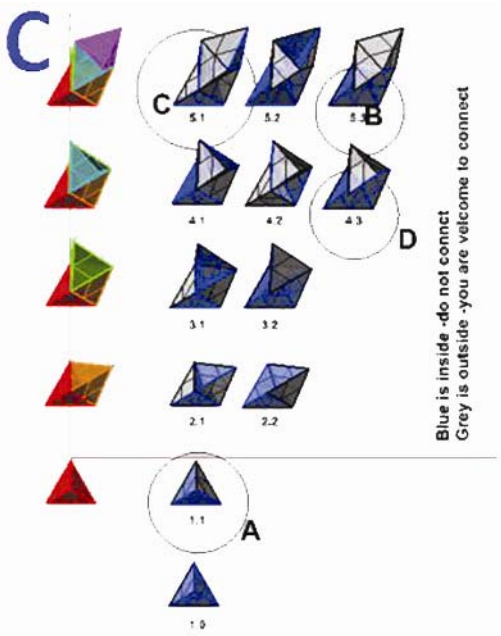
---

[176] Ibidem, page 118-119
[177] Ibidem, page 131
[178] Kelly K., 1994, *Out of Control: the rise of a neo-biological civilization*, Basic Books, Cambridge, page 63

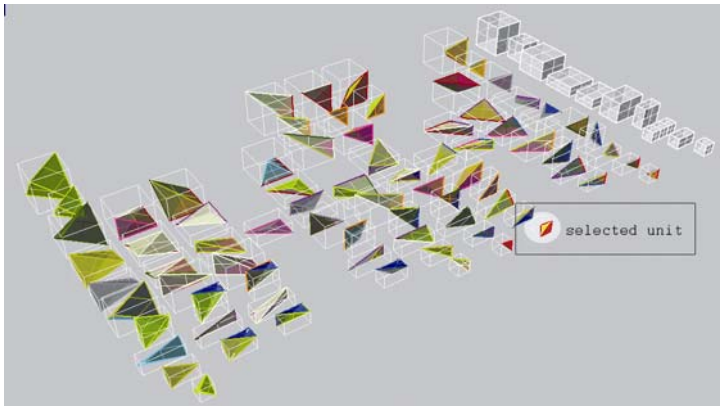
3.7. Project: Museum (building for itself, about itself and for other)

It's an experimentation process to test architecture together with reality and to evaluate the content. An abstraction to question what is the level of commitment with reality. The term "being" what is it. The procedure is very important. How to reach new discoveries, what strategies and tactics do you follow, and is it possible to reverse them back?

In the beginning we were asked for the construction of two systems which would be the language. To experiment with different ways of subdivide and scale primitives.



38. Sub-system I, (Vertex/Edge Systems), Topological relation from pyramid origin. Elements A,B,C, D are specified. Digital image by team work.



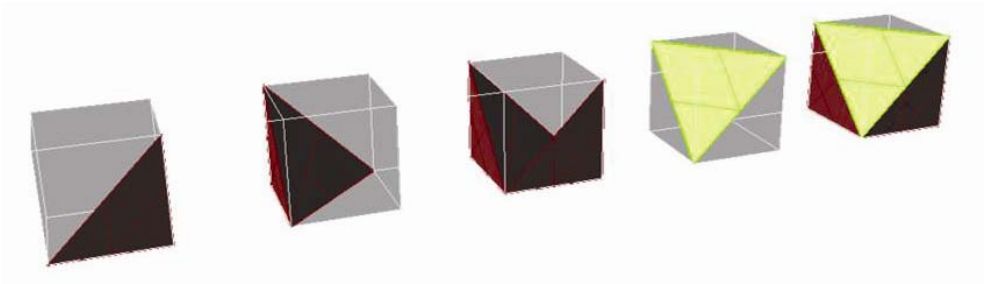
39. Sub-system II, (origin from the cube) and the selected element. Digital image by team work.

We worked with topological subdivisions of the 2 basic primitives, cube and pyramid, to create two rule systems, referred as cubic and vertex/edge system.

The reducible fixed forms of simple mathematics as sphere, cubes, pyramids, cones and cylinders- have a simplicity and purity that allows them to transcend their formal particularities[179], in contrast with organic forms that don't have the ability to be reduced to an ideal form. Working with such primitives, a surface analysis makes more sense in the point of re-constructing a basic-logic. The polygons that are created from each system represent the smallest units of information of the system. In an attempt to analyze the elements of articulation of this certain language we arrive to a code capable to serve as a meta-language for it.

[179] Lynn G., 1999, *Animate Form*, Princeton Architectural Press, United States of America, page 19

Working from inside, the purpose was to find a genetic logic, a synthetic grammar that would say how to connect both systems. This robust system should be equivalent to the genetic code. An autogenic "becoming" of a building based on rules of combination from all possibilities. The intrinsic rules of combination could give meaning to a wall as "being in itself". This was the trickiest part of the composition and different rule combinations were tested. The polygons had to be connected face to face and to compose a map of the building-body.

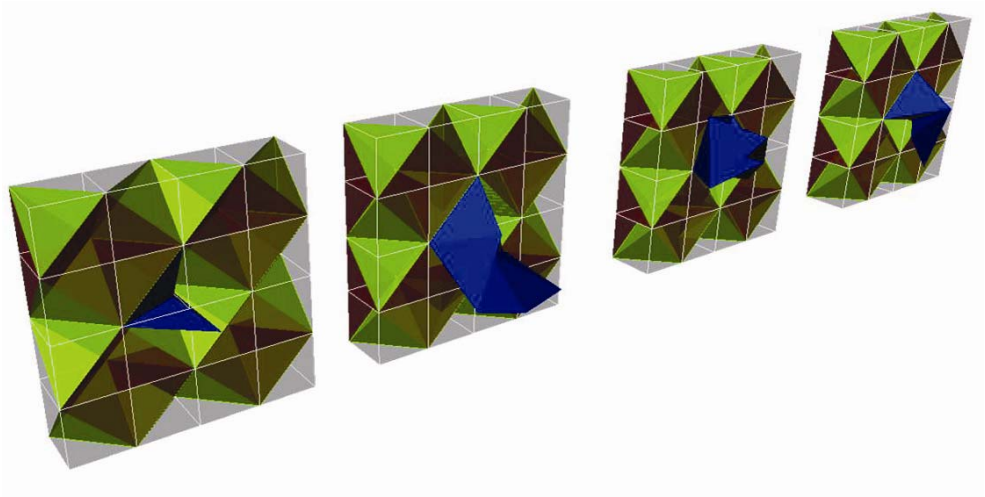


40. The three units put together. Digital image by Benavides, Giannopoulou, Montás

The rules – Grammar – The wall

From the cubic sub-system one unit was specified. Faces were defined. Three of them are put together, face to face, to form one element. The population of that element give form to a cluster of 4x4 elements.

