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Biomimicry as a Turning Point in Reducing COVID-19 Infection

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ABSTRACT

The vision behind biomimicry has always been the pursuit of solving the difficult problems that confront us in life in general, and architecture in particular. The coronavirus is without a doubt the most serious problem and the most dangerous threat since 2019 till now. And architecture has a human dimension that is interested in the prevention of infection and disease and keep human health. This necessitates architects and researchers to attempt to gain access to approaches that make human life less dangerous and threatening, as well as design that is safer and has fewer infection causes. The purpose of this paper is to create indicators that aid in the reduction of coronavirus infection by using nature and its characteristics as a model, which will serve as a starting point for the pandemic architecture of the coronavirus era.

Keywords—*Biomimicry, coronavirus era, infection, biomimetic indicators, pandemic architecture, COVID-19*

1. Introduction

Nature is a never-ending source of inspiration and creativity for designers, planners, and scientists working in a variety of fields. (El-Ghobashy & Mosaad, 2016) Nature possesses unique abilities such as adaptation, response, resistance, and others. And every organism has characteristics and behaviors that allow it to adapt to its surroundings. Organisms use less material to create effective and intelligent solutions in their homes. Biomimicry is more than just imitating and copying forms; it is also about fully comprehending the philosophy of natural life and how it affects design to solve a specific problem. The building can be tailored to the environment, including organisms. Thus, biomimicry could be used to solve environmental problems and create a sustainable design by drawing inspiration from and studying the characteristics of organisms. Organisms' characteristics can be seen in their behavior, structure, form, pattern, and material.

The nature of the building could be compared with the nature of a living organisms, according to behavior and interaction with the surrounding environment. Biomimicry is active in many disciplines and fields and produces significant results Biomimicry, on the other hand, remains a larger research activity than applied aspects frameworks in architecture. Biomimicry provides answers to a series of questions that can be applied to design and optimize the outcome.(Farzaneh & Lindemann, 2018) Design in the coronavirus era is an architectural mission that both designers and planners are interest in. As well as the problem all faces us. So, this paper is one step in

highlighting the indicators for using biomimetic principles in pandemic architecture to limit infection in internal spaces.

2. Biomimicry and Biomimetic Architecture Definitions

Janine Benyus defined "biomimicry" in 2002 as "the study of nature's most successful techniques, followed by the replication of these functions and processes to solve human problems". Nature has created successful systems and processes that can be used as internal solutions to a variety of waste management, asset effectiveness, and executive issues. Table 1 contains a list of biomimicry definitions.

Table 1: List of biomimicry definitions according to scientists and architects. Source: collected by researchers.

Author / Scientist	Specialization	year	Definitions of Biomimicry
Jack E. Steele	Engineer in Wright-Patterson Air Force Base in Dayton, Ohio	١٩٦٠	"The science of systems which have some function copied from nature, or which represent characteristics of natural systems or their analogues".
Janine Benyus	The scientist and author of the book Biomimicry: Innovation inspired by nature.	١٩٩٧	"Biomimicry is a method based on 3.8 billion years of observation, evolution, and development on our planet. Historically, organisms (animals, plants, and microorganisms) have been able to adjust their structure to their function, establish survival strategies, and increase their organization and functioning".
		١٩٩٨	"Biomimicry is a new science that studies nature's models and then emulates or draws inspiration from them to address human problems".
Maibritt Pedersen Zari	Researcher in Victoria University of Wellington ·	**2005**	"Biomimicry is an applied science in architecture that employs not only nature's beauty but also the lessons acquired from it to solve difficulties with building functionality. A multidisciplinary approach follows a set of ethics rather than a stylistic approach".
The Biomimicry Institute	A non-profit organization based in Missoula, Montana, USA	**2006**	"Biomimicry is an approach to innovation that seeks sustainable solutions to human difficulties by replicating nature's time-tested patterns and techniques".
Michael Pawlyn,	Architect and one of the pioneers in biomimicry	٢٠١١	"Biomimicry is the emulation or imitation of nature in its many forms, systems, and processes to solve the most pressing challenges faced by our world today. Biomimicry methods have so far proven to optimize in terms of sustainability and efficiency, particularly in the fields of design and construction. However, this increasingly prominent approach has also generated development in other fields as diverse as aerodynamics, robotic navigation, medicine, clothing design, and the detection of water pollution".
Dayna Baumeister	the Co-founder of Biomimicry 3.8	**2014**	"The biomimetic design should act like a well-adapted creature and generate life-friendly conditions".

