CHAPTER 4.

GENERATIVE GENETICS AND PARAMETRIC EVOLUTIONARY DESIGN

Evolutionary architecture can be expressed in 2 main roads which are through generative bio-digital and genetics concepts or through parametric algorithms
The generative bio-digital and genetic evolutionary design will be expressed as the main subject of the research then the parametric algorithms will be stated quickly.

This chapter will show some definitions, uses of generative genetic design of bio-digital and genetics and its uses in architecture, impact of bio-digital and genetics on architecture. (MAIN THESIS POINT) Also this chapter will present the most important biological design principles used in the coming chapters.

Keywords:

GENERATIVE GENETICS, GENOTYPE, PHENOTYPE, OFFSPRING, MUTATION, RECOMBINANT ARCHITECTURE, BIO-MORPHOLOGY, BIO-DIGITAL DESIGN, GENETICS, GENETIC SPACES, GENERATIVE GENETIC DESIGN ALGORITHMS, BIOTECHNOLOGY

CHAPTER FOUR

GENERATIVE GENETICS AND PARAMETRIC EVOLUTIONARY DESIGN

CHAPTER STRUCTURE: ANALYTICAL SECTION

CHAPTER FOUR: GENERATIVE GENETICS AND PARAMETRIC EVOLUTIONARY DESIGN

THIS CHAPTER WILL SHOW SOME DEFINITIONS, USES OF GENERATIVE GENETIC DESIGN OF BIO-DIGITAL AND GENETICS AND ITS USES IN ARCHITECTURE, IMPACT OF BIO-DIGITAL AND GENETICS ON ARCHITECTURE. THIS CHAPTER WILL END WITH THW MOST IMPORTANT BIOLOGICAL PRINCIPLES USED IN THE COMING CHAPTERS.

- INTRODUCTION: DEFINING GENETICS
- DEFINING BIOLOGICAL AND GENETIC CONCEPTS IN ARCHITECTURAL DESIGN
- GENETIC SPACES
- GENERATIVE EVOLUTIONARY GENETICS AND BIO-DIGITAL DESIGN
- GENERATIVE EVOLUTIONARY PROCESS IN DESIGN
- WAYS OF DEVELOPING BIO-DIGITAL ARCHITECTURE
- ARCHITECTURE THAT APPLIES GENETICS CAN BE CLASSIFIED TO:
- IMPACT OF BIO-TECHNOLOGIES ON ARCHITECTURAL IMAGINATION
- INTRODUCTION: PARAMETRIC ALGORITHM EVOLUTIONARY ARCHITECTURE
- PARAMETRIC ALGORITHMS IN EVOLUTIONARY DESIGN
- PARAMETRIC DESIGN PROCESS
- SELECTED BIOLOGICAL DESIGN PRINCIPLES IN EVOLUTIONARY PROCESS
- SUMMARY

4.1. INTRODUCTION

As De Landa states in his essay 'Deleuze and the Use of the Genetic Algorithm in Architecture,'

> *"Evolutionary and genetic design algorithms will replace design and allow designers to become race horse breeders, it's the century of form computation"*

We use digital architecture to imitate genetic architecture using nature through bio-digital and genetic inputs compressed in genetic algorithms to produce evolutionary computational design, where genetics and bio-digital evolutionary inputs is the new architecture in the early third millennium. This chapter will explain the two main branches of evolutionary design and will go in details through the main branch of it which is the research title (generative bio-digital and genetic evolutionary design). (DeLanda , Deleuze, 2008)

4.2. DEFINING GENETICS

4.2.1. The Genetics literal review to be

Genetics from Ancient Greek γενετικός genetikos, "genitive" and that from γένεσις genesis, "origin", a discipline of biology, is the science of genes, heredity, and variation in living organisms. (DeLanda , Deleuze, 2008)

4.2.2. In biology

Genetics are rules that direct the genesis of living organisms, which generate their form, are encoded in the strands of DNA. Variation within the same species is achieved through gene crossover and mutation, through the interactive exchange and change of information that governs the biological morphogenesis, this biological and genetic concept work within the evolutionary process using a suitable algorithm or genetic algorithm to solve a certain problem using a biological solution. Refers to the underlying genetic basis of a phenotypic trait, A synonymous term is the 'genotype-phenotype map', the way that genotypes map to the phenotypes. See figure 4-1 (Griffiths, M., Miller, H., Suzuki, T., 2000)

Figure (4- 1): Is the shells of individuals within the bivalve mollusk species Donax variables show diverse coloration and patterning in their phenotypes

4.2.3. A genotype

- The genotype of an organism is the inherited instructions it carries within its genetic code. Not all organisms with the same genotype look or act the same way because appearance and behavior are modified by environmental and developmental conditions. Likewise, not all organisms that look alike necessarily have the same genotype.
- The genotype is the genetic makeup of a cell, an organism, or an individual (i.e. the specific allele makeup of the individual) usually with reference to a specific character under consideration. (Griffiths, M., Miller, H., Suzuki, T., 2000)