From the second vertex/edge sub-system five units were specified. Each one is wedged to a 4x4 cluster of the cubic system, with a face to face bond. This expression prefigures the pattern of condensation where the position of the joints arises in zones between these condensations. Clusters of genes create a "code", or the building block.



41. Building blocks: a topology of possible movements of the body as a map. Digital image by Benavides, Giannopoulou, Montás

A wall contains a conceptual reference and a metaphysical idea of construction derived from the whole new way of looking at development. The wall (Figure 43) is generated as a matrix, (Figure 42) a pattern of condensation, first periodical and then un-periodical. A rule/function was introduced and the results of the generations were written in an excel file.

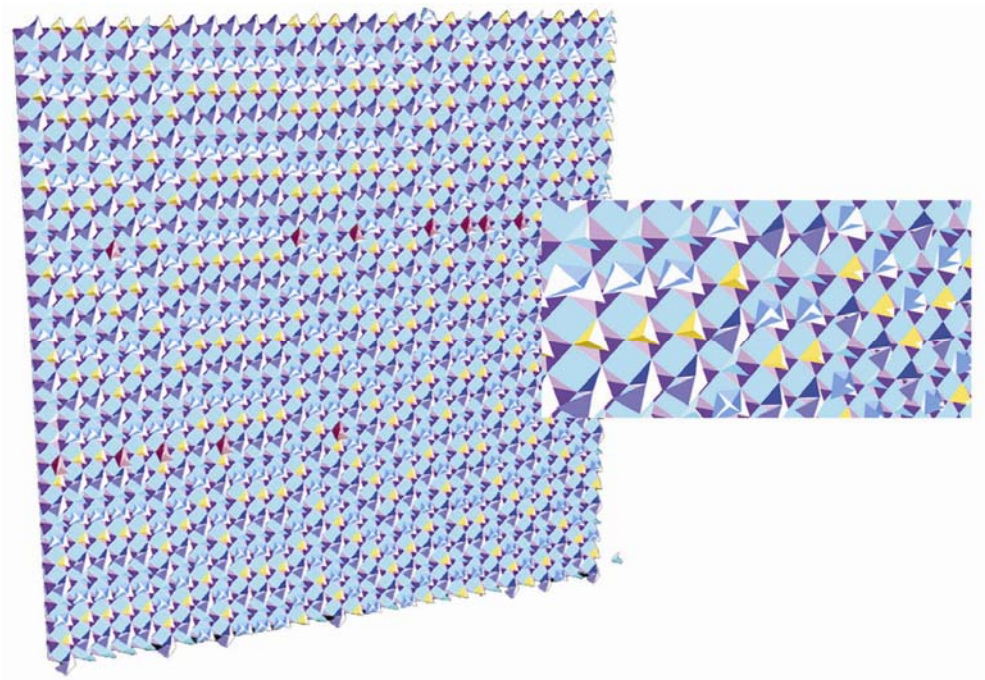
The first line is random set of information. The rule:

"a goes to c, c goes to b, b goes to d, d goes to a",

makes a loop and generate a pattern until the line ten. Here, in this line, the periodic circle is transformed with an addition of information (unit e is introduced). And again, the same happens at line twenty one. Every ten lines the pattern is changed, but the rule remains the same. The letters a, b, c, d, e, represent the five specified units of the sub-system I. (Figure 38)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD
1	C	A	D	C	B	C	A	C	C	A	C	B	A	B	C	D	A	C	B	B	B	D	B	A	D	A	A	A	A	D
2	B	C	A	B	D	B	C	B	B	C	B	D	C	D	B	A	C	B	D	D	D	A	D	C	A	C	C	C	C	A
3	D	B	C	D	A	D	B	D	D	B	D	A	B	A	D	C	B	D	A	A	A	C	A	B	C	B	B	B	B	C
4	A	D	B	A	C	A	D	A	A	D	A	C	D	C	A	B	D	A	C	C	C	B	C	D	B	D	D	D	D	B
5	C	A	D	C	B	C	A	C	C	A	C	B	A	B	C	D	A	C	B	B	B	D	B	A	D	A	A	A	A	D
6	B	C	A	B	D	B	C	B	B	C	B	D	C	D	B	A	C	B	D	D	D	A	D	C	A	C	C	C	C	A
7	D	B	C	D	A	D	B	D	D	B	D	A	B	A	D	C	B	D	A	A	A	C	A	B	C	B	B	B	B	C
8	A	D	B	A	C	A	D	A	A	D	A	C	D	C	A	B	D	A	C	C	C	B	C	D	B	D	D	D	D	B
9	C	A	D	C	B	C	A	C	C	A	C	B	A	B	C	D	A	C	B	B	B	D	B	A	D	A	A	A	A	D
10	B	C	A	B	D	B	C	B	B	C	B	D	C	D	B	A	C	B	D	D	D	A	D	C	A	C	C	C	C	A
11	D	B	E	D	A	D	B	D	D	B	D	A	B	A	D	E	B	D	A	A	A	E	A	B	E	B	E	B	B	E
12	A	D	A	A	C	A	D	A	A	D	A	C	D	C	A	D	D	A	C	C	C	B	C	D	C	D	A	D	D	B
13	C	A	C	C	B	C	A	C	C	A	C	B	A	B	C	A	A	C	B	B	B	D	B	A	B	A	C	A	A	D
14	B	C	B	B	D	B	C	B	B	C	B	D	C	D	B	C	C	B	D	D	D	A	D	C	D	C	B	C	C	A
15	D	B	D	D	A	D	B	D	D	B	D	A	B	A	D	B	B	D	A	A	A	C	A	B	A	B	D	B	B	C
16	A	D	A	A	C	A	D	A	A	D	A	C	D	C	A	D	D	A	C	C	C	B	C	D	C	D	A	D	D	B
17	C	A	C	C	B	C	A	C	C	A	C	B	A	B	C	A	A	C	B	B	B	D	B	A	B	A	C	A	A	D
18	B	C	B	B	D	B	C	B	B	C	B	D	C	D	B	C	C	B	D	D	D	A	D	C	D	C	B	C	C	A
19	D	B	D	D	A	D	B	D	D	B	D	A	B	A	D	B	B	D	A	A	A	C	A	B	A	B	D	B	B	C
20	A	D	A	A	C	A	D	A	A	D	A	C	D	C	A	D	D	A	C	C	C	B	C	D	C	D	A	D	D	B
21	E	A	E	E	B	E	A	E	E	A	E	B	A	B	E	A	A	E	B	B	B	D	B	A	B	A	E	A	A	D
22	D	C	A	C	D	A	C	A	B	C	A	D	C	D	A	C	C	C	D	D	D	A	D	C	D	C	A	C	C	A
23	A	B	C	B	A	C	B	C	D	B	C	A	B	A	C	B	B	B	A	A	A	C	A	B	A	B	C	B	B	C
24	C	D	B	D	C	B	D	B	A	D	B	C	D	C	B	D	D	D	C	C	C	B	C	D	C	D	B	D	D	B
25	B	A	D	A	B	D	A	D	C	A	D	B	A	B	D	A	A	A	B	B	B	D	B	A	B	A	D	A	A	D
26	D	C	A	C	D	A	C	A	B	C	A	D	C	D	A	C	C	C	D	D	D	A	D	C	D	C	A	C	C	A
27	A	B	C	B	A	C	B	C	D	B	C	A	B	A	C	B	B	B	A	A	A	C	A	B	A	B	C	B	B	C
28	C	D	B	D	C	B	D	B	A	D	B	C	D	C	B	D	D	D	C	C	C	B	C	D	C	D	B	D	D	B
29	B	A	D	A	B	D	A	D	C	A	D	B	A	B	D	A	A	A	B	B	B	D	B	A	B	A	D	A	A	D
30	D	C	A	C	D	A	C	A	B	C	A	D	C	D	A	C	C	C	D	D	D	A	D	C	D	C	A	C	C	A
31	A	B	C	B	A	C	B	C	D	B	C	A	B	A	C	B	B	B	A	A	A	C	A	B	A	B	C	B	B	C

