Manifestations of Growing in Contemporary Architecture

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Abstract. The concept of employing bioinspired, eco-friendly architecture has attracted the interest of architects, material scientists, as well as researchers in the field of Biomimetics. Inspiration of nature is carried out as a guiding spirit and it creates an advanced field by (direct and indirect) mimicking and observing or Biomimicry, as a tradition of lifestyle. In the field of architecture, looking at nature and living beings and seeking solutions in them is of great value, which is useful in reducing design problems to a minimum, and choosing the most appropriate materials for it. Nature is a great permanent factory with aesthetic aspects. For all of that, it was possible to find solutions for the design by mimicking the growth characteristics of living beings, as one of the solutions that can be adopted to maintain context and access to the community, thus achieving sustainability.

Moreover, architecture inspired by living beings has the characteristic of livelihood (bio-architecture) and has the ability to provide good job spaces at a reasonable cost in an ecofriendly way. However, the methods of transportation from the organism as (growth) to architecture are still less reliable since the architects do not realize the real possibilities of these methods. Still, the problem of the current research from that emerged represented by "the unclear of the role of growth characteristics in achieving functional and environmental sustainability in contemporary architecture". The aim of the research is to "reveal the role of these characteristics in achieving functional development and environmental sustainability of contemporary architecture" depending on what the technician provided of digital for transferring these properties to architecture and finding different solutions according to changing needs over time and to produce sustainable (bio)architecture. The first step to answer this problem was building a theoretical framework for the aspects of growth and the methods for transferring it to architecture. Then the applying it to two selected projects to touch on the results and conclusions of the study.

1. Introduction

Everything in life is constantly changing over time, and the change in human needs requires adaptation and interaction with all the tools of that accomplish these needs and requirements necessary for continuous life. Architecture is one of the tools for human accommodation and a mirror for the society. Therefore, it is imperative to attain an architecture that meets this need; that is, interaction with the variables in order to adapt to achieve the goal from one hand. On the other hand, buildings have significant negative effects on the environment, and the concept of sustainability as a result of these effects has become a threat to the entire planet. The study of nature and living beings and the concept of inspiration and how to benefit natural provisions of the systems, mechanisms and methods for the continuation of life has enormous impact on achieving sustainability in its various types. Therefore, the growth was studied as one of the basic principles of the living beings. It is one of the important concepts of development to achieve meeting the new or changing needs for the survival of the living
being and to adapt and interact with the surrounding environment. If architecture is to be considered a living being that affects and is affected by the environment, it necessarily needs interaction and adaptation; thus, development to meet the changing needs of society of (functional sustainability). Also, it needs to benefit from the characteristics of growth in reducing the negative influence of buildings and achieve harmony with the surroundings and habitats (environmental sustainability). To achieve this and to reveal the method that can be used, we must first identify the concept of growth linguistically and conventionally; the difference between growth and development, the main characteristics of growth, and its relationship to architecture. Furthermore, it is vital to disclose methods and mechanisms of transferring these characteristics to architecture. The research is conducted in three main parts:

First: Conducting a theoretical study of a set of scientific studies and books on the concept of growth in living beings, its characteristics that can be used in architecture, and how to achieve functional development resulting from the changes in the basic requirements of society. It also deals with producing an ecofriendly architecture to preserve natural resources and reduce their consumption. Then the revealing modern technological approaches for transferring these characteristics to architecture. Second: Conducting the analytical study of two study cases of global projects and applying the settings of the theoretical framework opted for them. Third: Presenting the results pertaining to the role of transferring growth characteristics from the organism to architecture in achieving functional and environmental sustainability.

2. Growth and architecture

2.1 Lexical definition of growth

It is possible to understand the concept of growth linguistically by looking at the definitions found in the Arabic and English dictionaries and in other disciplines. Growth: a source noun of grow, meaning increase. (Growth) was defined in Arabic by Ibn Manzur as (\[yanmu\] grow, [nama], plant, etc. grew in the sense of increase and increased, and \[anma\] to grow (tr) means to make sth. grow). It was defined in the intermediate dictionary as:

As for the definition of the concept of growing /development in language, the lexicon jami’ almaani (all-inclusive meanings): to develop is to increase gradually, and for the plant to develop: is to increase and augment [1].