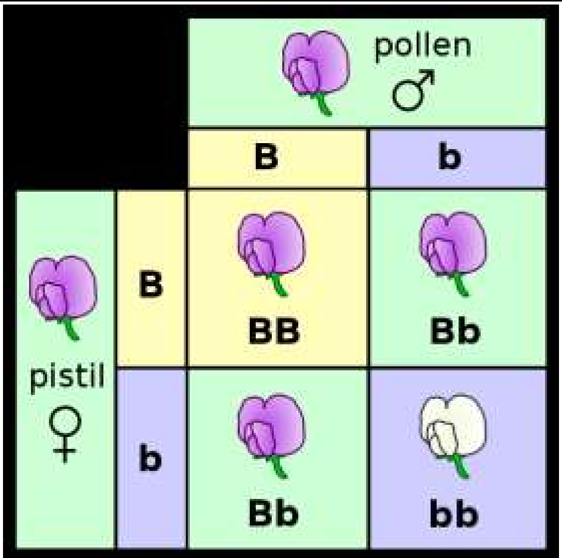
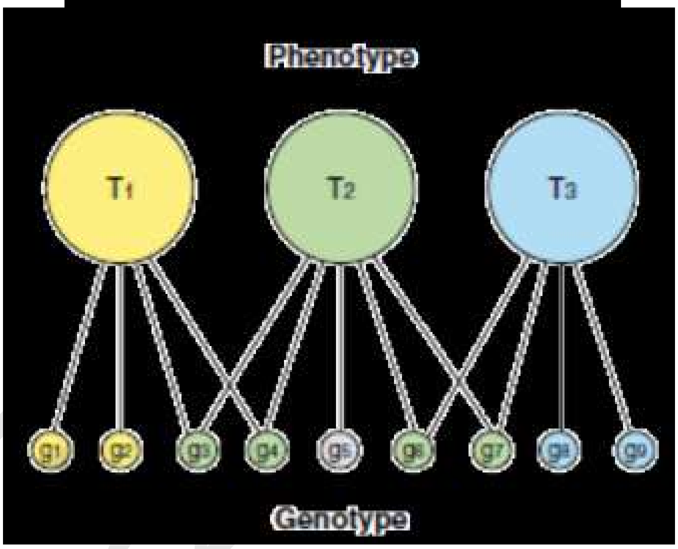


Figure (4- 2): Is the relation between genotype and phenotype is illustrated, using a Panetta square, for the character of petal color in pea. The letters B and b represent genes for color and the pictures show the resultant flowers b) represent the phenotype and genotype
Source: http://en.wikipedia.org/wiki/Phenotype

4.2.4. A phenotype:



- The phenotype is the composite of an organism's observable characteristics or traits: such as its morphology, development, biochemical or physiological properties, phonology, behavior, and products of behavior (such as a bird's nest). Phenotypes result from the expression of an organism's genes as well as the influence of environmental factors and the interactions between the two. See figure 4-2 (Griffiths, M., Miller, H., Suzuki, T., 2000)

4.3. DEFINING BIOLOGICAL AND GENETIC CONCEPTS IN ARCHITECTURAL DESIGN

It's the inputs of natural concepts of genetic cells or details and biological reactions applied in nature and survived, which can be applied in architecture to solve a certain problem, this concepts are added as codes in programs as genotype to get a phenotype solving a certain problem after applying the environmental variables. (Benjamin, 2002)

4.4. GENETIC SPACE:

Genetic space is a tapping into the creative logic of evolutionary systems where the possibility for recursive generation of intelligible structures is folded into complex variables and functions. These are generative systems endowed with self-modifying and self-organizing capacities, and their potential for unfolding into object-structures is already implicit or present within the universe of possible states of affairs contained within formally induced sets of dynamic configurations. As such, genetic space is the logical outcome of the convergence of a cosmic concept of reason and a transcendent concept of nature, thereby, pointing to a creative principle that is demiurgic in spirit (Chan, 2008)

4.5. GENERATIVE EVOLUTIONARY GENETIC AND BIO-DIGITAL DESIGN:

A process which is modeled as an object the original characteristics of the genesis, not the extreme form of the object. With a preset algorithm help in generating new object's shape or other properties of solutions, it can sometimes be random in nature and thus provide unpredictable or infinite solutions. (Riekstins, 2011)

Genetic architecture is defined in several ways by many architect, it can be defined to be an understanding of architecture deeply in which, for its conception and development, learning and applying techniques of genetics, techniques of biological and digital learning through computer science, investigating how to transfer the benef its observed in nature for the benefit of the architecture and its users, using the latest technologies (Liu H., Tang M. X., and Frazer, J. H. , 2002)

Also genetic architecture can be defined as the structure of the mapping from genotype to phenotype, determines the variation properties of the phenotype and is instrumental in understanding its evolutionary potential. (Thomas , 2008)

4.6. GENETIC EVOLUTIONARY PROCESS IN DESIGN

Figure (4-3) is a diagram shows the genetic evolutionary process. From decoding of genotypes and applying cross over, mutation, then selecting of the individuals needed to continue in the genetic process then getting the off string and initializing the final output or going back to the genetic operation and offspring to initialize better population, adding adaption can also be part of this process. (Bentley, O'Reilly, 2001); (Rosenman, 1996)