42. Excel table: 1st line random, 1 rule, 2 transformations. Digital image by Benavides, Giannopoulou, Montás



43. Representation of the matrix wall. Digital image by Benavides, Giannopoulou, Montás

The disappearing rule

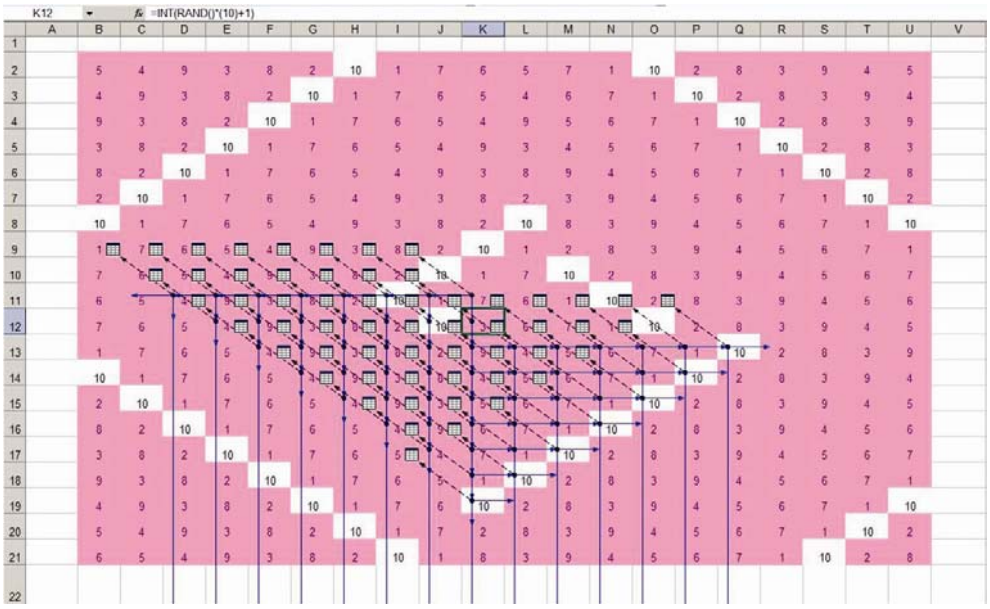
To define a disappearance path, expression of a tool kit instructs some cells to undergo programmed cell death. On a spreadsheet we use Excel's random number generator

fx =INT(RAND()*(10)=1

to create a random number between 0 and 10 for one agent (cell K12). In this case the program is working like the cellular automata. Each time you run it gives a different result. This cell generates a number to a neighbour based on a rule that was chosen from an infinite number of possibilities and it is:

If X = initial cell, then becomes Y
If X = 7, then Y = 1
If X = 1, then Y = 10
If X = 10, then Y = 2
If X = 2, then Y = 8
If X = 8, then Y = 3
If X = 3, then Y = 9
If X = 9, then Y = 4
If X = all the rest, then Y = X + 1

The direction of the affecting cells is inversed clockwise. In the figure 7, the blue lines indicate the generation path. To establish a disappearing rule we considered cells engendered as 10, empty space, or void. This 20 X 20 database was chosen to define the final size of the "building body".



44. Table which indicates the disappearing rule and the position of void. Excel based morphogenesis with vector fields. Digital image by Benavides, Giannopoulou, Montás.

Fractal Lego

An algorithmic fractal is used here to define different actions of the tool gene and to give more complexity to the body, and therefore exists as a significant noise present in the body, or brain. The addition of this expression is generated randomly by the program.

