MSA UNIVERSITY ENGINEERING JOURNAL

Augmented Design to Create a Sustainable Environment in Interior Architecture

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Abstract

Synthetic biology has allowed us to generate bioproducts from our natural environment. Modern natural sciences have been created to acquire technological mastery over natural processes, resulting in a never-ending stream of new items and technology being introduced into current society, enhancing living comfort and raising overall human well-being. As a result, this technological advancement has unintentionally resulted in increased fossil fuel use, population expansion, urbanization, and deforestation, all of that put further strain on future resources owing to pollution, resource depletion, and biodiversity loss. The study aims to analyse discussions over digital architecture and new industrialization as well as the impact of biotechnology on architecture, interior design, and more especially, the usage of living or semi-living materials in our built environment. Furthermore, as a material and technical innovator, a strong understanding of the disciplines of computational data generation, 3D printing, and digital manufacturing is critical. In addition, bio-augmented design investigates our current interaction with nature. It is the scientific study of life and living entities, ranging from simple organisms to the most sophisticated. The study demonstrates bio-fabrication, which involves designing with living beings where biosynthesis is replacing traditional manufacturing, plants which manufacture items, microbes which develop new materials, and energy-efficient bio designs. Furthermore, these new composite materials provide a vision into the near future when synthetic biology may be used to assist us in designing and building the built environment with higher performance and lower environmental impact than traditional architectural, as well as interior design approaches. The research highlights the shift from nature-inspired design to nature-integrated design. Many recent biological trends identify bio-futuristic design as a paradigm shift in interior design, creating a distinct interface for tectonic and ecological materials between nature and design, as well as an orientation towards healthier structures. Finally, the study concludes that using

living materials, probiotic design, bio-fabrication, bio-receptive design, and bio-augmented design can help to create a sustainable environment in interior design.

Keywords: Bio-Augmented Design, Sustainable Environment, Bio receptive Design, Bio fabrication, Probiotic Design.

Introduction

In a world where natural resources are becoming increasingly scarce, we must constantly reassess what sustainable items customers purchase. Live systems are intended to assist in the resolution of problems in a variety of sectors. Animals, plants, water, wind, materials, and people all move at varying speeds, following the spatial patterns which can be found in most landscapes and areas. The ecology of the Earth's diverse regions, where natural processes and human activities interact spatially to generate an ever-changing mosaic, is explored in this updated synthesis. Because there are many concepts in the realm of design and sustainability, the topic is very significant in today's society [1].

"Environmental," "sustainable," "green" materials and products are no longer uncommon. Although there is a growing market for all things "green," no number of green products can assure a "green" interior design solution. Understanding the importance of life cycle design, which is created as material selection, will change an ordinary design into a dramatically sustainable design. More studies about reducing the life cycle impacts of products during manufacturing have already been published, so designers should be aware of this. Furthermore, environmental factors during manufacturing are significant when selecting materials and products for interior environments, such as those linked to consumption, material practice, and product standards [2].

Designers and architects work in tandem with nature. They collaborate with bees, fungi, bacteria, algae, and plants to create new technologies which will help them advance in the design industry. Designers and artists collaborate with synthetic biologists to imagine what future products and interfaces could look like if living beings were manufactured. Their concepts depict a hypothetical future world to create new hybrid species, as well as designers, architects, and artists propose combining biology, chemistry, robotics, and nanotechnology. It mixes biological and non-biological (electronic and chemical) technology. Designers and artists are starting to embrace or revolt against the constructed world. As a result, new design trends emerge. The field of bio-augmented design is a new design path, reconciling elements of a potentially programmable "artificial" future with different perspectives on "natural" design. These designers are constructing and infiltrating a futuristic hybrid environment in which our everyday tools and products will be realized. [2] Designers must approach local interiors from a

E-ISSN 2812-4928, P-ISSN 28125339 (https://msaeng.journals.ekb.eg//)

lifecycle perspective, preserving items and materials for as long as feasible while reducing renovations and larger renovations.

The use of materials in the interior when selecting materials and products for interiors based on their life cycle processes, as well as the necessity of selecting materials for sustainable qualities, is the key to success for sustainable interiors. The trend of housing and living in city centers has increased the need for huge numbers of housing units. This indicates which the demand for materials used in the manufacturing and construction of structures and housing units will rise. Threats have risen rapidly as a result of an unsustainable increase in demand for natural resources without regard for their limits.

As a result, our environmental resources are facing a bleak future. The research is based on bio-augmented design, which works in a variety of "naturalistic" and "programmable nature" scenarios. In the topic of bio-augmented design, the research allows the creation of composite materials through a pioneering junction of synthetic biology, architecture, and computation. Changes in lifestyle, as well as an increase in consumption, are increasingly impacting how interiors are built in the residential and commercial sectors. Nature serves as a source of inspiration, role models, and novel engineering solutions for designers and architects. They use biomimicry principles to mimic processes or behaviors found in nature, although they use digitally created techniques.

These trends from artists and designers are looking towards the far future of living technology and high-tech sustainability. The study reveals a novel and inventive design which combines architecture, biology, and engineering. It investigates novel architectural production and simulation methodologies, as well as breakthroughs in synthetic biology, biotechnology, molecular engineering, and materials science. Furthermore, it examines how these subjects contribute to an increasingly interdisciplinary approach to environmental design. As a result, our contemporary built environment has a new sense of materiality, new hybrid technology, and unique modes of living.