2.2 Definition of growth conventionally

Psychologists unanimously agree that their area of interest (growth) means (the set of changes that occur to the individual as a result of aging). Growth may not be an increase or a decrease, but rather a change in quality as is the case when the way of thinking changes when moving from one stage to another. Growth is a set of sequential changes that proceed according to a coherent and integrated method and system, which appear both formally and functionally in the organism. This definition applies to both human and inhuman growth. Growth in this sense includes any kind of change in any aspect of the organism, whether it is related to its anatomical structure, biological formation, physiological functions, or activity in the environment in which it lives [2]. Growth is the process by which the individual's potential opens up and manifests itself in the form of abilities, skills, attributes and personal characteristics. It is is a continuous and permanent change in the individual and is linked to the stages of life, and growth: it is patterned in certain stages of the change that the organism goes through in order and consistency. Here: a distinction must be made between growth and change. Change indicates a transition from one state to another, whereas growth focuses on the dynamic elements of change in one direction. Accordingly: growth is a process, while change is a product. Growth takes place within devices determined by its underlying motor processes and courses. Or is "the structural changes that move the organism forward to maturity" [3].

Growth is a set of progressive changes of an orderly and coherent pattern aimed at achieving maturity. The term progressive indicates that the changes are directed and lead to starting the growth forward and not back, and the terms orderly and coherent emphasize that growth is not an accidental casual process, but rather there is a specific relationship between each particular stage of growth and
the stages that follow in the developmental/allometric sequence. Each change is based on the precedent changes [3].

The definition of growth in other disciplines is a biological term related to the physical increase in the size or structure of the organism in the different phases of its life, and psychologically, it is all the intertwining, sequential, and systematic changes in all physical, mental, emotional, and behavioral aspects that occur to the individual, and aim to complete its maturity and its compatibility with itself and with the community surrounding it. Behaviorally, it is the continuous changes in the adaptive functions that are related to time, and the complementarity of the changes in behavior, structure, and functions, which build the personality of the individual. Growth includes an increase, such as an increase in intelligence and height, or a decrease and decline as in the older stages of life [4].

2.3 The relationship between growth and architecture

It is indicated from above that the phenomenon of growth is related to living organisms as it is known.

To link this phenomenon and its applications to architecture, we must realize that architecture is a living being within its environment that interacts with it, affect and is affected by it, changes and responds according to the changing surrounding conditions and adapts as a result of meeting new and changing needs.

2.3.1 Characteristics of living beings. There are numerous characteristics that all living beings share such as responding to their environment, growing and changing, reproduction, having complex chemistry, maintaining balance, structures (cells), and passing on their characteristics and traits to their offspring [5]. In nature there are many phenomena; the living being is one of the most important and most systemic phenomena, therefore, the it is a complex organic biological phenomenon with a set of interrelated systems that undergo many transitional states towards the potential balance in nature which is the reason for its change and continuous transformation and permanent movement [6].

2.3.2 Characteristics of bio-architecture. J. Ruskin denoted to the necessity of looking at architecture seriously. He justifies his position with the premise that we can live without architecture and we can worship without it, but we cannot remember without architecture. The theorist includes the importance of the historical dimension in the architectural work and it refers to two facts these are: in seeing history through architecture, and the second is that the architectural proposals should contain characteristics that qualify them to be eternal (historical) [7]. Design decisions tend to overlap and control against feedback and learning. Does man desire to control the environment and all its contents, or to recognize, respect, and understand its lifestyles? If we choose the latter, we must document and explain the effects that interventions have on the human-nature based environment [8]. Hence, the architect's design must, according to Ruskin's book, be eternal and durable. Society has to construct its buildings in precise, diligent and interesting way so that they can endure for a long time and serve as a living architectural record for next generations. This interest is reflected in controlling the fine proportions, choosing durable materials to make durable construction, good elements, and appropriate decoration in line with the identity of the environment of the building. With this, the historical characteristic will be fulfilled, and the work will contribute to enriching the historical stock. A novelty is not the only thing we seek in architecture. Such a goal will be misinterpreted; rather, we need a whole new way of thinking about practicing architecture, extending far beyond merely new appearance (as being superficial).

The new shift of model re-evaluates bio-architecture. This will not be easy because we realize that any new shift in the way we evaluate the built environment will destabilize the existing system as the system of the twenties of the last century. A solution in the current century is found by the rediscovery and documentation of the characteristics of quick responsive spaces that naturally adapt to human needs [8]. The concept of a “living” building is not new; at the earliest beginnings of building and construction, architects have compared artificial structures to natural structures.