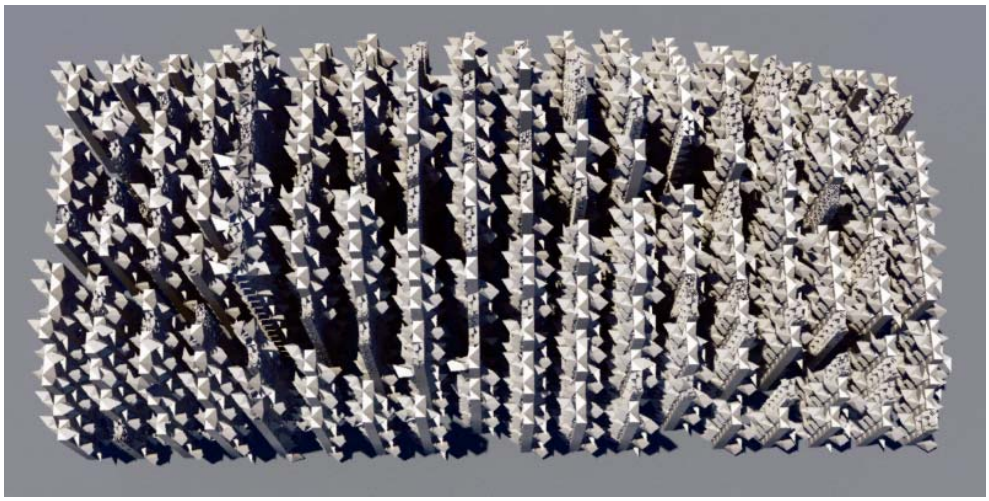
45. Fractalization of the building block. Digital image by Benavides, Giannopoulou, Montás.

The matrix is the map where the tool kits will activate for the formation of the basic design of the body plan. There are steps to the formation of this stage. First the establishment of the main body axes, and second to define a possible tool function that can generate patterns.

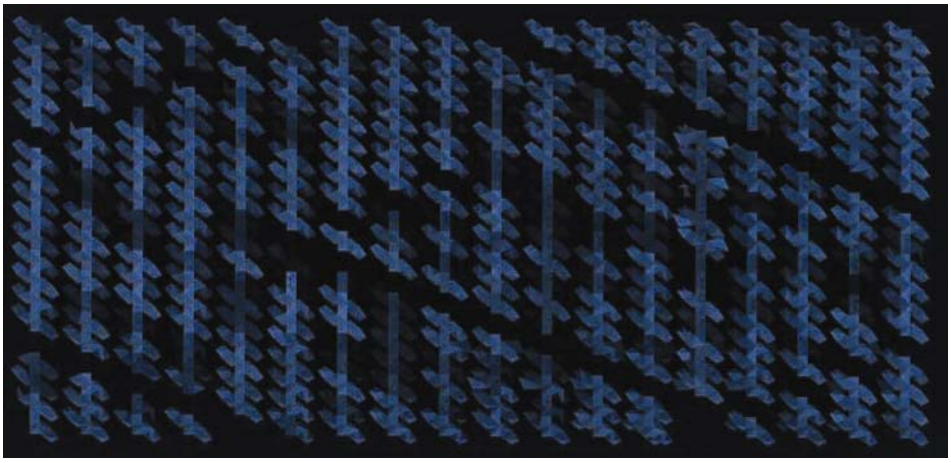
When a mass is dense, it has particular consistency. Dense intermingle relationships and afford the in-betweens potentialities. But the massive characteristic of the structure is asking for some kind of alleviation. If it has to deal with the void, the emptiness as a philosophical idea needs to set up more disappearing set of laws.

From a formal system we take the geometry based on generation maps. We put each generation into a plane. By running the simulation a number of times we generated different patterns, each one to diagram the growth of its cell vertically. The patterns are expressing the growing by the numbers 0 and 1. If it becomes 0 stops growing, if it becomes 1, continues. The other numbers are specifying the position of the fractalized genes.

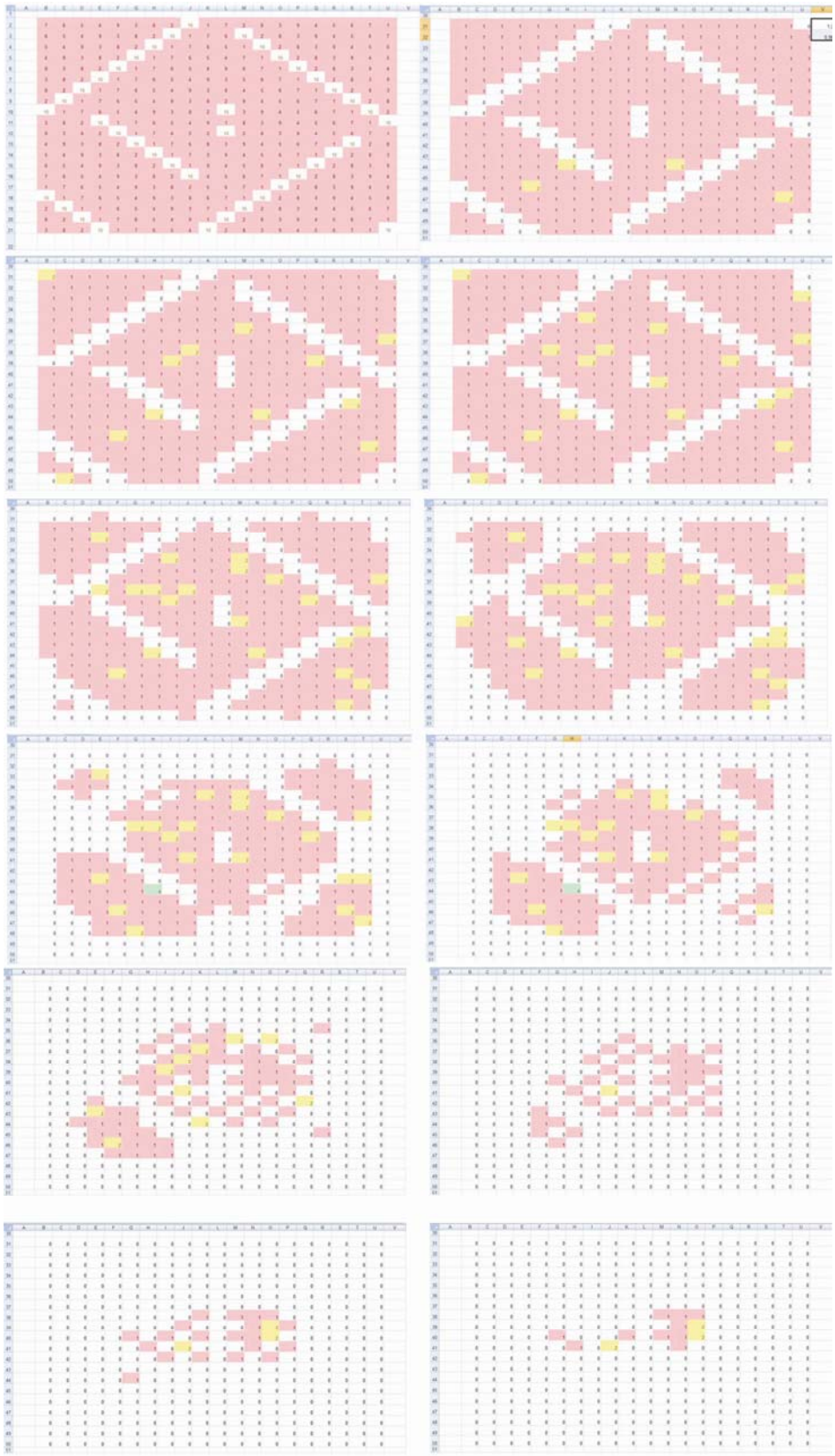
The advantage of using a spreadsheet to investigate cellular automata is that the working of the model is made explicit. The assumptions employed and the relationship between cells is encapsulated in the formulae used. These helped for the construction of the final body. Every sheet represents a building-level.