The research aims to

- Exploring how we can design and integrate living materials inside buildings, improving the health of the individual and the planet. Hence, the need for sustainability solutions to highlight the role of interior designers and their clients in promoting the values, concepts of sustainable architectural and interior environments.
- Exploring the role of interior and architectural designers in promoting the concepts of sustainability in interior spaces through the correct selection of materials and design solutions to preserve the environment, in addition, achieve optimal use for users interacting with the spaces around them.

- Contributing to the understanding of sustainability alternatives by imagining the methods of employing sustainable materials, describing their properties, and establishing design approaches in making components of design elements.
- Investigating the topic of bio-augmented design in interior design to develop new sustainable materials, In addition, merge digital architecture and biotechnology.

Finally, the study focuses on natural and synthetic instances of the bio-augmented design trend, which offers tools and perspectives for biological design [2]. The study explains how interior designers and architects can process some of their practice's most significant environmental impacts, identifying materials and products, by understanding the influences of the biological design field, rather than just the materials they use to design residential, commercial, and other spaces [2].

Research Methods

The study paves the way for creative designers who are willing to imagine new relationships with nature and life. The study focuses on novel concepts in bio-sustainable models. Furthermore, developing a set of practical and effective criteria to assure sustainable interior design solutions is critical for supporting interior designers in their selection of sustainable interior design solutions via the field of bio-design. Furthermore, bio-augmented design is an alternate future in which the design shifts to a biological paradigm rather than relying on materials obtained from the industry's unsustainable petrochemicals.

The study includes many criteria and directions for attaining sustainable interior design, all of that are required to discover and accomplish a sustainable interior environment. The study focuses on issues of sustainable materials and their qualities in interior design. Hence, a two-stage strategy was implemented:

1. The first stage is to conduct a research study of the literature on topics related to the concepts of bio-augmented design. This also includes the study of the sustainable environment, definitions, classifications of sustainable materials, and elements of sustainable interior design. Hence, coming up with criteria for the foundations of creating an indoor environment is classified as sustainable through its design components.

2. The second stage includes a review of models which depend on strategies for the concepts of sustainability in the bio-augmented design process, their creation, in addition to the application of criteria extracted from the literature study in their analysis of elements and components.

E-ISSN 2812-4928, P-ISSN 28125339 (https://msaeng.journals.ekb.eg//)

The importance of the study is to comprehend the relationship and contribution of architects and interior designers to the preservation of the environment and natural resources. Furthermore, they considerably minimize energy consumption, hazardous and environmental pollutants, pollution caused by material manufacturing and conversion, in addition to the role of interior designers in establishing the notion of client demand in sustainable interior design.

Bio-Augmented Design Concept

The research focuses on bio-augmented design, which is a continuous body of work which works at the confluence of biology and architecture. It investigates new architectural paradigms and concepts using an interdisciplinary approach which employs design, computer, microbiology, and materials science approaches.

The significance of innovative approaches in developing strategies which are more sustainable, resilient, and healthy for the built environment cannot be understated [3]. There is a connection between physiology, biochemistry, and physical qualities in the realm of bio-augmented technology.

The study focuses on digital architecture and manufacturing, as well as the effects of biotechnology on architecture and interior design. Investigations on the use of living or semi-living materials in our built environment are especially needed. As a result, the study illustrates computational data generation, 3D printing, and digital manufacturing as technological and material innovators [3].

Environmental Sustainability

Sustainability is roughly described as "development which meets current demands while staying sufficiently adaptive to meet future needs." It was defined as a technical phrase for dealing with environmental challenges, together with its three dimensions: economic development, social development, and environmental protection. These dimensions interact with one another and may even complement one another. The goal of sustainability is to meet present needs without affecting future generations' ability to meet their own.

A sustainable environment is defined as "the result of both the structure and implementation of ecologically responsible and resource-efficient processes throughout the life cycle of a building: from planning to design, construction, operation, maintenance, renovation, and demolition." Every building and space built following sustainability standards which provide environmental solutions and efficient material use is considered a sustainable environment. As a result, "a sustainable environment will contribute more than it consumes" .It is the result of environmentally friendly design and material selection methods [4].

The issues concerning the environmental context of interior spaces and their constituent components meet the requirements of sustainable design to protect natural resources [5]. Through bio-augmented design techniques, the study introduces the concept of creating interior components to create a sustainable environment using biomaterials [6].

Sustainable materials

Many concepts define sustainable materials, which are based on the values of energy consumption, pollutant emissions from manufacturing processes, abundance, resource renewal, durability, material permanence, and economic implications. It is defined as materials which have a relatively good impact on societies and the environment, in addition, they are utilized to construct products, offer services, as well as improve the environment, such as structures. Every year, over three billion tons of raw materials are consumed by development operations around the world, accounting for one-fourth of total resource consumption. The goal of sustainable interior design is to rationalize the use of materials in an inventive way which allows for the preservation of natural resources without causing environmental degradation [4].

Source of Materials

The selection of materials may be an essential issue within the interior design approach, as materials are the primary element of the weather of interior locations. The way materials are employed, their quantity and distribution within the interior, as well as their ability to provide different design concepts, can all be regarded as distinct design elements [4]. Building and finishing materials can be classified based on their source.

1. Natural materials: These are materials which are left in their natural state with the option of applying various treatments on their surfaces, such as stone and wood.