A century ago, Frank Lloyd Wright used the term organic to refer to (bio-architecture). But what is different is perhaps in the past nature architects used a model of form, while they are now describing it as a model of function. Imagine buildings that were created to function elegantly and efficiently as a
flower. Architecture should not look like a flower; it needs to function like a flower. This is the basic concept of biomorphism, which uses the lessons of nature to stimulate innovation [9].

Table 1. shows the characteristics of a living being and its application in architecture (preparation of researchers)

| Characteristics               | Living Being                                                                 | Architecture                                                                 |
|-------------------------------|------------------------------------------------------------------------------|------------------------------------------------------------------------------|
| **Environmental Response**    | Responding to the environmental changes to ensure the survival of the living beings such as bird migration, and defoliation...etc. | Adaptation in architecture which represents a series of changes and shifting in architecture to fit in and adequate to the environmental changes to ensure continuity in responding to the need. |
| **Changing and Growing**      | Living Beings grow, grow in size over time, and change shape according to conditions. | The growth process in architecture corresponds to the addition and expansion of buildings built for particular need. It is an increase process and is of two types; physical and intellectual. |
| **Has a complex chemistry**   | Corresponds to the process of metabolism in a living being and how energy is used for nutrition. | Produce the energy needed from the same architecture and in a high-technology environmentally friendly way (sustainable architecture). |
| **preserve the balance**      | Balance and preservation in a living being is essential to its survival such as maintaining internal human temperature 37°C under various atmospheric conditions. | The temperature inside the building is maintained within the comfort of the human being in summer and winter for to ensure its comfort and continuing of its activities. |
| **Is built of cells**         | The organism’s body is made of structures called cells. | Consists of units and structural elements that make up the general structure that corresponds to the cells. |
| **Reproduction**              | Numerical increase in individuals within a family. | Increase the number of buildings and expand the scope of construction as a result of increased need or the addition of new functions as needed by humans. |
| **pass their characteristics onto their offspring** | The existence of genes that are proliferating among individuals and that are responsible for the inheritance of traits (genetics). | Each society has its own culture and architecture is the mirror of the society, so when designing a building in a given time, the architect tries to pass the characteristics in different ways (architecture identity). |
As in living beings, there must be a diversity in the production of contemporary architecture by avoiding monotony and replicating. There is a fallacy that in the living being DNA is used to replicate, thus one expects the results to be identical. In fact, everything in nature is generated and is never replicated. An object is created and generated from the same design template, but eventually there is a slight difference every time a new organism is produced.

2.3.3 Fundamentals of growth. After examining the characteristics of living beings and comparing them with the properties of (living) bio-architecture, it is necessary to list the basic principles of biological growth, as some of the most important characteristics of living organisms, and importance of transferring them to architecture.

2.3.3.1 Growth is both quantitative and qualitative. The child grows and develops; he grows in size (quantitative growth) and develops functionally and environmentally (qualitative growth). The change in size is followed by a change in the internal functions of the body [10].

2.3.3.2 Growth is a stable and organized process. By its stability we mean as it begins, it progresses rapidly on its way, and continues to progress until the end. But growth is a systematic process; it takes place in a systematic and regular manner. Each stage of growth is a product of the previous stage, and an introduction to the next, because growth is based on the evolutionary sequence with certain characteristics appearing in each phase [3].

2.3.3.3 Growth progresses from general to specific. In all aspects of growth, responses are of a general pattern before they become specific. Also, the general activity precedes the qualitative specific activity. Based on this basic principle of growth, “the evolution of response grows from the part to the whole.” [3].

2.3.3.4. Growth is an ongoing process. The change in behavior continues to take a stabilized course throughout the life of the individual. Characteristics, whether physical or mental, do not grow in a sudden way, they are all products of growth that began before birth. But there is hidden growth and apparent growth, slow growth and rapid growth until maturity [11].

2.3.3.5. Growth is predictable. If the rate of growth is largely stable, it means that we can predict the extent to which growth is likely to occur, and expect the maximum level of growth, because of the amazing capabilities inherent in the organism is its ability to make many adjustments in the context of its life [3].