46. Perspective view of the building body from top. Digital image by Benavides, Giannopoulou, Montás.

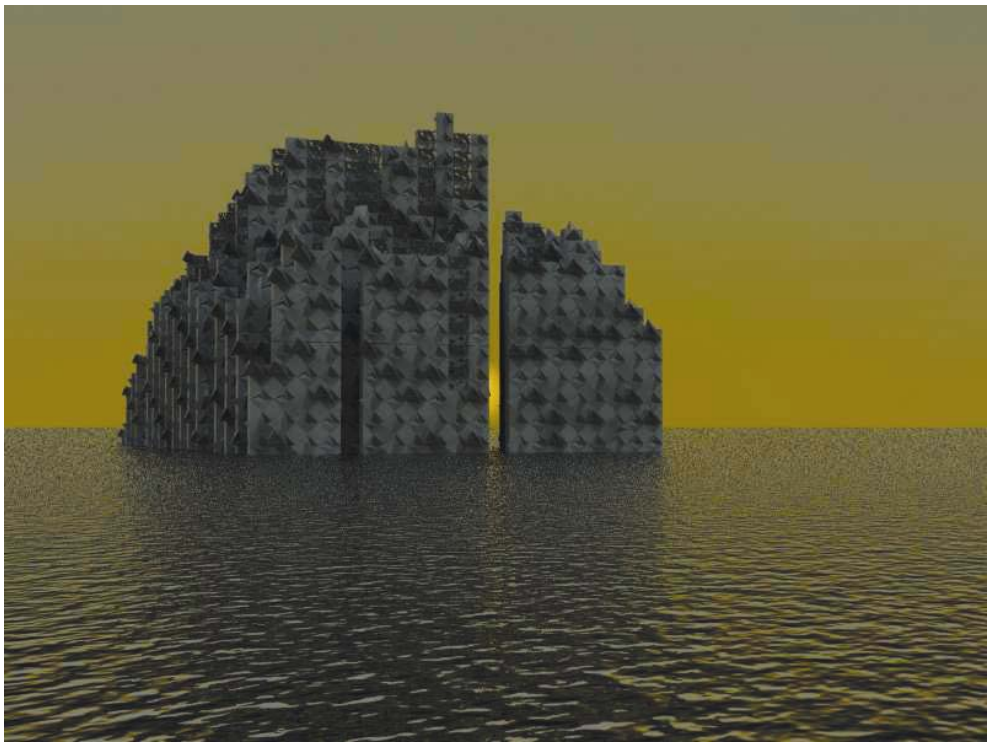


47. Top view of the building-body. Digital image by Benavides, Giannopoulou, Montás.



48. Generation maps top view in Excel. Digital image by Benavides, Giannopoulou, Montás

48. Generation maps on side view. Digital image by Benavides, Giannopoulou, Montás



49. Final render, perspective view. Digital image by Benavides, Giannopoulou, Montás

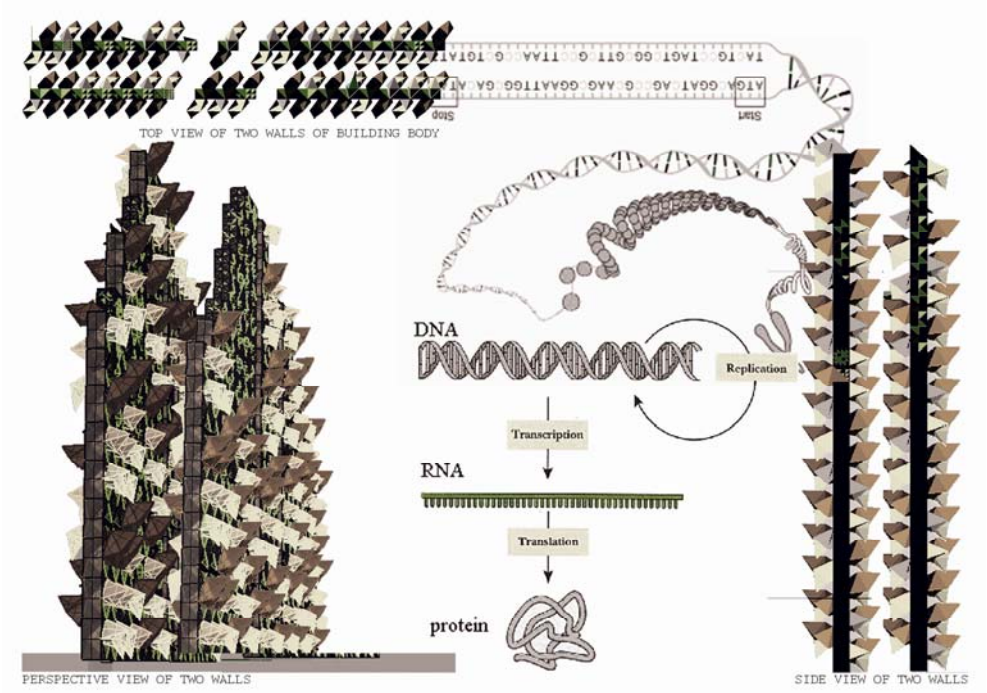
50. Final render, perspective view. Digital image by Benavides, Giannopoulou, Montás

51. Final render, perspective close view. Digital image by Benavides, Giannopoulou, Montás

Conclusion

The project process is an example of a traditional concept of systems as predetermined mechanisms of control, with top-down overarching principles. This process looks into patterns of behaviour, not those which are premised on dynamic adoption, but those which freeze into one particular static expression. For example, when we approach physical systems as if they were conservative - that is, artificially isolate them (experimentally or analytically) from ambient fluxes of energy and matter- we are led to expect that these systems will eventually reach a point of steady-state equilibrium. However, when we acknowledge that these fluxes necessarily flow through the system, a new possibility emerges- a dynamic equilibrium[180].