2. Transformed materials: These are materials which have been transformed from natural materials, such as tiles and bricks, into transformed materials.

3. Synthetic materials: They mean materials which result from manufacturing processes. In addition, these materials do not exist in nature, such as plastics, dyes, and glass. Industrial materials have greater impacts on the environment in the processes which accompany the production stages, followed by the converted materials, while natural materials have the least impact. Therefore, in the disposal processes, industrial materials record the highest rates of negative environmental impact in terms of pollution, energy consumption, and converted materials.

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Their environmental impacts upon disposal are fewer than those associated with production procedures; additionally, natural materials continue to have the lowest environmental impact rates. The selection of sustainable materials in interior design is dispensed based on specific characteristics, besides the area unit is determined through the standards of things which scale back negative impacts on the setting through property materials properties which are employed in interior design, as well as become a part of environmental property systems. Furthermore, they contribute to the conservation of natural resources by reducing waste emissions and energy usage. As a result, a sustainable interior design helps to reshape the cycle of natural resource usage [4].

Bio-Augmented and Sustainable Design

Designers and artists create digital bio models based on cutting-edge biotechnologies. They create a series of systems which investigate a new ecological paradigm of building. It responds to various climates based on the interaction of ambient variables and the interfacial characteristics of materials containing living organisms. In contrast to traditional complicated and highly expensive "green architecture," the utilization of these planned systems creates a new symbiotic relationship between buildings and nature which is more computationally advanced and less expensive for buildings in densely populated cities [3].

These systems' applications are created employing advanced computation, such as modeling and simulation. Organisms are grown, in addition, materials are tested in real-world laboratories, providing rigorous iterative feedback and data for advanced prototype manufacture. Through a unique combination of abilities which enable the linkage of novel computational design, manufacturing, as well as laboratory protocols, with a special focus on innovative bio-digital design, we may explore new environmental design agendas which answer our cities' expanding issues [3].

On the most fundamental level, it investigates how to design and integrate living materials into buildings as a means of achieving more sustainable, resilient, and healthful strategies for the built environment. Several technologies are used in both the design studio and the laboratory, including computational design and innovative production methods, as well as material characteristics testing, experimental microbiology, DNA sequencing, and environmental monitoring. The research is being used in a variety of disciplines, including the following: [7]

Greening cities (Living Walls)	Probiotic Design and the Indoor Microbiome	Bio Design and Bio Manufacturing	Digital Fabrication and Robotics Bioprinting Technique

Figure 1. Diagram of bio-augmented design fields in interior design. [7]

Living Walls

Today, in an era of unparalleled urban development, there is an urgent need to improve city environmental quality. Plants and leaves are grown on the sides of buildings to create "green walls." [8] Interior living walls are strengthened in part because of their ability to improve indoor air quality, potentially lowering ventilation-related energy consumption. An indoor living wall is a vertical structure which promotes plant life indoors and can have an impact on indoor air quality. The designers devise methods for incorporating living walls into buildings which optimize positive effects on indoor air quality while minimizing negative effects on indoor air quality [9].

Figure 2. Interior Living Wall - XL Catlin project - 2011, London, United Kingdom. The reception area of the main office was renovated, in addition, a living wall was required to complete the look of the spectacular fixtures. It was a one-of-a-kind job with specific needs because the wall was double-sided, as well as on the 7th floor, weight was a crucial factor [10].

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Figure 3. Nike-Lab Store, Shoreditch, London, ANS, 2015. System of Living Walls (Interior). Nike is a well-known sporting and footwear brand.
The living wall was required for the Nike-Lab store in London as part of a project to make the room feel tranquil to remind customers of the outdoor application of the products for sale. This living wall was both impermanent, as well as did not necessitate the use of a watering system [11].

Figure 4. The left picture is the Melissa Galeria project, 2017 in London, United Kingdom, using the ANS Living Wall System (Interior). Melissa is a well-known manufacturer of jelly shoes and fashion accessories. The Galleria (a concept store) in London's Covent Garden has been described as a meeting place for fashion, art, and design. They intended to change the area, in addition, provide a one-of-a-kind retail experience by adding a lush green backdrop. With eight different species of indoor plants, the walls provide a magnificent green screen [12].

Figure 5. The right picture is the **All-Good Things** project**, 2019 in Birmingham, United Kingdom, ANS Living Wall System (Interior).** The store's sustainable design statement was produced to be displayed behind the counter. Signage on the living wall distinguishes the element, as well as makes it readily recognized [13].

Probiotic Design

Bio-digital work is being published at a new intersection of design, biology, and engineering. It fosters a new network of designers, artists, and scientists who are exploring biological materials in the built world through new design processes and creative manufacturing techniques. Advances in synthetic biology, biotechnology, molecular engineering, materials science, as well as new methods of manufacturing and simulation in architecture, product design, in addition, textiles, are resulting in a more complicated approach to design. As a result, there is a new feeling of materiality, new hybrid technologies, as well as new living styles [14]. However, there is an increasing awareness of how architecture influences human well-being, architectural philosophy still sticks to the function of antibiotics. The research proposes the concept of probiotic architecture as a way to frame the changing understanding of health in architectural design, implying which the microorganisms which colonize humans (the human microbiome) and our built environment (the built environmental microbiome) have the potential to influence our health and the resilience of our buildings [15].