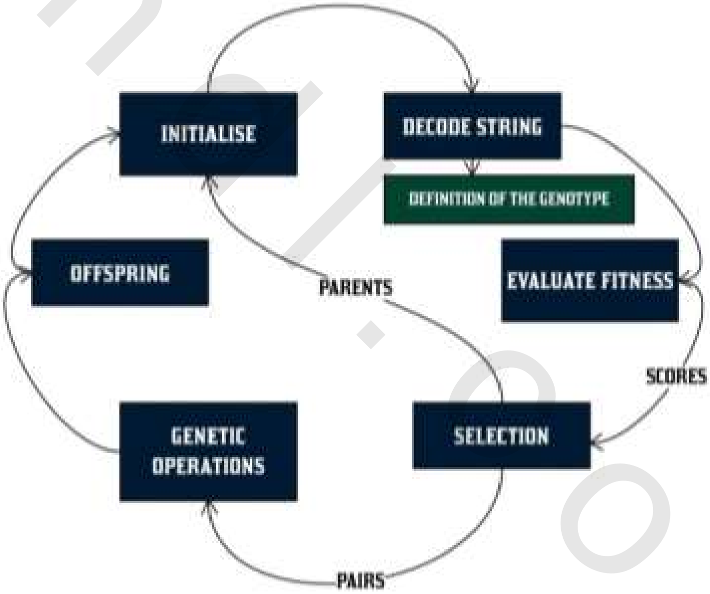


Figure (4- 3): Shows genetic evolutionary process of initialization evaluation, selection, fertility reproduction, and evaluation
Source: Researcher 2014

Adaptation can be part of this chart where adaptation of the genetic evolutionary model in the design field is represented by means of the following formulation:

- Creation of a large pool or population of design solutions
- Selection of solutions is applied through a random selection mechanism based on their fitness; this describes their performance within the confines of the specified architectural problem
- Generation of new solutions employing characteristics of the existing ones using genetic operations such as crossover and mutation. (Bentley, O'Reilly, 2001); (Rosenman, 1996)

4.7. WAYS OF DEVELOPING BIO DIGITAL ARCHITECTURE, EMERGENCE, GENETIC AND GENERATIVE CONCEPTS:

4.7.1. Eco-Cyber Fusion Design

A. Cybernetic digital resources and achievement of sustainable architecture mix.

B. Cybernetic digital resources and a new understanding of modern mixture, where the understanding of the natural or urban environment constant evolution is neither imaginative nor conservative.

C. Cybernetic digital resources and genetic mix, rereading connect the zeros and ones of architectural drawings by DNA robotic manipulator, and to arrange the necessary genetic information, which is responsible for habitable living creatures in the natural growth in accordance with a design that has previously developed a computer also check cybernetics in chapter 2 (2.4.3) (Estevez, 2005)

4.7.2. New Cybernetic -Digital Design)

The design replacing and compares the use of the computer as a substitute for a clear drawing hand, his including the construction of virtual and computer-based artificial elements. It is implemented as within the same software as the tool that is not only a graphic, but also creative, for the design and manufacture of robotic production depends on the options still with temporary restrictions on the architecture. It would be genetic architecture, where it really works with software like the artificial with the natural DNA, in some extent they are similar, and both series of the own-account information and growth. (Estevez, 2005)

4.7.3. New ecologic-environmental

For new eco-environmental project means that, in improvement and pictures environmentalism and conservation, integrated real living things, natural, in the construction of their works, whether for ethical or aesthetic, by improving the physical or metaphysical.

4.8. ARCHITECTURE THAT APPLIES GENETICS CAN BE CLASSIFIED INTO:

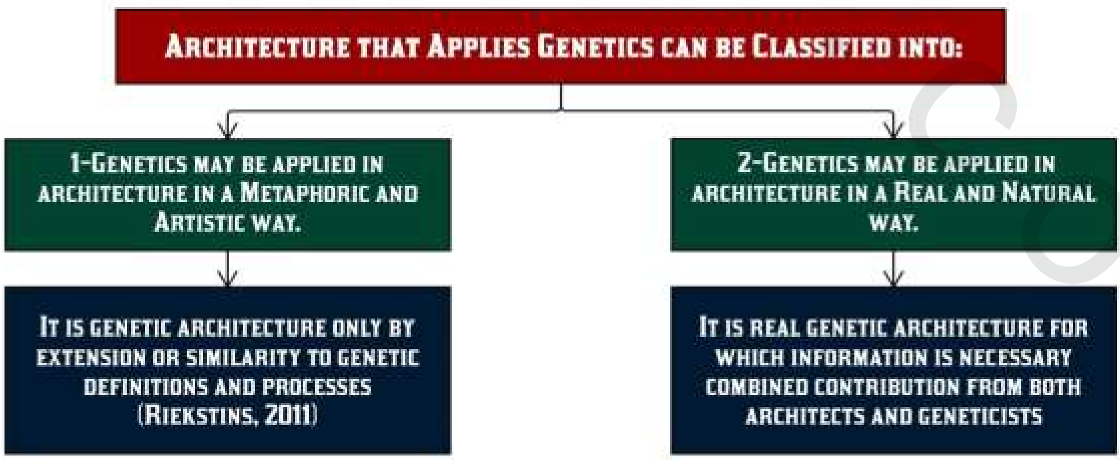


Figure (4- 3): Architecture that applies genetic diagram
Source: Researcher 2014

4.8.1. Genetics may be applied in architecture in a Metaphoric and Artistic way.

It is genetic architecture only by extension or similarity to genetic definitions and processes (Riekstins, 2011)

These projects by dennis dollens are a simulation of genetic and bio-digital design in architecture which is a metaphoric and artistic way of generative genetic design. It is called Pod Hotel in Barcelona (see figure 4-4). Growth inspired from the flower stalk of a yucca, this tower was botanically simulated and digitally generated to the plant's flowering spiral in order to provide habitation units with passive air circulation and maximum solar orientation.

