ENGINEERING FOR SUSTAINABLE DEVELOPMENT AND LIVING

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Preserving a Future for the Next Generation to Cherish

Edited by

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Dedication

To every person who endeavors towards
sustainable living and development.

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Preface

Mike Huckabee put it perspicaciously, "The most important thing about global warming is this. Whether humans are responsible for the bulk of climate change is going to be left to the scientists, but it's all of our responsibility to leave this planet in better shape for future generations than we found it." All of us have the responsibility to exercise good stewardship in realizing more sustainable living and development. This volume brings together experts around the world to disseminate the latest knowledge and research in selected aspects toward engineering for more sustainable development and living. Who could argue against the assertion that collaboration is needed to materialize the sustainability loop? **Abdallah and Estévez** enlighten us that sustainability is part of our DNA in *Chapter 1*; "Sustainable Development and Living—Now or Never." Yes, even a living cell utilizes inherited biological intelligence to organize its resources for current needs and future existence. For the human species, this includes taking care of every fellow being around the globe. To do so, we must help developing and remote communities to have access to electricity, as exhorted by **Reader** in *Chapter 2*; "Developing Remote Communities: Access to Electricity." Reader highlights that two key targets of UN Sustainable Development Goal 7 are to ensure universal access to electricity and increase the share of renewable energies by 2030. **Zhang, Enevoldsen and Xydis** show that hybrid renewable energy systems can be much more cost effective than on-grid connection for some remote communities in *Chapter 3*; "Hybrid Renewable Energy Systems—An Emerging Way for Power Generation only for Off-grid Cases or not?" One cannot avoid energy storage when discussing renewable energy. In *Chapter 4*, "Beyond Efficiency: Balanced

Renewable Energy Storage System for the Future," **Onwuchekwa** posits the right question concerning how we can manage the 'toilet paper crisis' when fossil fuel utilization is suddenly halted. While Mars may be a future possibility, the more down-to-earth solution is to be ready to deploy efficacious energy storage systems to fill the void with renewable energy more promptly. To further energy efficiency in building, the local weather needs to be more accurately accounted for. **Sharma** presents "Joint Frequency Bin Weather Data a More Accurate Approach in Estimating Air-conditioning Load," in *Chapter 5*. It is shown that joint frequency bin data of dry bulb temperature and relative humidity predict building energy requirements more accurately. Talking about energy usage for human thermal comfort, **Balo and Polat** disclose "Energy Productivity with the Effective Design: Case of Medical Waste Storage," in *Chapter 6*. With cooling making up the highest energy cost in medical structures, combining low-energy building strategies with source-efficient and low-cost manufacturing envelopes can carry a long way in mitigating climate change. To ensure improvement, we must assess the performance after implementation of the promising measures. **Gökgöz and Erkul** communicate the energy efficiency scores of European countries in *Chapter 7*, "Analyzing the Sustainable Energy Efficiencies of European Countries." It is shown that some European countries may not achieve the desired levels of sustainable clean energy efficiency. Construction is the right place to start incorporating sustainable development and living. **Jimoh, Yusuf and Oyewobi** present a framework for this purpose in *Chapter 8*, "Framework for Sustainable Construction Practices in Abuja-Nigeria." Another means to promote sustainability is to improve engineering system performance. In *Chapter 9*, "Engineering Vortical Flow via a Cylindrical Rod," **Ahmed et al.** suggest that a cylindrical rod can be exploited to do just that. For example, desirable vortical flows can be generated for enhancing heat transfer and thus the efficiency of many systems which involve heat exchangers. The volume ends with a very timely sustainable living issue, "Post Covid-19: A Water-Energy-Food Nexus Perspective for South Africa," as *Chapter 10*. **Naidoo et al.** provide adaptation strategies through water-energy-food nexus planning, building resilient communities for tomorrow.

Acknowledgments

This book would have been decimated by COVID-19 if not because of providence from above and the resilient experts who furnished the state-of-the-art chapters. A big round of applause goes to the anonymous reviewers who enhanced the quality of each chapter. We are most grateful to William (Xi) Wang who graciously put the individual chapters into one unifying volume. It would be amiss if we do not promulgate the super-supportive team led by Dr. Jeff Young at BrownWalker Press/ Universal Publishers, Inc. We look forward to the opportunity to collaborate for a follow-up on Sustainable Development and Living.