3. Biomimicry Framework

Biomimicry principles, biomimicry as a teacher, approaches to biomimicry, biomimicry levels, and a biomimicry design spiral are all components of biomimicry framework that will be discussed and explained further below.

3.1 Principles of Biomimicry

Principles of biomimicry can be explained in Table 2.

Table 2: Principles of biomimicry. Source: collected by researchers.

	principles	Explain
1	**Nature runs on sunlight**	Nature can generate energy efficiently, such as by orienting leaves toward the sun, and can receive 95 percent of the energy required through the photosynthesis process. The wind is an example of a "natural source" of energy; however, all sources of energy in nature are dependent on the sun.
2	**Nature only uses the energy that it requires.**	Nature does not overuse its resources, which means it does not consume and deplete them unnecessarily. It relies on the benefits rather than the total amount of natural capital available to it. To make the best use of its limited environment, each organism devises a unique strategy, relying on only what it requires to survive and thrive.
3	**Nature adapts form to function.**	The structures of nature are larger than usual, and focus solely on form, and their size is only as large as is required to achieve their function. Nature's biological role models co-evolve, adapting to the changes in their surroundings as they fit form to function.
4	**Nature recycles everything**	Nature is a closed system, with each coexisting element consuming the waste of another as its lifeline. As a result, nature's system operates in closed frameworks, and does not produce its own waste or foul its own nest because it requires it to survive.
5	**Nature rewards cooperation**	Nature is based on associations between interconnected, mutually beneficial relationships and allows predation and rivalry to exist through participation. The properties of biological systems are based on a symbiotic, complex organization of mutually beneficial relations. As a result, collaboration is both rewarding and necessary.
6	**Nature banks on diversity**	The bank of diversity is the result of a wide range of plant and animal strategies that utilize the entire habitat rather than just pieces or parts. These systems respect the region's, cultural, and material uniqueness. Furthermore, these systems are adaptable, taking into account changes in individual and community needs.
7	**Nature demands local expertise**	As in nature, local ecosystems require a diverse range of overlapping resources and the presence of numerous local species to create a vibrant natural community. If a resource does not exist, it is not used because nature does not need to import it from elsewhere. Natural ecosystems are linked to the local region; sustainability necessitates reliance on local expertise and awareness.
8	**Nature curbs excesses from within**	Nature has no ego because it maintains balance with the biosphere, which is the part of the earth and environment that contains living organisms and is capable of supporting life - Sir David Attenborough, in his book The Secret History of Man by Sir Ian McEwan.
9	***Nature taps the power of limits***	Nature is constantly conscious of maintaining a life-friendly temperature, working within its limits, and efficiently using energy to save it for the future. Learning how to live with limited resources is the primary motivation for inventions, as limits create power. This concept is the polar opposite of seeing boundaries as the courage to overcome scarcity-related limitations.

3.2 Biomimicry as a teacher

Biomimicry, according to Benyus, sees nature as a model, a measure, and a mentor, as shown in Table 3.

Table 3: Biomimicry as a teacher. Source: collected by researchers.

	Nature	Explain
1	**A model**	Something that studies and imitates natural systems, using them as inspiration for ideas or processes that aim to solve human problems.
2	**A measure**	Evaluates the appropriateness of human advances using ecological criteria.
3	**A mentor**	A way of looking at, evaluating, and appreciating nature.