The design of probiotics is based on a recent understanding of the microbiome, as well as the need to incorporate environmental microbial variety into buildings. The study employs an interdisciplinary approach between microbiology and architecture, to develop living materials paired with beneficial bacteria for buildings in order to directly modify the inside microbiome toward a healthy microbial state. This method employs a combination of in vitro and in silico methodologies to investigate the design, manufacturing, as well as survival of probiotic materials. They are scaled up to the size of the building as a series of probiotic tile roofs, which are then installed in a test environment to be monitored for their impact on the interior microbiome.

The study demonstrates a successful approach for integrating live bacteria into ceramic and concrete substrates. Because they have been found to limit pathogen growth, they can also directly enhance the microbiological presence of healthy indoor bacteria in the environment. The study shows this method from a design standpoint, as well as highlighting the significance of bio-design as an established topic of architectural research due to its fundamental approach to design employing live cells and systems. Bio-design has the potential to establish a probiotic approach to architecture. The rise of bio-design as a research agenda in architecture and design has been primarily influenced by contemporary sustainability concerns. Designers have looked at breakthroughs in biotechnology and biomedicine employing live organisms, which are considered as favorable compared to present materials production systems, at the material level [16].

The concept of developing new types of living materials has a history in the field of bio-design, particularly among those who attempted to investigate the potential of designing and implementing live or semi-living materials on a variety

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of scales, from clothing to goods and buildings. Designers study the area of biomanufacturing, which entails designing with live creatures and focusing on new production procedures for existing materials to give them new identities. This method has recently been used in bio-design methods. As a result, one of the key obstacles of living materials and their application to architecture is the need for the permanence of nutrients and water, both are scarce in structures.

1.1.1. The Indoor Microbiome

The sorts of microorganisms found in our houses are influenced by architectural and interior design. As we learn more about "good" bacteria, in addition, to their function in our health and well-being, it is critical to design buildings that not only decrease our exposure to pathogens but also improve our exposure to beneficial microbial variety. Designing locations, materials, and interventions which can boost the number of environmental bacteria in our interior spaces is one method to accomplish this [7].

Richard Beckett is one of the most prominent bio-enhanced design researchers. He is a researcher at UCLA's Bartlett School of Architecture. His objective is to design structures that, like the human body, can support particular microbial communities (also known as "microbiomes"), as well as aid in the battle against infectious diseases [17]. Humans, according to him, are not just beings who inhabit space, but spaces which they inhabit themselves. This is the idea behind "probiotic architecture." These indoor bacteria have the potential to harm human health. He is curious about how buildings and their microbiomes may be designed to make them healthier and more robust [17].

In recent years, our understanding of the microbiome has advanced significantly. Researchers are only now beginning to unravel the complex web which, we believe, connects bacteria and our biological systems - from digestion to the immune response, hormones, as well as even neurochemistry. Meanwhile, he is interested in how architecture might help pave the path for healthier buildings. He plans to develop strategies to increase our daily exposure to microbial diversity while we wait for a better understanding of what a healthy microbiome is from medical fields [17].

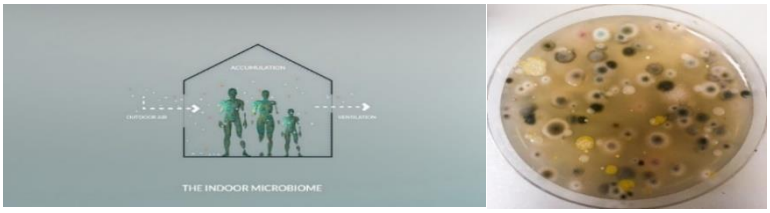

Figure 6. The indoor microbiome diagram and its analysis [7].

The design for microbial variety stimulates competition. Pathogens are shared in their new home with other, milder species due to competition. Alternatively, we may opt to actively grow strains of bacteria on our rooftops, for instance, antibacterial processes which can then inhibit the emergence of antibiotic-resistant germs. As a result, Richard's research seeks to construct structures capable of combating infectious diseases before they reach our bodies. In order to accomplish this, he used an interdisciplinary approach from all of the arts and sciences [17].

1.1.2. Bio-receptive Design

There is an urgent need to find new strategies to improve the environmental quality of our cities in an era of unprecedented urban development. Bio-Receptive Design investigates the advent of a new bio-digital physical phenomenon which is altering architecture's environmental performance. The bio-futuristic design represents a paradigm shift in modern design and architecture, giving a distinct interface for tectonic and ecological materials between nature and architecture, moving beyond design inspired by nature to design integrated with nature. Unlike current methods to vertical greening systems, the bio-receptive design investigates the biological colonization of buildings and infrastructures, in which varied microbial populations interact with the physical substrate, in addition, nature becomes an intrinsic component of architectural design [7].

As a new tool for sustainable design, digital design, simulation, and fabrication processes highlight a time-dependent changing state. The bio-receptive design investigates projects in which physical, as well as environmental variables, are examined on multiple scales at the same time. It employs complex self-generated computational tools to disclose an evolutionary, variable-driven design process which results in construction prototypes to specify new bio-digital-physical parameters. The bio-receptive design employs interdisciplinary working methods, necessitating expertise in advanced computation, manufacturing, design engineering, laboratory, and biology protocols [7].

1.1.3. Computational Seeding of Bio-receptive Materials

The purpose of the project is to create a new form of façade panel which is essential for the built environment. Using a new type of bio-receptive concrete and an eco-driven design, the panels are intended to foster micro-organic development directly on building facades as well as infrastructure walls [7].