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Sustainable Development and Living—Now or Never

Yomna K. Abdallah, Alberto T. Estévez

1. Sustainability loop: the answer is "collaboration"

Sustainability isn't a recent concern: as long as human beings have lived, they exhibited different levels of sustainability in their interaction with the surrounding environments. It is fair to assume that sustainable behavior is an instinct in every living being. This is simply inherited simultaneously through their DNA and their body's pure biological intelligence exhibited in the methods that a living cell uses to organize its resources to address its current needs and protect its future existence. The kind of intelligence that processes all genotypes and exhibit them as phenotypes in response to their micro and macro environment, guarantying not just the sustainability of resources and processes, but also the sustainability of their existence through morphogenesis and evolution. In this way, every single cell in any living being is performing sustainable behavior, furthermore, interestingly, all living cells exhibit a swarm intelligence as the essence of their behavior. They work for their survival and prosperity, but also, they work collaboratively with their population for the prosperity of the whole, understanding

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wisely that this is the way to ensure their continuity. This notion applies to all aspects of this infinite debate amazingly. Imagining a single living cell as a human and the whole organism as the urban fabric, through a socio-psychological lens, it becomes very clear why are some communities more prosperous economically and culturally than the others. Scaling this metaphor to architectural and urban design, considering architectural envelopes or buildings as agents and the whole urban fabric as the entire body, gives a hand on diagnoses of the current deficiency in attaining architectural sustainability due to the lack of collaborative patterns in architectural units and the entire urban fabric. In fact, sustainability never can be achieved in one face of life separately from the others. Sustainability is a state or a lifestyle that applies to all aspects of life together in different scales and with different amounts. Sustainability in architecture echoes strongly in economic sustainability, reducing materials, processes, and operation costs. It also lengthens the life of buildings, reduces the maintenance costs to the least. Another aspect that is related to architectural sustainability is public health, through ensuring the user's comfort and wellbeing which results in behavioral sustainability increasing the psychological tolerance, and boosting productivity that reflects on the economy again in a connected loop, not to mention already the fulfillment of environmental sustainability.

As reasoned sustainability was always based on "collaborative behavior", a lesson learned from all creatures that cooperate to survive and thrive together, only humans fail to fully understand and apply this notion. In times of great civilizations, it was obvious how people were organized in definite roles, that made them exploit their creativity to the maximum knowing that they are a pixel in the big picture, no wonder how great wonders such as the Giza pyramids were built. From this collaborative, role-based communities emerged great civilizations with advances in all aspects of life, and through interaction and creation emerged culture, that exhibited richness in various arts including architecture.

2. Sustainability is a basic instinct

Similar to the nutritional concept "your body tells you what you need to eat", this natural-informed model applies in every aspect of life. Our very early ancestors that lived in the caves were informed by their bodies to take shelter from harsh environmental conditions such as rain, sun, and natural disasters. Their natural instinct to adjust their rocky habitats to more comfortable and personalized homes have directed them to exploit their surrounding environmental resources in a native and basic way. Leaves, branches, animal leathers, and whatever materials they could find, handle, and adjust were used. This kind of personalization of a plain basic architectural eco-system such as a cave wasn't just a functional adjustment, but also a cultural development derived from the tendency to bond with the "second skin" and make it literally feel like a home. A safe shelter, a private and personally customized item; these ideas are intrinsic in human cognition for different types of architectures. Depictions found on ancient caves of a man wrestling wild predators (Figure 1.1) or hunting prey animals is not just religious meth, or a psychological need for assuring oneself that he can win over his natural competitors or wild enemies, but also a symbol of personalization, privacy, and belonging feeling, from where emerged all sophistication in architecture, artifacts and various visual arts. This is proven by the typical naive behavior of a two years toddler painting and drawing simple human shapes on the walls of his "home", before knowing even how to speak words or to grasp a pencil properly. This basic cognition of turning a habitat to a "home" isn't monopolized only to our primitive ancestors or children, in fact,