3.3 Approaches to Biomimicry

There are two approaches that researchers take to the biomimicry-based design process. The "bottom-up approach" and "solution-driven biologically inspired design" are both important. These two classifications can be used in the design process to identify human needs or design problems, as shown in Figure 1

- **Approach I:** Problem-based approach (Design looking to Biology)
- **Approach II:** The Solution-Oriented Approach (Biology to Design)

3.4 Levels of Biomimicry

There are three levels of biomimicry that can be studied and analyzed before being applied to a design problem. Each level has five distinct measurements, which include form or appearance, construction or how it works, process or what it can do, and function or capability, as shown in Figure 2.

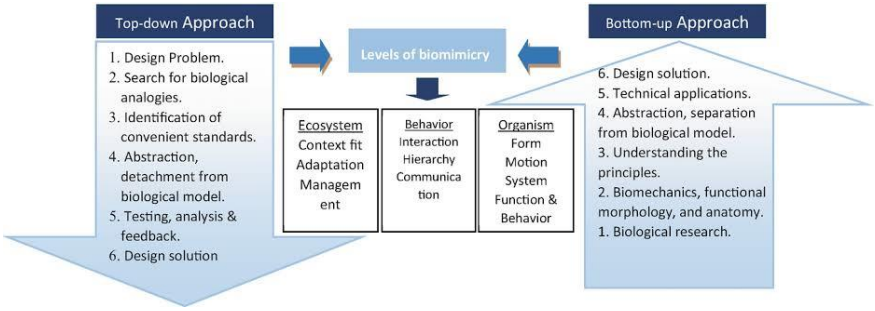


Fig. 1. Biomimicry top-down and bottom-up approach. . Source: [metodologia & ferramentas - Biomimética (biomimetica.com.br)]

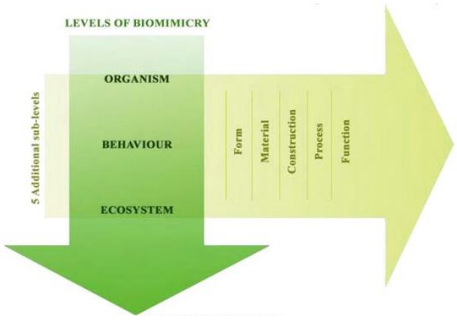


Fig. 2. Biomimicry levels and sub levels. Source: (El Ahmar, Fioravanti, & Hanafi, 2013)

3.5 Biomimicry design spiral

The Challenge to Biology Design Spiral was developed by the Biomimicry Institute to demonstrate this design method. Figure 3.

Fig. 3. Design spiral. Source: (Salah W, 2020)

The Design Intelligence Lab at Georgia Institute of Technology described this technique through six definite steps in 2006, which are quite similar to those established by the Biological Institute, as shown in Figure 3

The diagram below shown in Figure 4 explains all of the theories and dimensions of biomimicry, as well as its application method and role in achieving sustainability.