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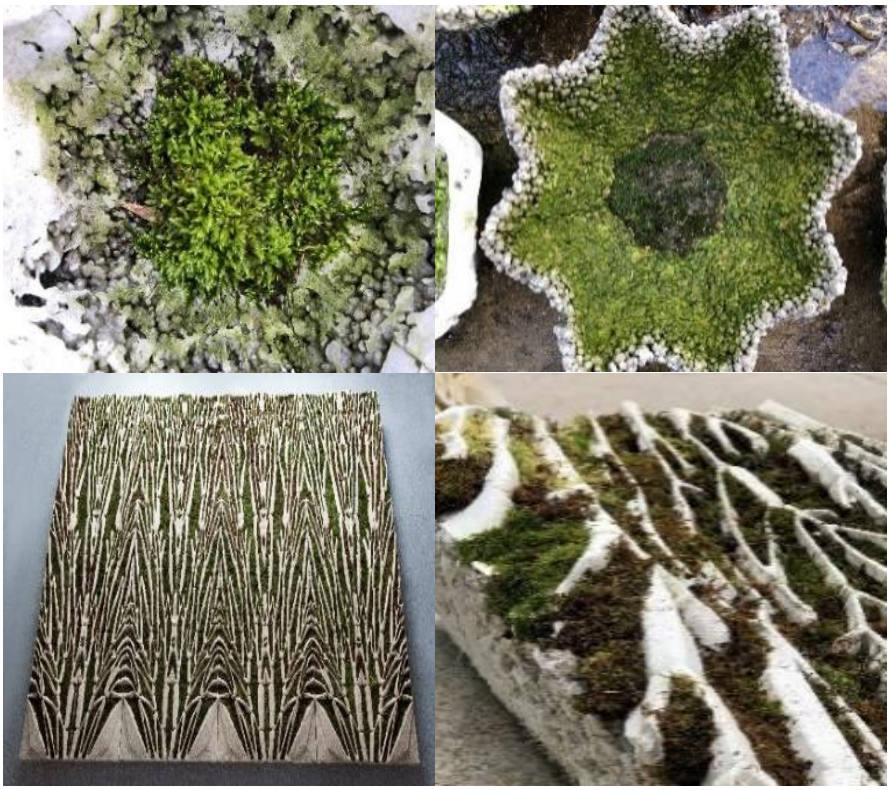

Figure 7. Bio-receptive Design is a project which creates a different interface between nature and architecture for tectonic and ecological materials [7].

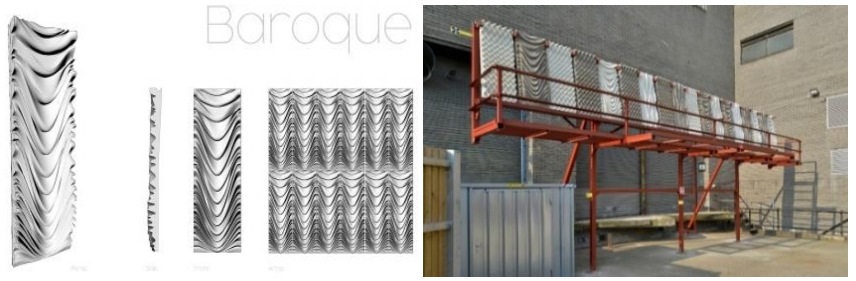

Figure 8. Creating a new form of facade panel which is essential for the built environment. [7].

Bio-design and Bio-fabrication

The emergence of contemporary design approaches which intertwine biology with art, architecture, and design, particularly those seeking to incorporate

living organisms into materials (growing materials; digital biomanufacturing), has been primarily driven by material sustainability and climate concepts. Aside from these vital domains, there is potential for these design methods to play a role in the less researched field of construction and resilience. Design using living or semi-living materials investigates the prospect of "moving buildings" which can sense and interact without computers, structures to detect damage and mend themselves after a flood or storm, in addition, buildings which can self-assemble and disassemble according to requirements. [7]

Figure 9. Biomaterials research and bio-fabrication. [7]

Bio-printing Technique

The bioprinting technology shows potential for constructing large-scale hybrid biological structures for applications such as bioprocessing in architecture and the built environment. [18] Nature has been known to demonstrate extraordinary structural and ecological features by depositing simpler materials. However, research into the production of additives and similar structures from natural or synthetic polymers for engineering or architectural applications is still in its infancy. The aim of living architecture research is to combine biological elements within structures, which is referred to as bio-hybrid. There is a rising push to create novel hybrid biological constructions which could boost vegetation, in addition, to green coverage of building envelopes and rooftops [19].

E-ISSN 2812-4928, P-ISSN 28125339 (https://msaeng.journals.ekb.eg//)

Projects in Bio-Augmented design

There are some projects including bio-augmented design, for instance:

[Probiotic Tiles] project

Probiotic Wall Tiles: Ceramic Tiles containing Bacillus subtilis .
Richard Beckett is a member of the NOTBAD project, along with Dr. Sean Nair and Carolina Ramirez-Figueroa. Probiotic wall tiles are cultivated with live bacterial cells capable of suppressing MRSA growth. These tiles describe a new way for creating bright interior materials and surfaces for buildings which contain live bacterial populations, as well as a direct influence on the indoor microbiome toward healthier buildings [20].