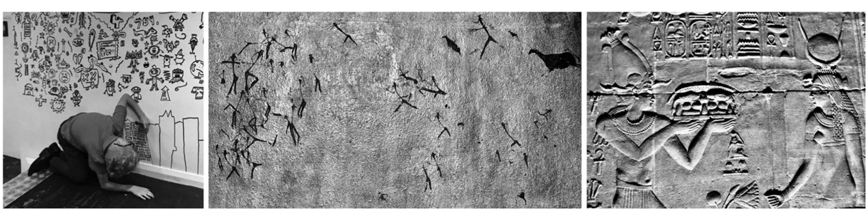

Figure 1.1 The natural instinct of personalizing the home environment, exhibited in the cave drawings, ancient Egyptian carvings on temples, and kid drawing on walls, this simplified abstract forms were later used as a source of inspiration in visual arts by numerous painters, like Henri Matisse. From left to right: a) The doodle boy, a child that developed the natural tendency to depict on walls, and got famous for his drawings and later was doing the "Number 4" restaurant wall decorations (https://www.boredpanda.com/doodle-boy-decorates-restaurant-joe). b) Prehistoric Mediterranean cave depictions. Photo by Estévez, A. T. c) Ancient Egyptian temple carvings, Temple of Isis on Philae Island (Aswan, Egypt). Photo by Estévez, A. T.

this was adopted even in the most advanced and sophisticated civilizations until the moment we didn't figure out all their advances in different fields. A powerful example is the depictions on ancient Egyptian temples or their permeant homes as their religious belief implied.

This customization or personalization of the surrounding environment is even a very natural and non-limited to human behavior. Take bacteria as an example, as soon as they find a rich environment to attach to, they begin to secret chemical substitutes called "extracellular matrix" that they use for customizing their "new homes". Interestingly this matrix is mainly for mediating their communication through the intelligent phenomenon of "quorum sensing" or chemotaxis as bacterial cells are able to communicate using quorum sensing (QS) products such as N-acyl homoserine lactone (AHL) to guarantee their collaborative work for the prosperity of the colony, warning each other from danger and informing each other with resources' places. Once they managed to colonize a surface, they form collaboratively a stronger form of microenvironment which is called the biofilm that grows through a combination of cell division and recruitment. Polysaccharide matrices typically enclose bacterial biofilms. In addition to the polysaccharides, these matrices also contain material from the surrounding environment as soil particles, proposing harmony and unity between the habitat and the inhabitant. Reaching the final stage of biofilm formation which is dispersion, in which the biofilm is established and may only change in shape and size (Robertson, et al., 2017, pp. 1157–1163).

Developing the architectural sophistication but not necessarily sustainability grew by the continuous interaction between human and his surrounding environment. As a matter of fact, luxury could be contradictory to sustainability, as the scarcity of resources triggers the tendency to the wise use and management of them. This concept is also very typical to human nature and almost all living creatures, for example, fungal cells convert themselves into a dormant state in the situation of resources' scarcity. Persistent Mycelial Networks performs 'Sit and Wait' Strategy, as the arrival of new resources can result in reallocation of biomass, as fungal mycelial networks are connected they have a sort of communication since hyphae maintain continuity with their immediate 'ancestors' and if contact is made with neighboring regions, theses hyphae can become connected via new formation of cross-links. This results in collaborative loop forms or structures that are both radially and tangentially connected in these hyphal systems with many loops (Fricker, et al., 2008, pp. 3–18). Not only does the mycelium respond by changes in resource availability by sitting and waiting in times of scarcity but also with physiological responses as there is highly coordinated uptake, storage, and redistribution of nutrients throughout the network. Many factors, including the overall nutritional status of the mycelial system, and the distribution and quantity of colonized and newly encountered organic resources, affect the balance between, and the main sites of uptake, storage, and demand for carbon and mineral nutrients. In fungal strains, the internal substrate is used to obtain external substrate by active transport across the plasma membrane. The acquisition rate must, therefore, depend on the amount of internal substrate available to perform the active transport, external substrate available for absorption, and the hyphal surface area over which the absorption occurs (Fricker, et al., 2008, pp. 3–18; Boswell, et al., 2007, pp. 605–634). This process is then related to the translocation mechanisms in order to distribute the uptake substrates where needed most. These two different translocation mechanisms, which are responsible for nutrient reallocation in many fungal strains, are called simple diffusion and the active movement of intracellular metabolites from regions of local excess to regions of local scarcity (Boswell, et al., 2007, pp. 605–634). Only newly-formed hyphae (and associated hyphal tips) use active translocation, while older, established hyphae use diffusion as the major means of internal nutrient reallocation (Boswell, et al., 2007, pp. 605–634). These translocation mechanisms align with two distinct spatial propagation patterns of growth: exploration and exploitation. The exploration phase is adopted in low-nutrient environments and features fast-moving hyphal tips coupled with minimal branching, resulting in a sparse mycelial network. The exploitation phase is adopted in high-nutrient conditions and features slower-moving hyphal tips and increased branching and anastomosis, resulting in a dense mycelial network.