2.3.3.6. Instability of growth rate. The growth process does not occur in equal stages regarding its movement in all the different aspects of growth. Each aspect goes at a different speed than the other growth aspects, i.e., each aspect of growth has its own curve [10]. Then it is normal that growth proceeds only in the organs which the body needs for activity and effectiveness the most given that the basis the maturation of the structure prepares the organ for the function. Every organ or system grows in its time, that is, when the need for a job is urgently needed [12].

2.4. Methods for transferring growth characteristics to architecture
After identifying the most important characteristics of the organism and the basic principles and features of growth, it is convenient to list the approaches and methods that in turn transfer these properties to architecture.

2.4.1. Biomimetics. The term biomimetics is from the Greek Bio: life, and mimesis: convention. Benyus (1997) describes the approaches to this science as follows: Nature as a model: Biomimetics is a new science that studies the models of nature and then imitates them or inspire from their processes for solving human problems. Nature as a measure: Biomimetics uses an environmental criterion to judge the validity of our innovations. After 3.8 billion years of evolution, nature has learned what
works, what is appropriate, and what lasts (sustainability). Nature as a teacher: biomimetics is a novel way to study and evaluate nature. It is not only related to what we can extract from nature, but rather what we can learn from it [13]. It is a practice of learning from the strategies in nature to solve the challenges of human design. The imitation of nature demonstrates how life works. The goal is to create new ways to solve our greatest design challenges in a sustainable and solidary manner with all life on Earth [14].

Biomimicry in architecture is an emerging field that is currently defined and explored. The application of observations in nature has always been a challenge for architects. The strategic search for models in nature is the line between biomimetics and the inspiration from nature. It uses functional analogies, processes, mechanisms, strategies or information derived from living things [15]. Biomimetics is the key to transferring principles and natural behaviors to all engineering fields, including architecture. Digital technologies have a prominent role in overcoming the difficulties and complexities of transferring from nature to architecture. Hence, every living being is adaptive and responsive to the surrounding environment and works towards finding appropriate solutions regularly. It is capable of developing its shape and adapting its morphology or structure in response to various conditions and functions. Add to that the role of digital technologies in the architectural design, simulation and transmission of properties. It has tools that enable it to accomplish these; two methods to design, these are:

1. The method of digital Form Making: It depends on the representation of the digital shape in the electronic space by software and the 3D scanning technology.
2. The method of digital Form Finding: It depends on two sources, the first is the adoption of digital medium to produce the shape by its various techniques, where the result is unexpected configurations, and the second is finding the shape by simulation outside the digital medium such as growth simulation.

There are two methods for digital programming and designing: algorithms and parameters. They try to configure shapes according to special mathematical data and equations that give results accordingly. Examples of their results are bio-digital architecture, which is the result of biomimetic architecture of living beings by digital technologies [16].

The importance of biomimetic architecture in architectural design has consequences for solving problems of emerging changes and meeting future human needs. There is no doubt that the remarkable developments in digital technologies have facilitated the design process and made it more creative and flexible. It also helped the architect to come up with creative ideas to create designs with new and unexpected shapes adopted from nature.

2.5. Literature review

After presenting the concepts of the topic of the study and touching on the most keywords related to it, the most important architectural proposals are discussed about the role of growth characteristics and the biomimetic approach to achieve sustainability in contemporary architecture.

2.5.1. "Architecture Design through the Geometrical Principle of Biological Growth" by Gago /2016.

The study examined how to decode the engineering patterns of a shape in nature and transfer it to architecture. The transfer process is accomplished by special tools that work on the basis of the principles of biological organization (growth). These tools separate the biological design of shapes in nature from their environmental origins, by generating a wide range of architectural structures depending on their morphology. The growth process is described as starting with something that expands and never stops being part of the surrounding environment. So, it contains three criteria that cannot be separated, namely, the origin, which is the source of information for the structure, and determines the morphological and structural cohesion, and expansion that focuses on how the parts multiply and distribute in space. This depends on characteristics such as repetition and the center which is studied under the topic of structural growth, then communication that focuses on how biological structures work and their ability to adapt to the surrounding environment. It is related to the addition and integration properties and is discussed under the topic of spatial integration.
The study is then important in determining the tools for analyzing and decoding the symbols for characteristics in the organism such as growth, transferring it to architecture by means of algorithmic design, determining the levels of growth in designing, and achieving integration with the surrounding environment.