Figure 10. Probiotic wall tiles have the potential to reduce human exposure to dangerous germs while also limiting the proliferation of antimicrobial-resistant bacteria in buildings[20].

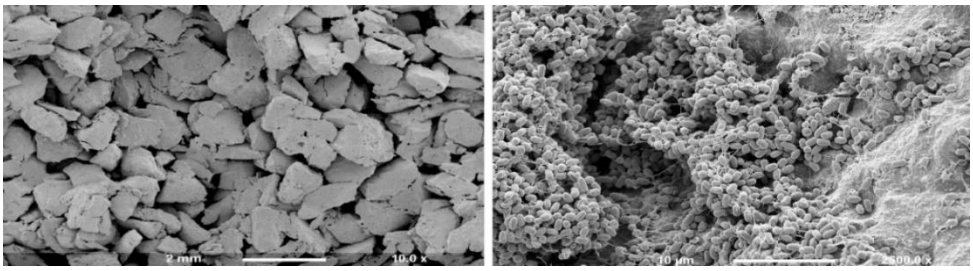

Figure 11. SEM images show the porous material at 10x magnification and the dispersion of bacterial cells within the material matrix as a biofilm at 2500x magnification [20].

Figure 12. The porous and non-porous ceramics in the multi-material tiles were computationally developed and poured into two-part rubber molds constructed of 3D-printed positive materials to inhibit pathogen growth on the surface, the tiles were autoclaved and infected with bacterial cells [20].

[Robotic Inoculation] project

Computational design: Four different types of tiles can be layered in different directions to generate contrast [20].

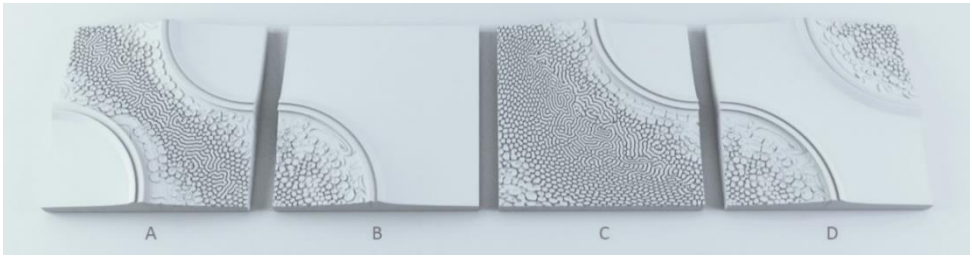

Figure 13. The robotic Inoculation project is composed of four different types of tiles. [20]

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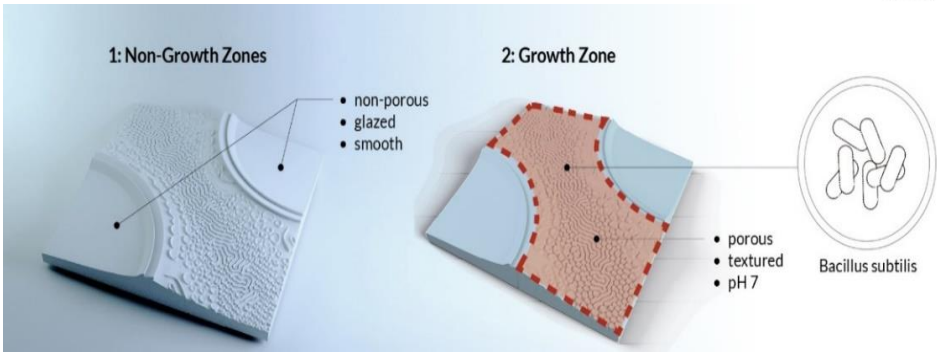

Figure 14**.** In the Robotic Inoculation project, there are non-growth zones and growth zones[20].

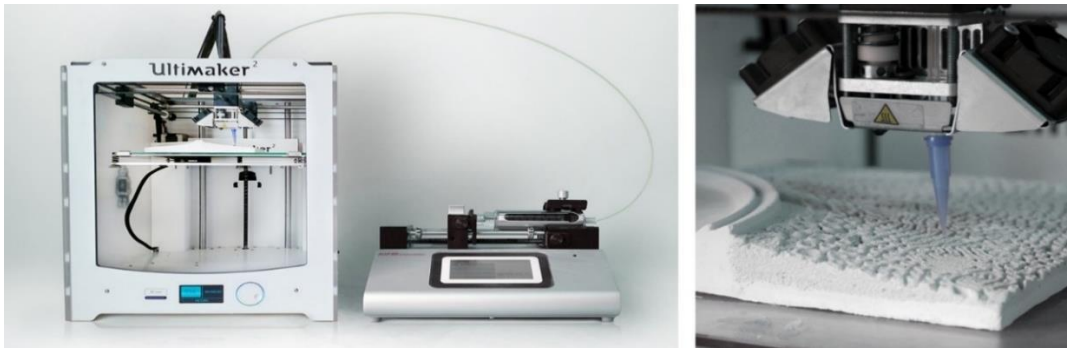

Figure 15. Each slab's porous biological zones are designed to allow more or less biological activity, which may be informed geographically by microbial scanning of the building [20].