[180]DeLanda M., 1992, 'Non-organic Life,' Zone 6 : Incorporations, Jonathan Crary and Sanford Kwinter, Zone, New York, page 129



52. Virtual analogy of building blocks connection system to RNA construction. Image by author

To challenge this traditional concept of systems there must be a shift in understanding, that from "low-level" rules you can arrive to "higher-level" sophistication. The bottom-up development of complex adaptive systems focus on self-regulating, have adaptive capacity and are being constantly mutating based on interactions, informational feedback loops, pattern recognition and indirect control. In that way we can see the "invisible" changes and discern phenomena, that few decades ago, we couldn't notice, or were dismissed as anomalies.

These ideas are extended into an analysis of the structure of our cities by Manuel DeLanda and Steven Johnson. Cities are physical traces of patterns of social behaviour operating through time[181]. The obvious parallel between the self-organizing capacity of ants or termite colonies and the natural patterns of growth of human cities, for example Hong Kong, is questioning the need for 'master-plans". To these centered systems, the authors contrast acentered systems, finite networks of automata in which communication runs from ant

[181] Leach N., Turnbull D., Williams C., 2004, *Digital Tectonics*, John Wiley & Sons, Italy, page 72

neighbour to any other, the stems and channels do not pre-exist, and all individuals are interchangeable, defined only by their *state* at a given moment- […] Transduction of intensive states replace topology, and 'the graph regulating the circulation of information is in a way opposite of the hierarchical graph.[…] (we have been calling this kind of graph a map).[182]So even if the state seeks to impose a certain form on everything with hierarchical order, the city, on the other hand is predominantly a result of a process, a formation, and in terms of Deleuze and Guattarri, is becoming a 'machinic phylum[183]'. The town exists only as a function of circulations and of circuits. […] It represents a threshold of deterritorialization[184], because whatever the material involved, it must be deterritirialized enough to enter the network[185] .

A genetic process needs parallel processes. You need to learn how to control points, to select what is wrong, or problematic. Mistakes can be retraced inside a logic production. Without establishing external inputs or plug-ins, efficient like nature, you arrive to an organization of and from itself, an origin of something, a transcription that can modify itself devoid of exterior stimuli. You don't know what would be the final result. It is possible to subscribe other tools inside the system, like a new set of instruments, or different scales to relate it to reality, to address cultural systems. Scale is not important if it is in itself, or about itself, but it is necessary if it is for the others.

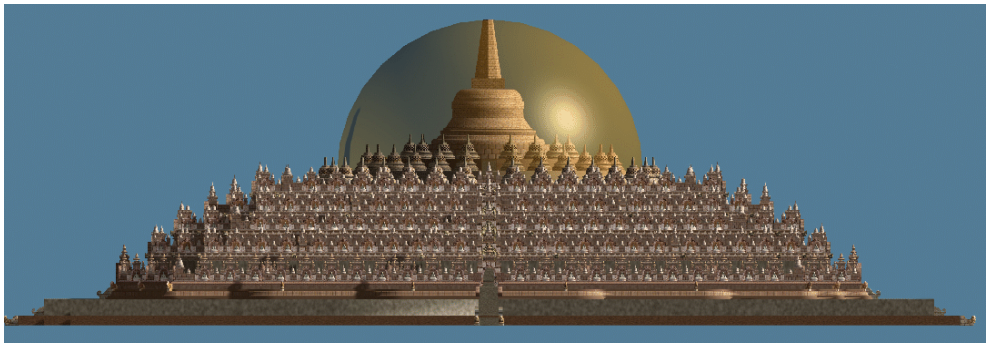
---

[182] Deleuze G., Guattari F., 1987, *A Thousand Plateaus: capitalism and schizophrenia*, University of Minneapolis Press, United States of America, page 17

[183] The term "phylum" refers to a branch in the evolutionary tree (the first bifurcation after animal and plant "kingdoms") but it also carries the idea of a shared body - plan, a kind of "abstract vertebrate" which, if folded and curled in particular sequences during embryogenesis, […] DeLanda M., 2001, Deleuze and the Use of the Genetic Algorithm in Architecture

[184] deterritorial signified as landless, rootless, nomadic

[185] Leach N., 1997, *Rethinking Architecture: a reader in cultural theory,* Routledge, New York, page 313



53. Buddhist monument in central Java, built *c.* 778 – 850 the stūpa was constructed as a giant maṇḍala or sacred diagram[186]

[186] Retrieved from http://www.borobudur.tv/survey_4.htm, 10/11/09

General Conclusion

Nature's multifarious organisms seem imbued from birth with a precise directive-knowing where to build, what materials to use and how those materials go together.[187] In animals it is written on the code of life, the DNA, how to do, like the small ants and termites which live in colonies. Humankind should also know. Should have kept this intrinsic knowledge of design and construction in harmony with nature, unless in the evolution of human kind something went wrong (for example, lost it, hence forgot how to leave with/in nature). Or, the global issue of environmental falloff and the huge catastrophic conjectures in the future is just terrorism, a narrow vision, or a misunderstanding of the phenomenon of earth's evolution due to human evolution. That is, humans of all the times have to adapt to the new conditions they create for themselves and that's all to keep in existence as an evolved natural kind. The vision of the ancient Greek philosopher Heraclites, who observed that you can never step into the same river twice, reflects the idea that the world is fluid, ever-changing and alive.