2.5.2. Built to Grow - Blending Architecture and Biology by Imhof and Gruber/2014. The study explains how to integrate biology with architecture focusing on structures that grow dynamically. These structures can adapt to the environment and the needs of users in the process of continuous development. The study also explored the levels of growth in designing, namely; the organism represented by division at the partial level (cells), repetition and change at the total level (organs), and the second at the architectural level represented by summation at the partial level (structural elements), and repetition and change at the total level (the building block). The study surveyed the basic characteristics of biological growth that can be transferred to architecture through biomimetics and various digital technologies: self-organization, the ability to generate and recycle, differentiation, adaptation to the environment, flexibility, intelligence, ability to explore, and continuing development.

The study focused on how to take advantage of the growth patterns of nature and apply them to architecture to create a new life. This leads to the development of new architectural concepts for architecture inspired by the growth processes of living beings.

2.5.3. “Patterns of Growth- Biomimetics and Architecture Design” by Gruber and Imhof /2017. This study explores practical approaches to the production of bio-architecture, by revealing the role of growth as an important characteristic of living beings to achieve this. With the advanced digital tools there could be applications that may be useful in achieving the goal, which is how to transfer characteristics of the biological growth of organism, such as exploration, response, adaptation, communication and continuity, through architecture. Hence, the application of these characteristics can transform the building into a more integrated and sustainable environment. The study examined the criteria of biological growth in living beings that would be exciting interesting to transfer to architecture. For instance, growth in biology depends on the genetic code that is translated into an adaptive and differential treatment of materials and the building as a whole. Also biological growth is linked to the materials and resources of the local environment. The biological structures are designed at different levels of measures with overlapping structural parts lead to effective, lightweight and differentiated solutions with the properties of the materials. The living beings are effective and grow constantly, and their functions are preserved during the growth process.

It is clear from the above that this study provided practical results for the relationship between biology and architecture. It discussed growth as an important characteristic of living beings and explained how to benefit from it in architecture with to achieve sustainability at all levels.

2.5.4. The characterization of Biological Organization by Bhasin and McAdams / 2018. The study deals with bio-organization in contemporary designs classifying them according to the level of bio-organization, abstraction and novelty. There are many solutions in nature and biology that are more sustainable and flexible than those made by humans. To address the problems in biomimetics, the approaches that lead to successful implementation of the biomimetic strategy which is a problem-driven approach based on challenging biology and analogical simulation. It is a top-down, solution-based approach, and biomimetic process by induction and biology. It is a method that is driven by living organisms, a bottom-up approach. The study touched upon the factors of measuring and evaluating biomimetics, namely; bio-organization. It indicates the location of the biological phenomenon, where it depends on identifying and analyzing the phenomenon according to several levels of organization. Abstraction is transferring specific worthy- of-attention biological phenomenon to architecture to develop a new solution for some specific problems. Abstraction was used to determine the degree of transfer from biology to technology for each design, novelty is a measure of whether the design is new or not and it is a method for determining the qualitative measure of creativity since creativity plays a crucial role in innovation. Products are classified into four categories based on the element of novelty, these are: very high quality, high quality, medium quality, and low
quality. The study has divided the levels of biomimetics into three categories: principles, behavior and form which includes the materials and structures in a group, and the mechanisms, and groups in another. The study, then indicates that the level of biomimetics determines the nature of the design and the level of solution for the specific problem. Through experience, the results indicated that the structures and materials are used most for biomimetic design, but they rarely led to the development of jobs in the field of structures and materials.

3. Building the theoretical framework and selecting application samples

3.1. Elements extraction of the theoretical framework

The general concepts and architectural studies indicate that the theoretical framework for the concept of growth in the organism and development/growing in architecture and the approaches of transferring to architecture can be drawn out. Table (2) shows the main elements with their sub-elements and their possible values.