Another example is the Arizona Tower, 2004 – present (figure4-5), and the tree tower (figure 4-6) Digitally grown plant structures whose roots sprout bio-digesters then grow upward, supporting flower pods that are reprogrammed as stairways and offices; finally the structure's top leaves have been transformed into solar panels.

Also see Figure 4-8 Eugene Tsui's evolutionary architecture using nature as a metaphoric and artistic way for genetic architecture forms. (Dollens, 2009)

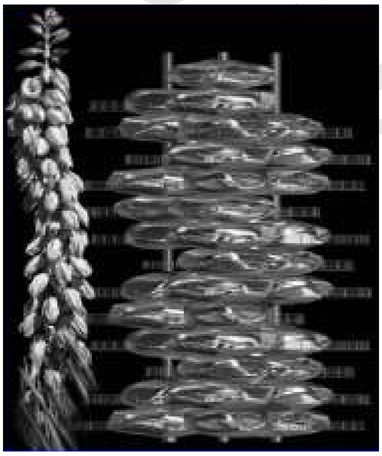


Figure (4- 4): Pod Hotel in Barcelona inspired from the flower stalk of a yucca
Source: (Dollens, 2009)

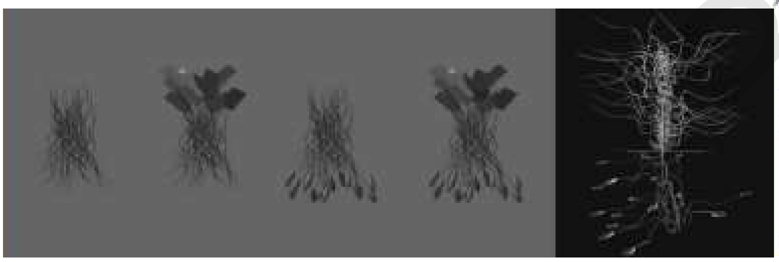


Figure (4- 5):Digital root and branch growth Structure, solar leaves, and rhizome-pods evolved into root/pod and branching truss; the looping structure does not have a single, central stalk---branches were digitally programmed to grow into each other and themselves, creating a linked series of structural bracing trusses. Source: (Dollens, 2009)

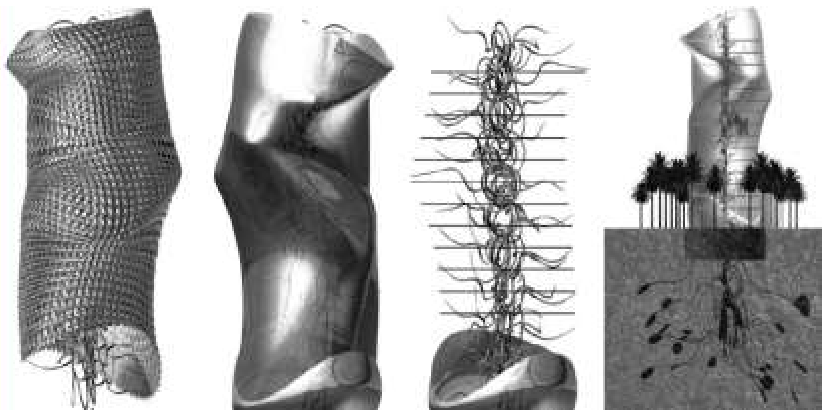


Figure (4- 6): Fourteen-Story Tree Tower, 2008--present. Structure digitally grown as a tree in Xfrog with the tips of its branches defining a point cloud for generating a glass surface, that surface was then used to parametrically generate components to create continuously linked interior and exterior walls/façade
Source: (Dollens, 2009)

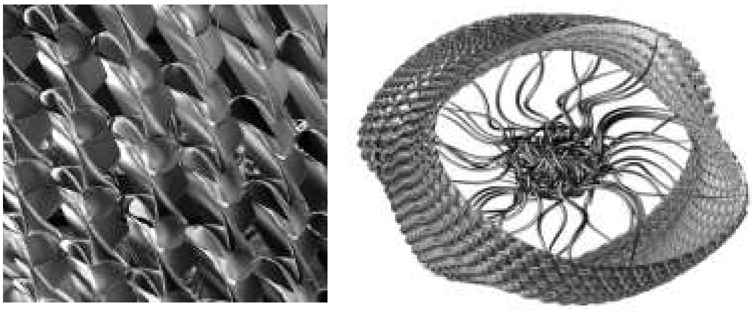


Figure (4- 7): Tree Tower Skin Detail Exterior view looking into the structure illustrating the woven or crochet likes quality of the component façade. Parametric prototype generated with Para Cloud.
Source: (Dollens, 2009)

Figure (4- 8**): Eugene Tsui's evolutionary architecture**
Source: (Dollens, 2009)

4.8.2. Genetics may be applied in architecture in a real and natural way.

It is real genetic architecture for which information is necessary combined contribution from both architects and geneticists (figure: 4-9). (Riekstins, 2011)

Also generative bio-digital and genetic evolutionary design applies genetics in normal process flow through generative bio-digital concepts and progress as studied in this research, which will be presented in details in chapter 5.