[Cilia 2] project

Sarat Babu and Richard Beckett posted Faux Fur Tiles with Additive Layer at SCIN Exhibition for Clerkenwell Design Week. Cilia is a collection of selective laser sintered roof tiles made up of tens of thousands of fibers which began as a commissioned investigation into BREAD's materials research capabilities for application in interior surfaces. Although the surface of each tile is pleasant to the touch, it is constructed from a single piece of nylon. Each feature of the architecture can be controlled, in addition, adjusted according to the designers' aim using digital modeling and Netfabb's Selective Space Structures software. It has made it possible to adjust the visual impact and feel of each tile. Cilia challenges our assumptions about the technical as well as the physical possibilities of additive layer manufacturing [21].

Figure 16. The combination of current modelling and fabrication enables us to control these elements at an unparalleled level of detail which traditional technologies cannot match [21]**.**

[Concrete Jungles] project

Richard began by designing the material on a small scale, with tiny holes less than half the width of a hair, to create the right porous conditions for bacteria to grow in, then half the medium-scale from 0-3 mm in texture, where the geometry of the texture can create microclimates and ports on the surfaces to trap or help bacteria spread. As a result, he designed at the macro level, which we can eventually see and touch. Richard's architecture functions as an interface for the microbiome, creating a link between us, our environment, in addition, each other while producing appealing tactile surfaces. Dr. Shaun Nair of UCLA's Eastman Dental Institute's microbiological knowledge contributes to the creation of bacteria strains which prevent the growth of MRSA. Professor Mark Miodonic, Director of the Manufacturing Institute, used his materials engineering expertise to help form clay, and concrete into porous surfaces ideal for microbial growth; in addition, Carolina Ramirez-Figueroa, Product Designer at RCA, assisted in fashioning tiles, knobs, and panels which drew people's touch [17].

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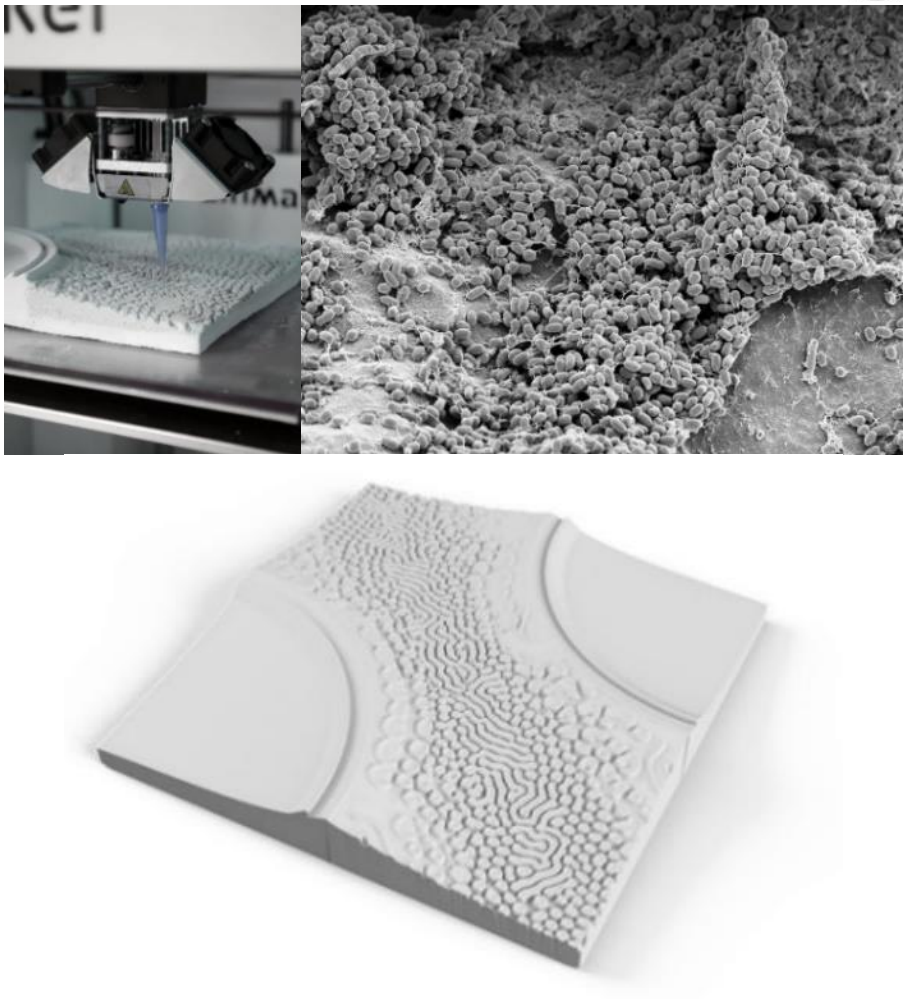

Figure 17. In the Concrete Jungles project, tile A render PERSP [17].

[Bio Illumine scent Plateau] project

The Bioluminescent Plateau is a bioluminescent urban road project in London's Camden neighborhood. As an architectural idea, the project employs the concept of a horizontal platform as a public place where urban greening is achieved through the growth of photosynthetic microorganisms such as bioluminescent algae, fungi, and microalgae. The proposal is made up of three key engineering components which multiply and merge to create multipurpose environments. For its occupants, the plateau comprises three key concepts: functional walking spaces, biological growth zones, benches, and transitional regions. Physical specifications and engineering gestures are related to the various regions [22].