Table 2. Shows theoretical framework

| Main Indicators | Minor Indicators | Possible Values |
|-----------------|------------------|-----------------|
| 1- Growth in a living being | Characteristics of Growth | The ability to explore |
| | | Sensing (Action and Reaction) |
| | | Kind of Response (Sensorial/Physical) |
| | | Adaptation to the Environment |
| | | Continuing Evolution |
| | | Generating and Recycling (living being/ construction material) |
| | | Self-organization |
| | Standards of Growth | The Morphological Nature of an Origin |
| | | Structural of Consistency |
| | | A Part with a Part |
| | | a part in all |
| | | Changing Proportions |
| | | Dimensions |
| | | Volumes |
| | | Future Expansion |
| | | Repeatedly |
| | | Centers of Expansion |
| | Communication | Adaptation to the Environment |
| | | Addition |
| | | Unity |
| | Growth Levels | Division at Part-Level (Cells) |
| | | Repetition and Changing at the Level of the Whole |
| | Growth Results | Changing Characters |
| | | Volume |
| | | Vital Characteristics |
| 2- Growing in Architecture | Levels of Growing | Accumulation at Building Element Level (Part) |
| | | Repetition and Changing at the Level of the Whole (Structural Block) |
| | Growing Results | Functional Specialization |
| | Standards of Growing in Architecture | Structural and Format Improvement |
| | | The Genetic Code |
| | | In Structural Materials |
| | | In a Building as a Whole |
| | | Materials from Nature |
| | | Interaction with the Environment |
3.2. Selection of projects
After extracting the theoretical framework that contains the basic and secondary elements and their possible values, two contemporary global projects are selected for which the biomimetic method is used to transfer the principles and characteristics of organism to architecture. Then, the theoretical framework elements are applied to them.

3.2.1. Housing Competition Hybrid Evolutionary Project by: Geoffrey Elander & Sang Duk Mo /2007.
It is a model of a residential building that grows with the growth of its occupants and tries to meet their needs over time. It carries the characteristic of self-development, i.e. continuous development; it could become a residential, commercial and administrative building at the same time according to the requirements at that time. It consists of a number of advanced units in one unit which represents the starting point of capsules that develops through a series of accurate calculations to produce a number of additional units. This process represents a simulation of the central nucleus in the organism and the resulting units and elements around it. The units of the capsules used are also diversified to accommodate the largest number of people, where there are groups that develop vertically located in the center of the building, with other groups that develop and grow horizontally and are located on...
both sides of the building. This diversity creates a dynamism, flow and flexibility that simulates the growth of plants in nature [17]. Several strategies were achieved in the project towards functional continuity of environmental sustainability, including the accumulation strategy through the use of developing units (horizontal and vertical) in accordance with renewing requirements, and the unity strategy; two housing units were designed, one for expandable family and an additional unit for individuals. Also, there is the structural strategy to support growth and its continuation in order to achieve development, where the structure consists of templates capable of moving horizontally and vertically to which the residential and commercial units are linked [18].

Figure 1. Shows the main component layers

Figure 2. Shows the main project activities
3.2.2. Algorithmic Housing by Marcin Pilsniak / 2007. A housing project in Shanghai, China, aims to explore solutions to housing problems in rapidly growing cities (developing). Since the city has many changes, that is, it is dynamic, the design includes a group of flexible buildings to suit the dynamics of the city. The growth rules are applied to the architectural structure so that it can ensure continued development and growth according to the interaction of the surrounding building and in response to its effects. This project is a model for creating buildings capable of self-developing, response and
adaptation to the various ongoing changes taking place. The project design was based on six different algorithms that were set on a three-dimension model represented by groups of dynamic surfaces that represent the ecosystem of the residential area [17]. By using these algorithms it is possible to create self-organizing structures that respond to the set of changes occurring and the surrounding urban effects, and the result is a set of rules designed to continuous development of housing where this system can be applied to a number of different environments and produce solutions that differ according to the location and the effects. Accordingly, the data that were created by these algorithms are converted to architecture through rules that translate information into equations and rules work on the structural and physical analysis [19].

Figure 5. Shows the distribution of the main areas in the project
3.2.3. *Bio Tower project, designed by: Dennis Dollens /2009.* The designing idea was based on the level of the organism and the plant called (Yucca). The aim of the design was to take advantage of the biological characteristics of the flowers of this plant. These are the perceptual sensitivity to light, movement and heat in obtaining techniques and systems that purify the air and ventilate the building. There are the features of sound proof and control of sound, heat and light. The exterior cover of the building is designed according to morphological formation processes, and using the stages of growth of this plant as digital data to create the structure. With the use of artificial intelligence technology to produce the materials used, it acquired the characteristic of biological behavior that is similar to the performance of the plant in its environment. The digital design tools and the concept of generative design were used based on the L-system, which simulates the rules of plant growth [20]. The project
used an idea that came from a series of sub-structures – asymmetric props for handmade paper membranes of yucca blades (leaves) For the facade, a series of folded sub-panels similar to the folded paper were developed. There are the external mechanical biosensors, biological filters, and passive cooling system embodied in digital paper panels [21]. They are eco-friendly buildings for residence, schools or offices. The design of the towers is inspired from the shape of plants and trees to support a healthy life, enhanced with generative biology, and artificial intelligence, to eliminate air pollution while contributing to energy and green spaces in modern cities [22].