Fig. 4: Biomimicry theory and practice summarized. Source: reseachers

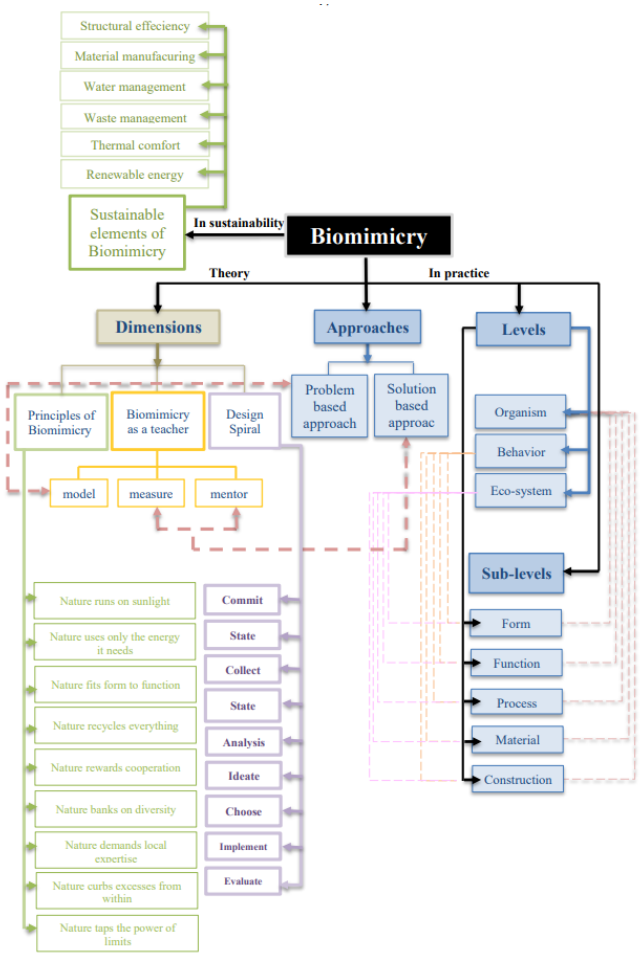


Fig. 4: Biomimicry theory and practice summarized. Source: reseachers

4. Biomimicry for Sustainable and Pandemic Architecture

Biomimicry, natural shapes of structures, vaults, domes, arches organic lines, and any architectural feature that improves the sense of nature are all used in biophilic architecture. Furthermore, natural-inspired cladding patterns may be used in designs. These concepts seek a long-lasting design that is also environmentally friendly. Furthermore, the design elements should be in sync in terms of colors, light, shadows, linking the inside and outdoors, and the general spirit of the spaces. (Zhong, Schröder, & Bekkering, 2021) Biomimicry is becoming more important than ever, especially given the many challenges that humanity will face between 2019 and 2022, and beyond. This entails reducing GHG emissions, particularly CO2, to near zero. The phrase "carbon neutral" is increasingly being used to mean "zero emissions." To put it simply, carbon neutral means that the total amount of greenhouse gases (GHGs) released into and removed from the atmosphere should equal zero. In the age of the COVID-19 pandemic, biomimicry in architecture can play a significant role in creating green cities and advancing the goal of climate neutrality. COVID-19 has infected over 1430 cities in 210 countries, with urban areas and

megacities accounting for over 95% of all cases. The majority of those at risk live in overcrowded and inadequate housing in informal settlements and slums.(Aboulnaga, Badran, & Barakat)

The search assume that biomimicry can aid in developing internal spaces and creating healthier buildings indoors against covid-19 as biomimetic design with green components contributes to the purification of the air in the rooms. Linking to the outer world and connecting it within leads to growth and looking out the window. This method can help reduce the stress of being quarantined, whether at home or at work. Bringing nature into the house helps to improve the overall environment Vertical gardens and green areas, for example, can filter the air, promote thermal comfort, and improve building dwellers' mental health. (Shangi, Ahmad, & Ahmed, 2020)

The implementation of a biophilic design with green components contributes to the purification of the air in the rooms. Linking to the outer world and connecting it within leads to growth and looking out the window. This method can help to reduce the stress of being quarantined, whether at home or at work. Colors and botanical elements have a significant influence on employee performance, productivity, and psychological well-being. This design is distinguished by natural materials and colors that are reminiscent of nature. The intensity of color affects how individuals feel and behave. Warm colors make a stronger effect than cool colors. Dark colors create the illusion that rooms are small. By giving movement and life to the atmosphere, the yellow color energizes the residents. Colors have a psychological as well as a biological impact. Red influences the reactivity of the heart and respiratory system, blue decreases blood pressure and heart rate, brown offers stability, and green relaxes the eyes and promotes tranquility. (Zaher, 2020)

5. Transmission of Infection from One User to Another in The Spaces

5.1 Factors Affecting Covid-19 Transmission

The techniques that relate to the design process and health are ambiguous, but they include settings that may be improved, such as materials used in building and finishing, ergonomics concerned with the user's relationship with their surroundings, and the spatial layout of the many elements. These points contribute to the enhancement of the health aspect) Forooraghi, Miedema, Ryd, & Wallbaum, 2020 (User behavior is an essential factor in the transmission range of the virus.