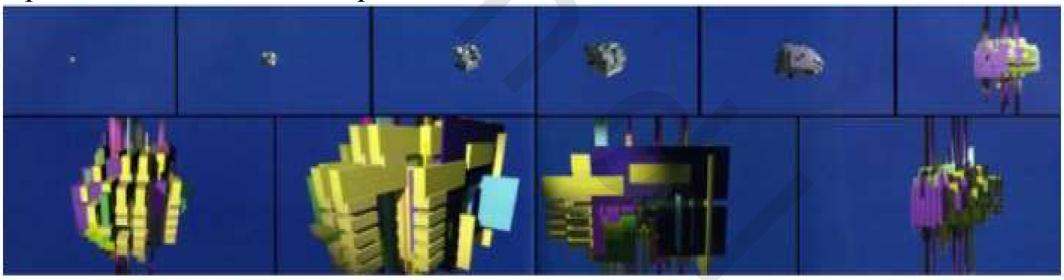


Figure (4- 9): Frazer's evolutionary architecture by imitating the morphogenesis in biology for making genetic architecture
Source: Frazer, 1995

4.9. IMPACT OF BIOTECHNOLOGIES ON ARCHITECTURAL IMAGINATION (RECOMBINANT ARCHITECTURE GENERATION):

This shows the impact of biotechnologies, including genetic, genomic and transgenic engineering, on the architectural imagination, which maps several theoretical and ethical positions on the dark matter of genetic design, algorithms and seeks to clear the ground for a material architecture based on these complex technologies of self, space and matter, this phenomena can be called recombinant architecture.

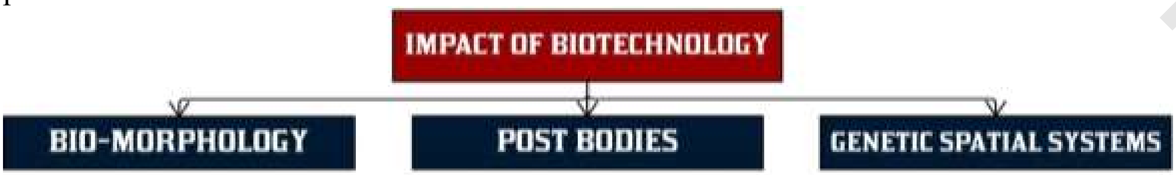


Figure (4- 10): Recombinant architecture as an impact of biotechnologies in generative designs
Source: Researcher 2014

Generative genetic evolutionary design explodes allegorical relationships between body and structure, incorporating biologic and architectural bodies into indiscrete and reversible interiors and exteriors including cyborgs and transgenic bodies, generative tissue textiles, body-architecture hybrids, replicating habitats and genetically engineered architectures and building materials.

Generative genetic evolutionary architecture is multiple, and can be stated according to three interrelate indexes:

1- The conception of architectonic forms in the image of genetic, biomorphic corporeality (architecture as physiognomic index of the post human),
2- The deliberate fashioning of recombinant bodily forms (genomic entities in the image of architecture
3- The application of artificial biomaterials in the construction of the built environment ((architecture as the result of genomic design) - from bodies to buildings and back again.(Benjamin, 2002)

4.9.1. Genetic, Biomorphic Corporeality (Bio-Morphology)

The conception of architectonic forms in the image of genetic, biomorphic corporeality, genetic architecture elaborates the epistemic centrality of a now genomically self-conscious body as a mythological index of structural investigation. The genetic body is considered to name and contain multiple and incongruous animate forms to be given architectural expansion. Each one of those is a figurative principle that could be used so as to extend purely biological processes into more comprehensive bio-technical systems. Greg Lynn's Embryological House is considered by Benjamin Bratton "likely the most publicly appreciated genetic architectural project".

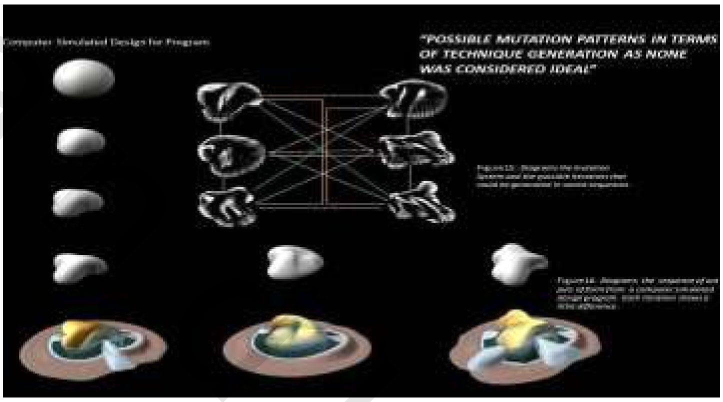


Figure (4- 11): Greg Lynn's Embryological House is considered the most publicly appreciated genetic architectural project
Source: (Benjamin, 2002)