**Figure 8.** Shows the idea of simulating Yucca rose in the project

**Figure 9.** Bio Tower project
Figure 10. Shows the idea of the project by creating a model that looks like a yucca rose

4. Experimental study

4.1. Application to the selected projects

After presenting the detailed description of the selected projects, the variables for the theoretical framework elements will be measured on the practical study of projects using the descriptive method of comparison between the selected projects by relying on the information form and the measurement form. The variables were measured by setting values ranging from (1-0), where (0 = unrealized value, 1 = realized value) and adopting the analysis and statistics for the measurement elements.

Table 3. shows results of applying theoretical framework

| Main Indicators | Minor Indicators | Possible Values | Elected Projects | Total Percentage |
|-----------------|------------------|-----------------|-----------------|-----------------|
| Growth in Living Being | Characteristics of Growth | Ability to Explore | 1 | 1 | 0 |
|                  |                  | Sensing (Action and Reaction) | 1 | 1 | 1 |
|                  |                  | Kind of Response (Sensory/Physical) | 1 | 1 | 1 |
|                  |                  | Adaptation to the Environment | 1 | 1 | 1 |
|                  |                  | Constantly Evolving | 1 | 1 | 0 |
|                  |                  | Generating and Recycling (living being/construction material) | 1 | 1 | 0 |
|                  |                  | Self-organization | 1 | 0 | 0 |
| Sum of Possible Values for Each Project | 7 | 7 | 6 | 3 |
| Percentage Achieved by Each Project | 100% | 85% | 40% | 75% |

| Growth Standards | Source of Information | The Morphological Nature of an Origin | 0 | 0 | 1 |
|                  | Structural of Consistency | A Part with a Part | 1 | 1 | 1 |
|                  |                  | A Part in All | 0 | 1 | 1 |
| Changing of Percentages | Dimensions | 1 | 0 | 0 |
|                  | Volumes | 0 | 1 | 1 |
| Future Expansion | Repeatedly | 1 | 1 | 0 |
|                  | Centers of Expansion | 0 | 0 | 1 |
| Communication | Adaptation to the Environment | Addition | 1 | 1 | 0 |
|                  | Unity | 0 | 0 | 1 |
| Sum of Possible Values for Each Project | 9 | 4 | 5 | 6 |
| Percentage Achieved by Each Project | 44% | 55% | 66% | 55% |

| Levels of Growth | Division at Part-Level (Cells) | 0 | 0 | 0 |
| Repetition and Changing at the Level of the Whole | 1 | 1 | 1 |
| Sum of Possible Values for Each Project | 2 | 1 | 1 | 1 |
| Percentage Achieved by Each Project | 50% | 50% | 50% | 50% |

| Results of Growth | Volume | 1 | 1 | 0 |
|                  | Vital Characteristics | 1 | 0 | 1 |
| Sum of Possible Values for Each Project | 2 | 2 | 1 | 1 |
### Results of Growing in Architecture

| Standards of Growing in Architecture | Percentage Achieved by Each Project | Percentage Achieved by Each Project | Percentage Achieved by Each Project |
|---------------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|
| The Genetic Code                      | In Structural Materials              | In a Building as a Whole            | Materials from Nature              |
|                                       | 0                                   | 1                                  | 0                                  |
| Vital Growth                          | In Structural Materials              | In a Building as a Whole            | Interaction with the Environment   |
|                                       | 0                                   | 1                                  | 1                                  |
| Biological Design Levels              | Materials Characteristics            | Designing Philosophy                |                                     |
|                                       | 0                                   | 1                                  | 1                                  |
| Growth Chronology                    | Distinguishing Stages of growth      |                                        |                                     |
|                                       | 0                                   | 0                                  | 0                                  |
|                                       | 1                                   | 1                                  | 1                                  |