---

[187] Tsui E., 1999, *Evolutionary architecture*: *nature as a basis for design*, John Wiley & Sons, Inc, United States of America, page 4

In all cases, it is important to add a new branch of knowledge. We must go the source to discover this primal knowledge of natures architecture that it may probably been hidden in the genetic code of every living being. This code has been proofed common or with small differentiations to all life forms and can teach us about what we should re-learn.

In the early decades of the 21st century, concentrated efforts can unify science based on the unity of nature, thereby advancing the combination of nanotechnology, biotechnology, information technology, and new technologies based in cognitive science.[188] This report addresses several main issues: What are the implications of unifying sciences and converging technologies? How will scientific knowledge and current technologies evolve and what emerging developments are envisioned?[189]The evolution of a hierarchical architecture for integrating natural and human sciences across many scales, dimensions, and data modalities will be required[190]. Highest priority was given to "The Human Cognome Project," […] "The Communicator" would remove barriers to communication caused by physical disabilities, language differences, geographic distance, and variations in knowledge[191].

Living aware is the current desideratum. […] Borders will be replaced by aesthetic differences created by everyone and will be controlled by arbitrary moral systems for the correct medication. In this environment, which is almost completely current, the simulations of pleasure within zones of medicated liberty can be literally life-saving. These simulations will be a new medium (using all the media) for plotting escape routes and egress points that may or may not lead out of Eden. […] Will claim to be part of everything and that everything has a soul, including the web.[192] Inside this virtual reality, a viral art-dada option should grow into the virtual certainty.

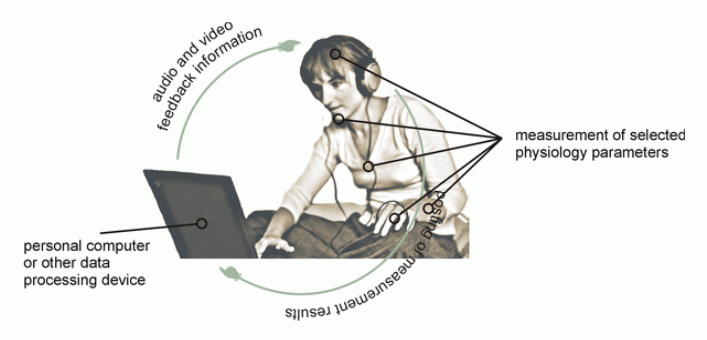
---

[188] Roco C. M., Bainbridge S. W., 2002, Converging Technologies For Improving Human Performance, National Science Foundation, Arlington, Virginia ,page ix

[189] Ibidem, page 1
[190] Ibidem, page x
[191] Ibidem, page xi
[192] Codrescu A., 2009, *The post human dada guide: tsara and Lenin play chess*, Princeton University Press, United States of America, page 5-6

The new task for architecture is to free from the boundaries, physical, social, internal or external and to investigate into the inner and outer limits of science and strategies of life to invent new meanings for technology. These qualities are difficult to truly manifest tectonically. Computer-generated architecture must not be perceived as a method to control human instincts and behaviour, but as to enable, make capable to evolve unpredictable ways of perception of reality, a meta-reality by expressing the invisible immaterial dimension of reality. Like Art and specially bioart to work on this direction.

Biodigital art can be seen as experiments done in the laboratories. With the use of high technology, it investigates living species behaviour, interactions with harmony between species, and cross species communication[193]. Projects like Interspecies, Biorama, Spectropia, Heart Library and other, can be related to architecture, because they open new fields of understanding reality and possible relations and processes for future architecture.



54. The Biofeedback Method[194]

The notion of 'umwelt' (subjective spatio-temporal world) developed by Jakob von Uexküll (1864 – 1944) and its influence on the development of bio-semiotics by Thomas Sebeok (1920 – 2001) should also be considered by architects who are working with cybernetics of life. A view opposite to a mechanistic perspective and its incompatibility with free will, and the

---

[193] MediaArtTube Exhibition 1.0 - Biofeedback Art, retrieved from, http://www.youtube.com/view_play_list?p=C51BC89CDE587C1F, 09/09/09

[194] Wiki/ Biofeedback, retrieved 10/11/09

oversimplification of complex phenomena, the concept of subjectivity has been introduced to biology.[195] This approach can be seen close to the intellectual movement, today known as "social constructivism". The guiding image of this strategy may be said to be "each culture lives in its own world".[196]

The goals and methods derived from that field should be in the most speculated. To deal with materiality and environments can be achieved through experimentation and scientific theories. And an architecture that can realize those aspects of art is truly innovative.

Parallel processes are always done in collaboration with specialists from other fields of expertise like mathematicians, programmers, theorists, structural engineers and software developers to name a few. […] With a synergic form of investigation and decision making, larger and more difficult tasks can be accomplished than individuals working on separately. All decisions within a truly synergic group are made within "decision heterarchy". It is the collective responsibility of the entire heterarchy to find this "best" solution. However, though synocracy gives us humans the opportunity to accomplish more together than we can accomplish separately, also requires more from us. It requires synergic consensus.[197]

The research has to identify the limits and with mutual decisions to manage the information resources. By evaluating innovation potentiality and exploring multimedia and multimodality, the research should be done in developing strategies and methods to translate investigation findings to design action. Creation and development of ideas should be done in an additive

---

[195] He made the claim that each species has a unique, subjective perception of its environment which determines its behaviour. He further argued that the environment is not an objectively determined fixed world common to all species, but the environment is formed subjectively according to each species.Retrievedfromhttp://www.newworldencyclopedia.org/entry/Jakob_von_Uexk%C3%BCll, 3/10/09

[196] DeLanda M., 1999, *"Deleuze and the Open-Ended Becoming of the World"*. To appear in E. Grosz(ed.), *Becomings: explorations in time, memory, and futures,* Cornell University, United States of America, page 30

[197] Notes taken from futurepositive.synearth.net

approach. Much like comedians or musicians, architects can feed off each other because ideas breed new ideas.

However, the problem in research, like any field with trained professionals, is that becomes an end in itself; when the process becomes more important than the insights and concepts that derive from it. When that happens we must reexamine the practice itself, and better understand where, when, and how it should be used. Intuition and pre-existing knowledge are always going to be a part of the design process. […] As is demonstrated so clearly in the digital realm, we've moved from a world of waterfall processes to one that exists in near-perpetual beta. Why not adopt that thinking for design research as well?[198]

[198] Retrieved http://creativity-online.com/news/insight-and-intuition-rigor-and-process/138289, 3/10/09

References

Barrow D. J., Davies P.C.W., Harper L.C., Jr., 2004, *Science and Ultimate Reality: Quantum Theory, Cosmology, and Complexity*, Cambridge University Press, Cambridge.