Similarly, one can find many examples in animal and insect kingdoms of either individual or group, the wise use of resources. And when it comes to human, shockingly, he proves to be way less wise than these advanced intelligent creatures, the difference is either the optimistic plan that mis-leadingly makes humans consume their environment resources in times of excess or the sudden unstudied response to disasters that limit their vision into finding a fast solution for a menacing situation. This interpretation perfectly aligns with the physical analysis of any natural ecosystem, the extremes never work properly, only reaching equilibrium state always offers the perfect solution, and maybe this is why mankind was always swinging between flourishing and decay, abundance, and scarcity.

3. Sustainable materials between vernacular and futuristic

Attaining sustainability shouldn't be an aim or a solution but rather a lifestyle, looking back to analyze most of the architectural heritage we can see that the most sustainable models were derived from the scarcity of resources. For example, in Islamic architecture, the concept of "Masharbia": the famous see-through window that is not just ultimately sufficient climatically, religiously, and culturally, but also and above all derived from material sustainability. "Mashrabia" was born from the need to cover wide architectural openings with a breathing membrane mainly made of wood. In Sahara environments were high trees of large spans of solid and resistant wood aren't existent, and where building and fabrication techniques are manual, the solution existed in the small pieces of wood wastes from other fabrication processes of other architectural elements. The functional necessity and the scarcity of adequate material to achieve it, led to the sustainable concept of "recycling". Moreover, the limited spatial dimensions of the waste wooden pieces led to "uniformity, unity and solidarity" concepts mainly reflected from the religious belief of the Muslim architect, driving him to shape this miniature wooden pieces into uniform pieces that when joined with each other form the lace breathing façade that enables the habitant a clear view of the outside where the contrary isn't possible, addressing also religious and socio-cultural aspects. Similarly, masterpieces are always born from challenges and limitations, as such the concept of "architecture of the poor" of Hassan Fathy, that he learned from the Nubian builders, building their homes from mud bricks, with optimized geometric forms that fits sufficiently the material properties. Moving to Gaudi's trencadís that he uses from ceramic wastes and introduce it in ultimate beauty as covering material in number of his outstanding marvels (Figure 1.2).

Figure 1.2 Scarcity leads sustainability, the limited material amounts or physical/mechanical properties trigger the sustainable architectural solutions based on "uniformity, unity and solidarity" (as exhibited from left to right). a) The Zisa, Palermo (Italy), 12th–14th century, the see-through lace window is inspired by Mashrabia from Islamic architecture, exhibiting the ultimate functionality of breathing, the see-through and privacy-maintaining window from miniature recycled pieces of wood. b) Gaudi's technique of trencadís employed on the marvelous coverings of seating benches at Park Güell in Barcelona. The name of this technique comes from the main feature perceived at first sight: broken tiles, plates, and cups, originally come from the recycling of broken pieces. Photos by Estévez, A. T.