5.2 How to spread the infection?

When going through BE, people come into direct and indirect touch with surfaces. (Dietz et al., 2020)

a) Infection By Direct Contact

Direct infection through respiratory illness has been reported as the major route of transmitting Covid-19 sickness. (Dietz et al., 2020) As a result, the WHO believes that social distance is the most effective strategy to minimize infection transfer between individuals in confined or even open areas. (WHO, 2020)

b) Infection By Indirect Contact

- Viral particles can be deposited and suspended as a result of natural or mechanical air flow patterns, as well as interior causes such as footfall, walking, and thermal columns of warmth. Human Body (Horve et al., 2020)
- Infectious tools can then stabilize the virus particles in suspension. (Horve et al., 2020)
- When a person comes into touch with a surface, microbial life, including viral life, is transmitted from the person to the surface. (Adams & Lymperopoulou, 2018)
- Quite the contrary COVID-19 patients lose particles before, during, and after symptoms. These viral particles can then be implanted on non-vital items in BE, where they are likely to behave as virus reservoirs (Brown, Kline, Mhuireach, Northcutt, & Stenson, 2016).

6. Design Considerations to Limit the Pandemic Spread

A healthy environment is dependent on improving interior spaces to prevent infectious illnesses such as COVID-19, where the quality of the indoor environment is a key role in enhancing physical and mental health. The

most efficient ways are related to the efficiency of the interior climate, such as good ventilation and adequate natural light, as well as the necessity for a big space as well as openings or windows to produce airflow to be a healthy and comfortable indoor environment. Design strategies must be depended on. (Shangi et al., 2020).

6.1 Air Flow

Viruses can spread in small regions via aerosols that can persist in the air for hours. The idea was to interchange the air between within and outside, with ventilation employed to remove harmful and unwanted chemicals**.** (Fezi, 2020) .There are several cases of airflow as shown in Figure 5

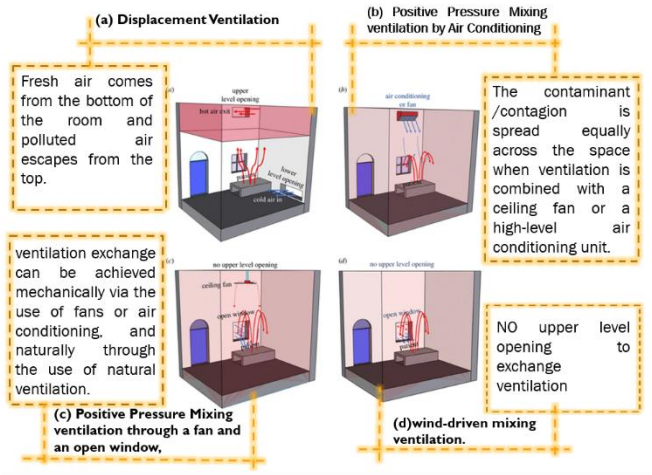


Fig. 5: Diagram showing many forms of ventilation.Source: collected by the researchers based on Rajesh K. Bhagat,2020

a) *Mechanical Ventilation*

- The air conditioning system in public buildings could help to transmit COVID-19. Therefore, Windows in mechanical ventilation areas must be opened at least four times each day. (Jamaludin, Azmir, Ayob, & Zainal, 2020)
- Mechanical ventilation must be conditional. (Guo et al., 2021)
- If mechanical ventilation is required, it is critical to use high-efficiency air filters, Using HVAC high-efficiency filters of the highest class, such as MERV-16. (Fezi, 2020)