It re-imagines dwelling according to genetic form as a first principle of interactive animation. The House adjusts itself, reacts and anticipates sunlight and environmental variables according to data received. Bratton believes that not only the Embryological House, but also genetic architecture itself, remain beholden to traditional architectural problematic. The House is a genetic metaphor in architecture and although there have been used bodily forms and human morphologies; it remains allegorical of genetic processes. As he comments about it: "It is undecided whether Embryological House is yet genetic architecture, or rather still architecture about genetics (Benjamin, 2002)

4.9.2. Post Bodies

The deliberate fashioning of recombinant bodily forms (genomic entities in the image of architecture). Recombinant architecture looks to the figure of the artificially designed body (genomically, surgically or otherwise realized) as a cyborgian measure of both structure and inhabitant, while genetic architecture infers or applies genetic grammars into the moment of creating formal architecture. The body is the first architecture: the habitat that precedes habitation.

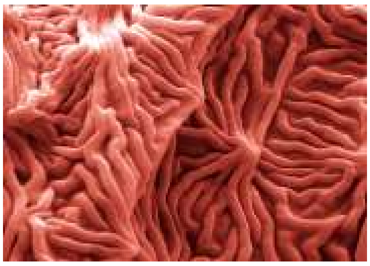
Bodies are now imaged as genomic territories, as cities of DNA events, due to the fact that they are sliced into component sub variables and statistical predispositions. Bodies could be considered not only as the first architecture, but also as the first digital architecture. DNA is a binary code which produces forms; the bodily forms produced are themselves architectonic in the highest order. Like all the other naturally occurring architectures these genomic manifestations are incredibly perfect as they are and available modifications. Bodies could be considered as machines, and machines as bodies, therefore they can be used for new design practices and modifications. Figure 4-12 (Benjamin, 2002)

Figure (4- 12):A spatial example could be the ear-mouse, in 1995 Dr. Joseph Vacanti, a transplant Surgeon at Harvard, who cultured a human working ear under the skin of a mouse, which was then removed, without harming the mouse.
Source: (Benjamin, 2002)

4.9.3. Genomic Spatial Systems

The application of artificial biomaterials in the construction of the built environment (architecture as the result of genomic design) Every day growing database of structural biomaterials, genetic and genomically designed fabric systems, is nowadays widely being explored and finds a lot of applications in medicine, agriculture, military and even conceptual art. At the same time the application of genetic material engineering to the design of physical habitats quite often collapses literal gaps between body and architecture. As for example Benjamin H. Bratton described in his article “The Premise of Recombinant Architecture: One” that “recombinant architecture” gives the premise “to explode the sitting-machine into new bodies of spatial narrative, new modes of habitat-circuit, new questions, and not just new answers.

Buildings, like bodies, have membranes, and the vocabularies of 'skin' should only become more pronounced. Buildings, like bodies, have orifices, and the materiality’s of interiorization exteriorization should likewise become further pronounced, even as bodily-programmatic conventions based on them (kitchen/ bathroom, for example) mutate beyond recognition.” (Benjamin, 2002)



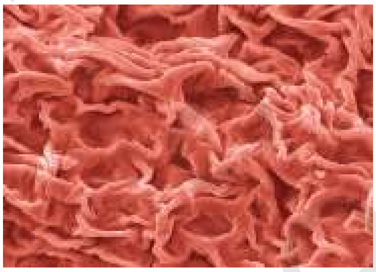


Figure (4- 13): Researches into genetic control of cell growth, making living tissue grow as a building material: cellular masses that become alive walls that emerge alone, soft and furry architecture that grows. (1) (2) (3) Bio wall systems - real soft genetic reform of the Mies German Pavilion, (4) Genetic Barcelona Pavilion Barcelona
Source: (Estévez, 2010)

We can finally say:

Bio-digital architecture now can be defined as the fusion of genetics and cybernetics at a time when new biological and digital technologies have given us the condition for new architecture. This new architecture of genetics and bio-digital designs can give us two approaches to their applications:

1- Genetic research to obtain living elements, building materials and useful living spaces for architecture
2- Work on digital design and production seen as a genetic process knowing that which can be drawn can be built, because that which can be drawn using digital tools has a digital DNA, which allows automated emergence, robotized self-construction and artificial growth.

4.10. PARAMETRIC ALGORITHMIC EVOLUTIONARY DESIGN

4.10.1. Definition:

Parametric evolutionary design is a common approach. A design is predefined and parts that require improvement are parameterized. The evolutionary system is then used to evolve these parameters solving a certain problem by using algorithms or scripts.
A parametric algorithm is an adaptive method that can be used for programming solves search and optimization. Its strategy is based on the processes evolutionary living organisms throughout the generations, the populations of living things evolve in line with the principles of natural selection and survival of the strongest or the fittest. Which is mostly applied through the use of genetic algorithm, the nature operates strategy producing a large number of models, which are evaluated by the environment. If these models are not able to adapt, disappear, only the fittest prevails. (Kolarevic, 2004)

4.10.2. Parametric algorithms in evolutionary architecture

Algorithmic Architecture is not just learning new programming languages, but at the same time a new way of thinking. In order to be able to use programming in architectural design one must become familiar with the term algorithm. It's a set of instructions that is given to a machine through parametric inputs by a human to accomplish a given task in a finite number of steps. Algorithms are already widely used among recent designers. Experiments that are advertised as an imitation of biological processes are nothing more than clever tricks performed with the use of computer programming to receive nature-like patterns.