Typically, material optimization and sustainability in nature never go alone, they are always combined with structural efficiency. No better example than Gaudi's Masterpiece "La Sagrada Familia", and his previous experimentation in Crypta of Colonia Güell, where the genius creator optimized the geometric composition according to natural forces of gravity with minimum materials and optimized structures. In the world's heritage, it is very obvious that attaining sustainability doesn't need fancy technologies or overrated materials. It needs "wisdom" in observing nature and learning something from it (biolearning). As ancient as the tendency to make peace with our mother Earth through harmonizing with it, the sustainability wisdom was reintroduced over and over again. This is why almost all surviving architectural heritage until the industrial revolution could be considered sustainable. This could be interpreted by the "reaction time" factor. Before mechanizing all industrial processes, the rhythm of interacting and understanding material properties was slower and yet was deeper and wiser. The building time was much longer and yet as negative as it sounds, it was really a chance for builders to experiment, observe, and optimize their structures and materials. A number of most sustainable post-industrial revolution architectural movements tried to resist the machine constriction over personalized interaction with building materials and design processes. Arts and Crafts, Art Nouveau, Gaudí, the Greene brothers, Frank Lloyd Wright, and many others, tried to refute the total dominance of mechanization over architecture, searching sustainability means and referring them to nature. Defying machine dominance over architecture was always related to social and cultural movements launched by wise people that felt the danger of moving away from simple nature, that might have envisioned that because of steam engines the term "pollution" is realized. To be fair, the industrial revolution has its merits that we hardly can be grateful to, we can't undo the past until we have the "time machine", but maybe we can plan and predict the future. Architectural trends based on disaster solutions should be managed strictly if not refuted at all. For example, the Chicago School architecture, that was not exactly a prompt response for the big Chicago fire, but, anyway, gave us buildings of harsh consume rates of steel, bulky volumes, and plain blocks. Followed later somehow by Ludwig Mies van der Rohe "boxes" and all the rational-functionalism architects, with no humanitarian or personalized features that outbroke in all world's regions regardless of their relevance to their environment. Mies van der Rohe and rational-functionalist solid plain cubes had only the most powerful merits of modularity and uniformity that fulfill their function to the maximum but defies any humanitarian or environmental aspect. These modular blocks of steel structures were easy to build, that made them recurrent ready-made solutions in times of emergencies, crisis, wars, pandemics, and laziness of mind to optimize the function and building process to nature geometries. The psycho-humanitarian poverty of these plain boxes pushed their inhabitants to rebut them. Numerous social activists emerged in "Postmodernity" as an act of hate to these lifeless steel machines: and even before, with the anti-rationalists of the 1950s and 1960s. Through this lens, it is proved that the sustainability of architecture is a multi-faceted loop. The debate between vernacular and "modern" will never end, and maybe we can learn from fungal colonies to switch or combine both strategies "exploration and exploitation".

4. Scale makes sustainability

As learned from nature, sustainability is proportional to scale, since the most persistent (existence sustainability) creatures are microbes, followed by insects and miniature creatures of animal and plant kingdoms. If we

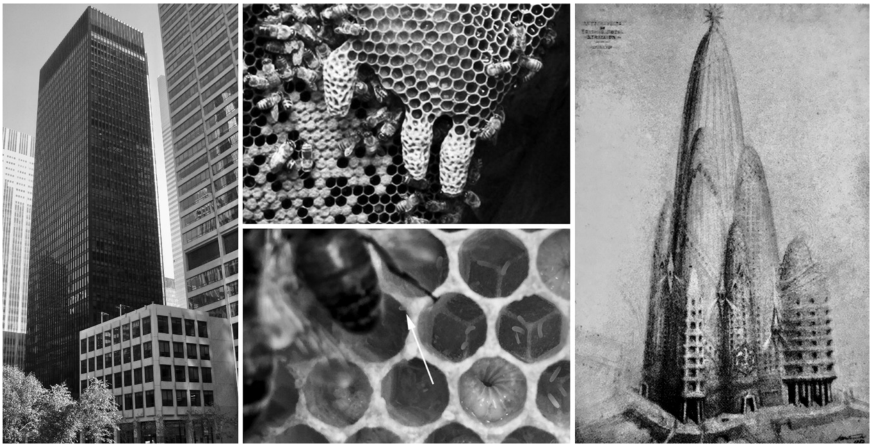

Figure 1.3 From left to right, plain modularity in Mies van der Rohe chic "Box" of Seagram skyscraper, New York, USA (Photo by Estévez, A. T.), exhibiting mechanistic lifeless cube far from sustainability. The optimized modules of a beehive, sustainable in material and structure obeying natural forces (gravity) and growth of function, as the hive grows in accordance with population growth. In the (middle-top) image, it is exhibited how the hexagonal capsules evolve into a suspended beehive tower as an inverted skyscraper following natural laws of gravity and intelligently morph into a complex modular structure. A detail of eggs inside the cells (middle down). (https://www.honeybeesuite.com/what-does-a-laying-worker-hive-look-like/). Right: the unbuilt skyscraper of Gaudí applying the same converted catenary methods and exhibiting morphogenetic similarity to a beehive (Photo in Estévez, 2010, pp. 168–173).