b) *Natural Ventilation*

- spaces, natural ventilation of 0.14 cubic meters per minute is recommended. (Hu, 2020)
- According to specified standards, natural ventilation should also be employed at least a quarter of an hour before and after occupancy hours. If mechanical ventilation is essential, high-efficiency air filters must be used. (Sari & Budiyanti, 2020)
- Natural ventilation has the benefit of being simple to create a high rate of air change, which is essential for maintaining a healthy atmosphere and dispersing toxins. (Guo et al., 2021)

6.2 Air humidity

- Air humidity can also impact viral transmission. According to a 2013 study, "keeping indoor relative humidity over 40% will significantly reduce the infectivity of the aerosolized virus." (Fezi, 2020).

6.3 Lighting

- It assists in the prevention and control of communicable illnesses. Dust and virus particles tend to accumulate less in well-lit locations. Both daylight and sunshine are examples of natural light. Extend the glass areas to enable as much natural light and sunshine as possible and give special attention to the supply

of sunlight to all spaces and the deepest sections of the structure via skylights and large, well-lit ducts. When not in use or at night, utilize UV lights to sterilize rooms (Ali, Farghaly, & Saadallah).

- All public buildings should have no-hands doors and sanitary equipment and materials in public areas. Including social distances in design considerations for any space or lift, which is 2.00 m per person and is determined by the placement of interior furniture and ground signals. User behavior is also important in reducing pandemics. Users must wear masks, maintain hygiene, and follow instructions and social distances.(Ali et al.)

7. The Clear Link between Biomimicry and Pandemic Architecture

The following are the considerations for built environment design to reduce the risk of pandemic spread. The Design considerations that could achieved by biomimetic approach will be shown in Figure 6. as a links between biomimicry and pandemic architecture, as shown in Table 4.

Table 4: Design considerations for built environment design to reduce the risk of pandemic

	Design considerations
1	Natural ventilation should be used for at least a quarter of an hour before and after occupancy hours, according to certain criteria. If mechanical ventilation is required, high-efficiency air filters must be used.
2	Sunlight aids in the prevention and control of infectious diseases. Every space must have enough natural light, which can be achieved by extending the glass areas to allow as much natural light and sunlight as possible.
3	All public buildings should have no-hands doors and sanitary equipment and materials in public areas.
4	Including social distances in design considerations for any space or lift, which is 2.00 m per person and is determined by the placement of interior furniture and ground signals.
5	User behavior is also important in reducing pandemics. Users must wear masks, maintain hygiene, and follow instructions and social distances.

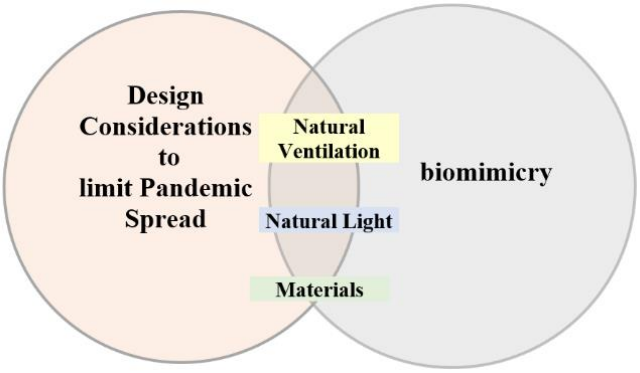


Fig. 6: Diagram showing common links between biomimicry and pandemic architecture. Source: researchers

According to the above, the following table depicts the points of convergence between design requirements for reducing coronavirus infection and biomimicry in sustainable architectural design, as shown in Table 5.

Table 5: Convergence between design requirements and biomimicry. Source: researchers.