4.10.3. Parametric algorithmic process:

In parametric algorithms design process algorithms operate to produce a certain amount of random patterns, or any solutions to a problem. Each of these solutions is encoded in some way, and is quantitatively evaluated under a fitness function. Individuals who do not meet the minimum fitness are eliminated. However, some individuals will be promising and they will be preserved and copied to be recombined and thus produce new lineages to incorporate small mutations in their chromosomes. In this way produce a new population of possible solutions, which will replace the old one. So what over the generations the good properties and features +6of the best individuals they will spread throughout the population, making the average fitness improves, after each iteration of the algorithm, Crossing individuals better then favor will be explored and adapted the best areas of the search space of the problem; all of these steps are introduced under the boundary of the parametric given inputs. They are based on genetic operators to perform its task (selection, crossover and mutation). Each prototype to be tested is represented by a strip of parameters, which receives the name chromosome. (DeLanda , M., Deleuze , G., 2008)

4.11. SELECTED BIOLOGICAL DESIGN PRINCIPLES IN EVOLUTIONARY PROCESSES:

From the previous lines and as shown in chapter 2, Generative and Parametric evolutionary design process depends on problem solution and design process on algorithms, especially the genetic algorithm. Hence, which form is a better solution to design problem through a strategic design process stated before (evaluation, selection, reproduction, offspring .. etc.).
Here are some applying concepts on this evolutionary design process to produce architecture through using some biological design principles in genetic and parametric process: **Adaptation, Behavior material and environment, emergence, self-organization, Optimization.**

These selected principles provide a basis for further study in the following chapter. Particular selection of these principles is due to a number of reasons such as their current applicability in computational design within the limitations of available technology and knowledge. This selection however does not imply the significance of these principles over others:

4.11.1. Adaptation:

Nature responds to changing environments both by behavioral adjustments of individuals and by Darwinian genetic changes in the attributes of populations. Adaptation is the evolutionary process whereby a population becomes better suited to its habitat. This process takes place over many generations and is one of the basic phenomena of biology and evolutionary design process. The term adaptation may also refer to a feature which is especially important for an organism's survival.

Such adaptations are produced in a variable population by the better suited forms reproduced more successfully, that is, by natural selection, which is generally present in the strategies of selection in the generative genetic process in architecture and can be one of the most important biological design concepts (Hensel, M., Menges,A., 2004)

4.11.2. Emergence

> *A system exhibits emergence when there are coherent emergent (property, behavior, structure...) at the macro-level that dynamically arise from the interaction between parts at the micro-level. Such emergent are novel with regards to the individual parts of the system.* (De Wolf and Holvoet 2005)

Emergence is a concept that appears in the literature of many disciplines, and is strongly correlated to evolutionary biology used in evolutionary architecture, especially generative genetic and bio-digital concept due to its applying of nature process and concepts from which many solutions of nature, artificial intelligence, complexity theories, cybernetics and general system theory emerge.

Emergence can be defined to be the properties of a system that cannot be deduced from its components. It is a word used too often is to conjure complexity but without the attendant concepts and mathematical instrument of science. However, in science, the term refers to the production of form and behavior by natural systems that have an irreducible complexity and also to the mathematical approach necessary to model such processes in computational environments. (Weinstock, 2004)

The evolution of all the multiple variations of biological form should not be thought of as separate from their structure and materials. It is the complex hierarchies of materials within natural structures from which their performance emerges. Form, structure and material act upon one another, and the behavior of all three acting on each other cannot be predicted by analysis of any one of them alone. (Hensel, Menges, Weinstock, 2010)
The task for architecture is to delineate a working concept of emergence and to outline the mathematics and processes that can make it useful to be used in the generative algorithm, where principles and dynamics of organization and interaction must be searched to be changed to applicable generative tools through algorithms, to apply mathematical laws that natural systems obey and that can be utilized by artificially constructed systems.

4.11.3. Behavior, Material and Environment

All living forms are hierarchical structures, made of materials with subtle behaviors that are capable of change in response to different environment. Biological material systems are self-assembled, using mainly quite weak materials to make strong structures, and their dynamic response and properties are very different from the classical engineering of traditional man-made structures, this give it a certain behavior. (Hensel, Menges, Weinstock, 2010)

Biological forms and their behavior emerge from process. It is a process that produces, elaborates and maintains the form and structure of biological organisms (and non-biological things), and that process consists of a complex series of exchanges between the organism and its environment. Furthermore, the organism has a capacity for maintaining its continuity and integrity by changing aspects of its behavior. Form and behavior are intricately linked. (Hensel, Menges, Weinstock, 2010)

The form of an organism affects its behavior in the environment, and a particular behavior will produce different result in different environments. Behavior is nonlinear and context specific. Organisms and natural systems are often composed of a number of interrelated components and materials that act on a continuous scale from the micro to macro structure. At each level of structural organization the cells within the organism perform a function that corresponds to a necessary requirement at that level.A material system can be defined as a set of self-organized materials, defining a certain spatial arrangement. In architecture, this material arrangement acts as a threshold for space, though space often only appears as a by-product of the material organization.