look through these communities, we can find it very clear that each agent is sufficient in its own and is in collaborative solidarity with other agents from the same species for the entire colony prosperity. Architecturally speaking, miniaturization, uniformity, and solidarity are very explicit in a beehive, Figure 1.3, where every bee is "encapsulated" in the optimized geometry of a hexagon that allows the extension in all directions by adding new "capsules" or units for the growth of the community. In the same essence "modularity" never failed to be adequate in terms of function, while the concept of its application was always the distinguishing point between sustainability or functionality at the expense of sustainability. For example, the concept of modularity in functionalism relied on the "brutal" simplicity of forms. The purism of geometric shapes to the very basic cubes created the sense of "building produced as a standardized machine" perfectly, that it ignored that a human would never fit inside a machine. This kind of modularity needs rehabilitation and customization to learn modularity from nature.

From an industrial and fabrication point of view, the scale of a module controls to a great extent the possibility of its replication, in terms of material and structural sustainability. This was the main initiative for the architectural movement of rational-functionalism to take the easiest option of pure basic geometries that are able to be replicated easily and cost-effectively. But as mentioned before scarcity leads sustainability, this scaled modularity also derived architects as Frei Otto and Antoni Gaudí to experiment on the minimal surfaces, applying natural forces as rules for delivering their forms through soap membranes or sacks of sand and catenaries.

Although these structurally and materially optimized minimal surfaces and hyperboloids were sustainable, their long building processes hindered their applications in times of disasters, they were conceived as "wonderland" luxury that wouldn't be easily and promptly applied to provide fast, urgent, time and cost-effective solutions. The "machine civilization" was limited this time to solve this equation of sustainability in emergencies. Thus, the functionalism plain boxes outbreak in all the world to solve the urgencies.

Such an equation would be solved easily if not emerging from architecture to urban but vice versa, the solution should start from the urban design refuting the gravity-challenging vertical boxes providing more solutions for horizontal urbanization learned from nature in the same essence that a colony of ants would build their underground buried cites, or a beehive is suspended from a tree branch.

Thanks to the numerous attempts made to revolutionize the building process, the digitalization in architecture has emerged, parametrizing the design and fabrication process and making it more controlled and easier to manipulate.

5. Digital and post-digital age material advances

Indeed, digital design advances through algorithmic aided design and parametric modeling tools have succeeded to free the architectural form to an almost unlimited extent, as well as offering a complete integrated kit of analysis and optimization to monitor, analyze, control and adjust all aspects of design through the entire design process from design to fabrication. Structural analyses and optimization, environmental analysis and climatic optimization, and numerical controlled subtractive or additive manufacturing digital tools have provided the designer with full control over all design attributes to make it easy to attain sustainability. The digital age has redefined sustainability to include more than the previously exhibited design sustainability loop connecting it with psychological, health, social, environmental, and economic aspects. The digital age emphasized on material sustainability through digital fabrication techniques optimization. 3D printing ranging from desktop machines to builder robotic arms have offered accurate control of the amount and composition of the material used and pushed forward advances in material science for composing sustainable materials of agro-wastes, biopolymers, and a lot of recycled pastes. The material sustainability has expanded to propose more than surviving against time, being cost-effective, environmentally and humanly safe, but also behaviorally active, possessing autonomous intelligence, that can interact not just respond, predict, adjust, manipulate and fulfill all current and future challenges and needs.

The material behaviorism, in its origin, could be referenced to the climatic responsive materials. The climatic responsiveness that was triggered by digitalization and advances in embedded kinetic systems have forced the search for simpler and more integrated solutions based on material behavior, rather than Arduino chips and tones of electric parts. Responsive materials starting from the very simple base of wood veneer that responds to humid weather by contraction or relaxation according to the level of its absorbed inner moist, have opened the horizon of material potentials and proposed promising applications in architecture that architects had ignored for a long time.