**Sum of Possible Values for Each Project:** 9

**Percentage Achieved by Each Project:** 55% 55% 66% 58%

### Biomimetic Methods for transmitting the characteristics of growth in architecture

| Measurement and Evaluation | Percentage Achieved by Each Project | Percentage Achieved by Each Project | Percentage Achieved by Each Project |
|-----------------------------|-------------------------------------|-------------------------------------|-------------------------------------|
| Bioregulation               | Exploring a Phenomenon              | Evaluate And Analyze the Phenomenon |
|                             | 1                                   | 1                                  | 1                                  |
| Deprivation                 | Determine the Kind of Transition    | Similarity between the Phenomenon  |
|                             | 0                                   | 0                                  | 1                                  |

**Sum of Possible Values for Each Project:** 4

**Percentage Achieved by Each Project:** 50% 50% 50% 50%
| Novelty | Very High Functional Difference | High Similar Function | Medium Similar Function, Different Behavior | Low Similar Function and Behavior |
|---------|--------------------------------|-----------------------|--------------------------------------------|-------------------------------|
| Sum of Possible Values for Each Project | 8 | 4 | 4 | 4 |
| Percentage Achieved by Each Project | 50% | 50% | 50% | 50% |
| Transition Goals | Research and Exploration | Characteristics | 1 | 1 | 1 |
| | | Figures and Forms | 0 | 0 | 0 |
| | | Biological Structures | 0 | 0 | 1 |
| Analysis | Vital Principals | 1 | 1 | 1 |
| | Specifications | 0 | 0 | 0 |
| Extrapolation | Natural Systems | 1 | 1 | 1 |
| | Future Changes | 1 | 1 | 0 |
| | Survive | 1 | 1 | 1 |
| Sum of Possible Values for Each Project | 8 | 5 | 5 | 5 |
| Percentage Achieved by Each Project | 62% | 62% | 62% | 62% |
| Methods of Design | Method Based on Problem | 1 | 1 | 0 |
| | Method Based on Finding the Solution | 0 | 0 | 1 |
| Sum of Possible Values for Each Project | 2 | 1 | 1 | 1 |
4.2. Results of the projects selected for application

4.2.1. Results related to the first Main Indicators (growth in the organism). The results of applying the first major element to the projects of the experimental study showed that there is a variation in the ratios in their secondary elements. Growth achieved the highest ratio of (75%), growth criteria achieved (55%), growth levels (50%) growth results (%66) as in the table.

4.2.2. Results of the second Main Indicators (development in architecture). By applying the second element to the projects, the results of the ratios of the secondary elements also varied. Development levels achieved the highest percentage of (100%), developmental results achieved (83%) translation of criteria of development in architecture achieved (58%), as in the table.

4.2.3 Results of the third Main Indicators (approaches of transferring characteristics of growth to architecture). The results of applying the third major item on the elected projects showed more consistency in the ratios of their secondary elements. Biomimetic levels achieved (50%), biomimetic measurement and evaluation achieved (50%), design approaches achieved (50%) as well, while transferring targets achieved the highest percentage of (62%), as shown in the table.

5. Conclusions
1- After studying and looking into the data, it is concluded that the concept of growth and its basic principles such as organization, sustainability, and prediction have a prominent role in achieving the functional sustainability and sustainability of buildings.
2- Growth in architecture achieves environmental sustainability as a result of the characteristics of response, adaptation, development, and the ability to explore and sense, in addition to using materials from nature and harmony with the environment.
3- The study concluded the procedural definition of the growth in architecture, which is “the ability of buildings for future expansion and to continuously develop in response to changing needs over time. It is an evolutionary architecture, and giving it the quality of life, it is a living, sustainable architecture. It is a responsive and adaptive architecture, and it is dynamic, interactive and renewable architecture”.
4- The emergence of patterns of buildings that have aspects and elements of life, with the laws, systems and mechanisms that govern them to create an architecture that possesses the characteristics of living things.
5- The characteristics of growth in living beings provide distinct solutions for contemporary architecture, which respond to external influences, interact with them and constantly evolve, taking into consideration the lack of influence on the surrounding environment.
6- By transferring the characteristics of growth of living beings to architecture, it is possible to produce bio-architecture, interactive, responsive, evolutionary, and renewable, and these are the manifestations of development in contemporary architecture.
7- The digital technologies and their design programs (such as algorithms) and production tools (such as robots) have a prominent role in overcoming the difficulties of transferring properties to architecture, after a series of interconnected processes starting with biomimetics and ending with the embodiment of the building in real situation.

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