Treating space as a resulting, therefore secondary, independent product minimizes the capacity to generate architecture that is astutely aware of concerns of functionality, environment and energy. An effective arrangement of material can only be determined in relation to the spaces that it defines. When proposing a more critical approach, a material system can be seen as an intimate inter-connection and reciprocal exchange between the material construct and the spatial conditions. It is necessary to re-define material system as a system that coevolves spatial and material configurations through analysis of the resultant whole, in a process of integration and evaluation. (Panchuk, 2006)

The behavior, the spatial components and forces (external and internal), are pressures onto the arrangement of material and space. This brings a high degree of complexity to the process. Biological systems are built on methods that resolve complex interactions through sets of simple yet extensible rules.

Evolutionary Developmental Biology explains how growth is an interconnected process of external forces registering fitness into a fixed catalogue of morphological genetic tools. Translating the specific framework for biological growth into computational processes, allows the pursuit of an architecture that is fully informed by the interaction of space and material. (Kelly, 1994)

4.11.4. Self-organization

Self-organization is a process in which the internal organization of a system adapts to the environment to promote a specific function without being guided or managed from outside. In biology this includes the processes that concern developmental biology, which is the study of growth and development of organisms and comprises the genetic control of cell growth, differentiation and morphogenesis.

Cell growth encompasses increases both in cell numbers and in cell size. Cellular differentiation describes the process by which cells acquire a 'type'. The morphology of a cell may change dramatically during differentiation. Evolutionary biological concepts involve the shapes of tissues, organs and entire organisms and the position of specialized cell types. It is interesting to examine available methods for modeling biological growth informed by a hosting environment. Through this investigation it is possible to derive architectural strategies and methods that are informed by environmentally specific conditions and, thus, to achieve advanced levels of functionality and performativity.

In 1968, the Hungarian biologist Aristid Lindenmayer researched the growth patterns of different, simple multicellular organisms. The same year he began to develop a formal description of the development of such simple organisms, called the Lindenmayer system or L-system. An L-system is what in computer science is called a formal grammar, an abstract structure that describes a formal language through sequences of various simple objects known as strings. For L-system-based plant modeling which will be stated once more in **chapter 5** as one of the imitating evolutionary design tools.

These might describe specific modules. There are two categories of formal grammars: analytical and generative. An analytical grammar determines whether a string is a member of the language described by the grammar. A generative grammar formalizes, where modeling plant growth and development is predominantly based on mathematical, spatial models that treat plant geometry as a continuum or as discrete components in space. Components might include the local scale of individual plant cells, the regional system scale of modules such as nodes, buds, apices, leaves and so on, or the plant taken as a whole for ecological models. (Hensel, 2006)

4.11.5. Optimization

Optimization in nature is applying the best solution compelling with the environment to find the desired objective for the problem. Optimization of a design could be simply minimized or maximized to the efficiency of solution. An optimization algorithm is a procedure which is executed interactively by comparing various solutions till an optimum or a satisfactory solution is found. Algorithms are mostly used in optimization and especially within the parametric algorithm evolutionary design concept. Optimization can be used to find the efficient solutions of environmental, structure, thermal, material...Etc. designs in evolutionary architecture. (Karaboga, 2007)

4.12. SUMMARY

This chapter presents two main approaches in evolutionary design with 2 main parts (generative genetic and bio-digital approach and parametric algorithm approach) which are discussed in part1: The generative evolutionary approach is displayed in details through its definition, applied process steps, their classification within the architectural design, and their impact in digital design as well as how to develop their use in architecture.

This new architecture of genetics and bio-digital designs can be summarized to two approaches to their applications:

1- Genetic research to obtain living elements, building materials and useful living spaces for architecture
2- Work on digital design and production seen as a genetic process knowing that which can be drawn can built, because that which can be drawn using digital tools have a digital DNA, which allows automated emergence, robotized self-construction and artificial growth.

Then, in part 2 there is a brief definition of parametric algorithm evolutionary approach.

A focus at the end has been made on some selected biological principles which will serve as criteria for the applied studies in the next chapter. They are chosen to link them with current research on morphogenetic and evolutionary computational design as will be presented in the following chapter.

Computational design software and technology present new tools for the investigation of such principles and their underlying potential. The current widespread fascination with nature is a reflection of the availability of new modes of imagining, and new ways of getting new solutions. However, this architectural design shows a paradigm shift from the making of form, to the finding of form through the generative and parametric design processes presence nowadays.

New working methods of architectural design and production are rapidly spreading through architectural and engineering practices, as they have already revised the world of manufacturing and construction. The material practice of contemporary architecture cannot be separated from this paradigm shift in the context within which architecture is conceived and made. The study of natural systems suggests the means of conceiving and producing architecture that is more strongly correlated to material organizations and systems in the natural world. (Hensel, M., Menges, A., Weinstock, M., 2010)