Material behaviorism has also refreshed the notion of minimal surfaces and optimized structures obeying natural rules and forces. Thanks to biodigital design that comes to the concept of biolearning (Estévez, 2010, pp. 168–173), and through integration with digital tools, for the first time exhibiting the non-conflict and harmony that could exist between digital and biology. Thus, encouraging other promising concepts as “material ecology” according to Neri Oxman (2007):

"Material Ecology is an emerging field in design denoting informed relations between products, buildings, systems, and their environment. Defined as the study and design of products and processes integrating environmentally aware computational form-generation and digital fabrication, the field operates at the intersection of Biology, Materials Science and Engineering, and Computer Science with emphasis on environmentally informed digital design and fabrication. With the advent of digital fabrication techniques and technologies, digital material representations have come to represent material ingredients. In other words, designers are now able to compute material properties and behavior built-in to form-generation procedures. Such unity—like that found in natural bone, a bird's nest, might promote a truly ecological design paradigm, facilitating formal expression constrained by, and supportive of its hosting environment." (http://www.materialecology.com; http://2012.acadia.org).

A material model, which is based on observations of real biological systems, admits that material organization in living systems is not designed but, rather, emerges from constraints inherent in the materials themselves, and in their interaction with the environment. This approach has been taken even further in a design paradigm, which suggests a 'literal biological paradigm', suggesting that the designer should "go beyond using shallow biological metaphors or a superficial biomorphic formal repertoire" and, through architectures of synthetic life, understand the built environment as "a synthetic life-form embedded within dynamic and generative ecological relations" (Hensel, 2006, pp. 18–25). Furthermore, academic architectural designers have suggested that a literal biological paradigm changes the relationship between visualization and the designed object (Cruz, Pike, 2008, pp. 6–7), enabling a design process similar to cultivation than engineering (Robertson, et al., 2015, pp. 28–39).

The material ecology notion has proposed the biomaterials to guarantee inherent harmony and sustainability naturally, through employing the exact biological intelligence by its own into action in the built environment. A biomaterial is any material, natural or man-made, that comprises the whole or a part of a living structure or a device which performs, augments, or replaces a natural function (Ratner, et al., 2012, pp. 150–185). While a bio-based material is a material made from substances derived from living (or once-living) organisms. Bio-based materials or biomaterials fall under the broader category of bio-products, which include materials, chemicals, and energy, derived from renewable biological resources and often biodegradable (A. Tathe, et al., 2010, pp. 19–23). Knowing biodegradation (bioremediation) is the fragmentation of materials by bacteria, fungi, or other biological decomposers (Vert, et al., 2012, pp. 377–410). The term is commonly associated with environmentally friendly products, capable of decomposing back into natural elements. Microorganisms secrete bio extracellular surfactant, to enhance this process.

In practice, almost all chemical compounds and materials are subject to biodegradation processes. The significance depends on the relative rates of such processes. A number of factors determine the rate at which this degradation of organic compounds occurs (Sims, Cupples, 1999). The main factors include light, water, and oxygen. Temperature is also important as chemical reactions proceed more quickly at higher temperatures. The degradation rate of many organic compounds is limited by their bioavailability (Sims, 1991). Biodegradability can be measured in a number of ways. Respirometry tests can be used for aerobic microbes, as a solid waste sample is placed in a container with microorganisms, soil, and aerated. Over the course of several days, microorganisms digest the sample bit by bit and produce carbon dioxide, the resulting amount of CO_2 serves as an indicator of degradation.

A composite material is defined as a combination of two or more materials that results in better properties than its individual components when used alone. Each material retains its separate chemical, physical, and mechanical properties, which remain separate and distinct on a macroscopic level within the finished structure, i.e., straw reinforced mud-brick (Cleveland, 2008; Campbell, 2010). The main advantages of composite materials are their high strength and stiffness, combined with low density, when compared with bulk materials, allowing for a weight reduction. The process of designing a bio composite material is to program living matter to get a composite material made of organic components showing amplified or shifted features, different from the ones the components show separately. These materials can be reinserted in a metabolic active life cycle after being used (González, et al., 2010). However, composites are a subclass of