Baudrillard J., 2000, *The Vital Illusion*, Columbia University Press, United States of America.

Bulletin of the Ecological Society of America, April 2002, *The Ecosystemic Life Hypothesis.*

Carroll S.B., 2007, *Endless Forms Most Beautiful,* Phoenix, Great Britain
Chu Karl, 1995, *Modal space*, A.D. volume 65, issues 7-12.

Chu Karl, 2003 *"Skinless Architecture"*, in *The State of Architecture at the Beginning of the 21st Century*, Monacelli Press, Columbia Books of Architecture.

Codrescu A., 2009, *The post human dada guide: Tsara and Lenin play chess*, Princeton University Press, United States of America.

Crang M., Thrift N.J., 2000, *Thinking Space*, Routledge, London.

DeLanda M., 1992, 'Non-organic Life,' Zone 6 : Incorporations, Jonathan Crary and Sanford Kwinter, Zone, New York.

DeLanda M., 1992, *War in the Age of Intelligent Machines,* Zone Books, New York .

DeLanda M., 1998, *The Machinic Phylum*, Technomorphica. Edited by Joke Brower and Carla Hoekendikj, Rotterdam: V2 Organization, (retrieved from http://framework.v2.nl/archive/archive/node/text/.xslt/nodenr-70071, 5/10/09).

DeLanda M., 1999, *"Deleuze and the Open-Ended Becoming of the World"*. To appear in E. Grosz (ed.), *Becomings: explorations in time, memory, and futures,* Cornell University, United States of America.

DeLanda M., 2002, *Deleuze and the Use of the Genetic Algorithm in Architecture,* in N. Leach (Ed*), Designing for a Digital World,* John Wiley & Sons, London

Deleuze G., Guattari F., 1987, *A Thousand Plateaus: capitalism and schizophrenia*, University of Minneapolis Press, United States of America.

ESARQ, 2005*Genetic Architectures II: digital tools & organic forms*, SITES books, Barcelona.

Gleiniger A., Vrachliotis G., 2008, *Complexity: design strategy and world view*, Birkhauser Verlag AG, Germany.

Hameroff R. S., 1987, *Ultimate Computing*, Elsevier Science Publishers B.V. Tucson, Arizona, U.S.A. (www.quantumconsciousness.org 5/10/09).

Hensel M., Menges A., Weinstock M., *Emergence: Morphogenetic Design Strategies*, AD, Volume 74, No3, May/June 2004, Wiley-Academy, London.

Holdrege C., Talbott S., 2008, *Beyond biotechnology: the barren promise of genetic engineering*, University press of Kentacky, Kentacky.

Huiskes R., Mullender M., 1996, *Adaptive Bone Remodelling in Cyberspace: tricks and Treats*, Netherlands.

Johnson S., 2001 *Emergence: The Connected Lives of ants, brains, Cities, and software,* Scribner, United States of America.

Kelly K., 1994, *Out of Control: the rise of a neo-biological civilization*, Basic Books, Cambrigde.

Kolarevic B., 2003, *Architecture in the digital age: design and manufacturing*, Grafos SA, Spain.

Kwinter, Sanford, 1992, *Landscapes of change: Boccioni's Stati d'Animo as a General Theory of Models,* Assemblage 19.

Leach N., 1997, *Rethinking Architecture: a reader in cultural theory,* Routledge, New York.

Leach N., Turnbull D., Williams C., 2004, *Digital Tectonics*, John Wiley & Sons, Italy.

Leach N., Xu Wei- Gup, 2004, *Fast forward, hot spot, brain cells: Architecture Biennial Beijing,* Map Office, Hong Kong.

Lefebvre H., 1905, *The production of space*, Anthropos, United Kingdom, 2004
Lynn G., 1999, *Animate Form*, Princeton Architectural Press, United States of America.

Mader S.S, 1998, Biology *6/E,* WCB/ McGraw-Hill, United States of America
Meredith M., 2008, *From Control To Design: parametric/algorithmic architecture,* Verb monograph, Actar, Barcelona.

Molly Young Brown, 2002, "*Patterns, Flows, and Interrelationship*". Retrieved from www.mollyyoungbrown.com, 27/6/09.

Oosterhuis K., 2006, *Game Set and Match II: On computer games, advanced geometries and digital technologies*, Episode Publishers, Rotterdam.

Prusinkiewicz P, Lindenmayer A, 1996, *The Algorithmic Beauty of Plants,* Springer-Verlag, New York.

Roco C. M., Bainbridge S. W., 2002, *Converging Technologies For Improving Human Performance*, National Science Foundation, Arlington, Virginia (www.wtec.org, 14/11/09).

Rosen R., 1991, *Life Itself: A Comprehensive Inquiry into the Nature, Origin, and Fabrication of Life,* Columbia university Press,(first published 1934) New York.

Silver M., *Programming Cultures*, 2006, AD, Volume 76 Issue 4.

Steward I., 2003, *Self Organization in Evolution: A Mathematic Perspective, Philosophical Transaction*, The royal Society of London.

Szalapaj P., 2005*, Contemporary architecture and the Digital design Process,* Elsevier, Oxford.

Terzidis K., 2006, *Algorithmic architecture*, Elsevier Ltd., Oxford.

Thomson W. D' Arcy, 1917, On *Growth and Form,* Dover, New York, 1992.

Thomson W. D' Arcy, 1917, *On Growth and Form,* University of Chicago Press, edition: 2- 1948.

Thomson W. D' Arcy, 1917, *On Growth and Form,* Cambridge University press, Cambridge, 1992.

Tsui E., 1999, *Evolutionary architecture*: *nature as a basis for design,* John Wiley & Sons, Inc, United States of America.

Venter, Craig, *Supermicrobe man*, Wired, No. 10.12 December 2002.

Weberling R., translation Pankhurst J. R., 1992, *Morphology of flowers inflorescences*, Cambridge University Press, Cambridge.

Woodruff, Sullivan, Baross J, 2007, *Planets and Life: The Emerging Science of Astrobiology*. Cambridge University Press, Cambridge.