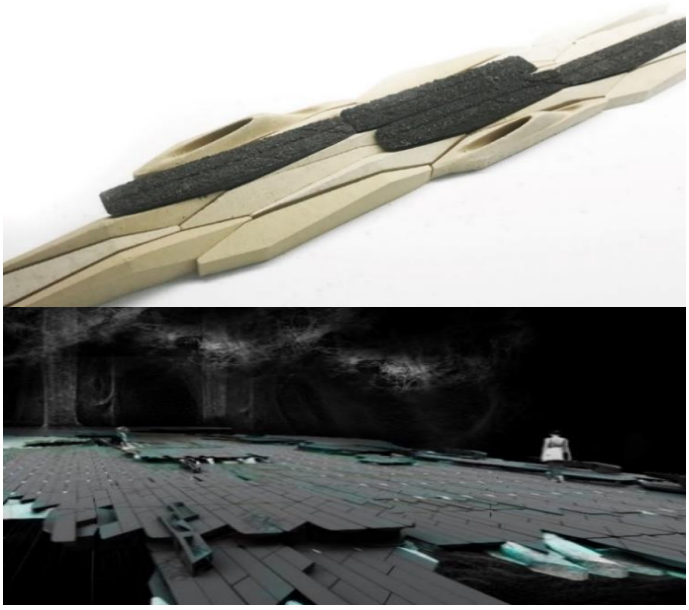

Figure 18. The Bioluminescent Plateau is a bioluminescent urban road project in London's Camden neighborhood [22].

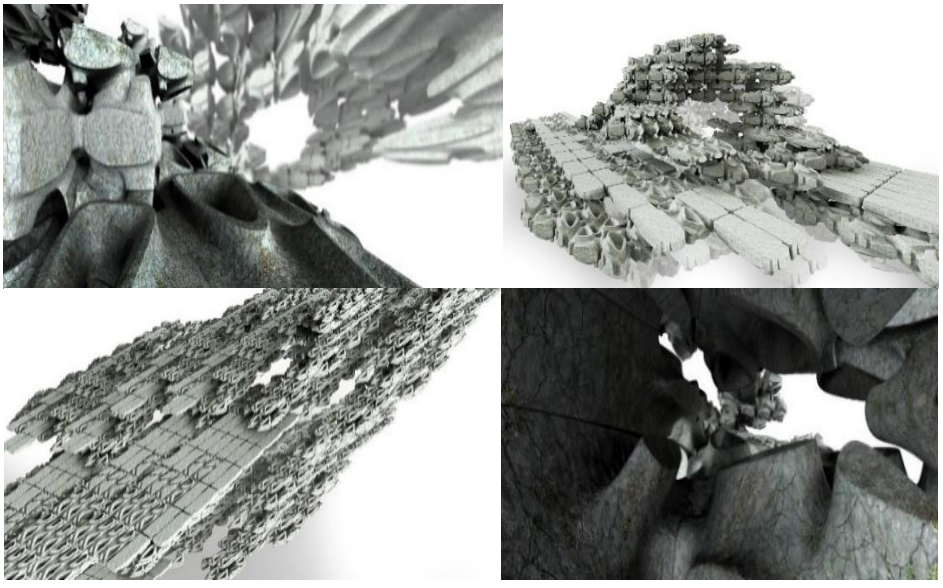

Figure 19**.** The proposal is made up of three key engineering components which multiply and merge to create multipurpose environments [22].

E-ISSN 2812-4928, P-ISSN 28125339 (https://msaeng.journals.ekb.eg//)

Discussion and Results

As our everyday tools and goods come to life through the integration of architecture, biology, biotechnology, and materials science, the discipline of bio-augmented design presents new directions in interior design. The study focuses on how biotechnology, digital design, and biomanufacturing affect the usage of living materials. The field of bio-augmented design investigates the human-nature link. It is the scientific study of living beings and life. As a result, the study delves into the topic of bio-manufacturing, which includes creating with live creatures to generate new materials and bio-sustainable designs in interior design. The study of bio-augmented design in interior design, the development of novel sustainable materials, in addition, the integration of digital architecture and biotechnology are all part of the research's goal of promoting principles of sustainability in interior environments. In addition, bio-augmented design concepts are being used to create sustainable settings and living materials.

Furthermore, the application of numerous approaches from computational design and innovative production methods with material property testing, biology, and application in sectors such as (living walls, probiotic design, bio-design, bio-manufacturing, digital fabrication, bio-printing technique, robotics). Finally, the study analyses the impact of bio-augmented design on establishing a sustainable environment in interior design by utilizing living materials, probiotic design, bio-fabrication, and bio-receptive design.

Conclusion

Artists, designers, architects, and scientists are experimenting with biological materials in interior design using new design processes and cutting-edge production techniques. Furthermore, some academics have expressed an interest in engineering buildings and their bacteria to make them healthier and more durable. The study of the bio-manufacturing field, which combines development using living creatures with innovative production techniques, is the foundation of the research. A paradigm shift in modern design and architecture is defined by the dynamic of futuristic design. Integrating living creatures into materials via digital bio-fabrication and sustainability ideas is critical. Finally, the study concluded that the use of sustainable materials to enrich and improve interior settings is a shared responsibility of interior designers and users.

Interior designers should create solutions to improve the aesthetic level and long-term performance of interior spaces, as well as encourage stakeholders (users) to provide materials and furniture which adhere to the principles of reuse and recycling, to improve the environmental sustainability of interior spaces and build a better sustainable future.

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