Design Considerations		Biomimicry corresponding effective applications
Natural ventilation	***Building and Skin design***	All living things, especially those that live in hot climates, require air flow. Termite mounds produce ventilation through convection using an air pocket system. Engineers are developing ventilation systems for man-made structures that, like termite mounds, will use outside air to cool interior spaces.(ElDin, Abdou, & ElGawad, 2016) Figure 7.

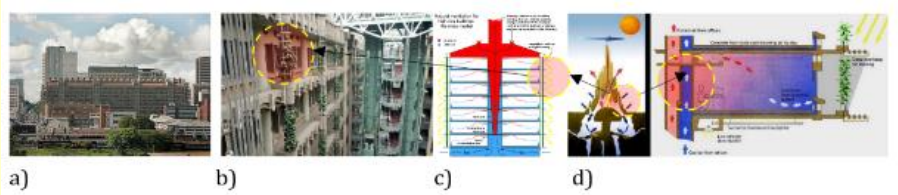


Fig. 7: Eastgate building concept. a) Eastgate building. b) Façade of Eastgate building. Source: (https://en.wikipedia.org). C) Section of Eastgate building. Source: (https://asknature.org). d) inspiration of Eastgate building skin. Source: (https://www.mickpearce.com) Developed by the researcher.

- The structure's façade is inspired by the skin system, specifically the epidermis (outer skin) and dermis (inner skin) (inner skin). The bark façade of the structure also aids in the natural ventilation of the wet systems.(Aamer, 2021)Figure 8.

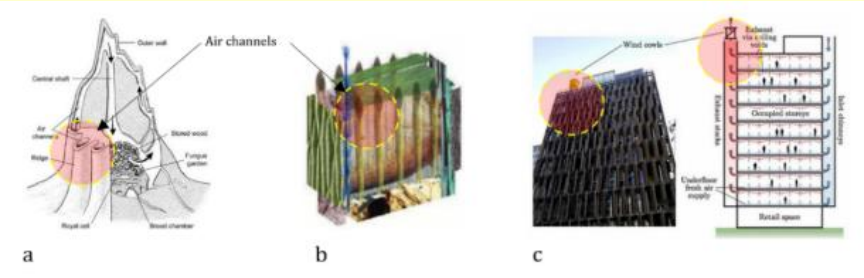
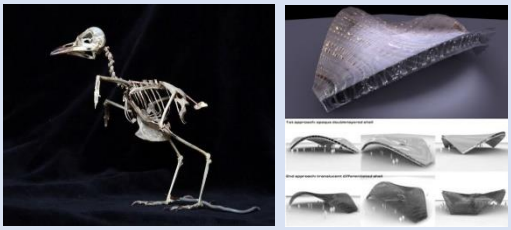
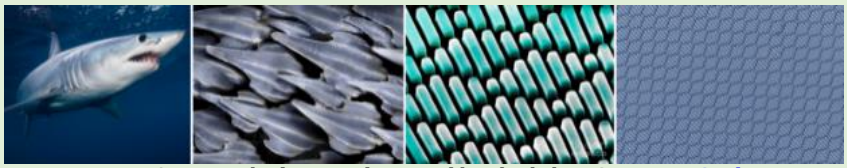


Fig. 8: The biomimetic concept of CH2 building skin. a) Termite mounds. Source(Jeanne RL, 2009), b)Windpipes on the façade. Source: (Gehan.A.N.RadwanDr.aNouranOsamaArch.b,2016), c) Building skin of CH2 Building. Source: (Dutta Pramanik P, Mukherjee B, Pal S, Pal T, Singh SP. 2019). Developed by the researchers.

- The ventilation system was designed after how sea sponges and anemones direct water flow through their bodies. As one of the first environmentally progressive structures, The Gherkin skyscraper is one of the most recognizable in both England and the world. Figure 9.

Fig. 9: The Gherkin, London. Source: ©www.arch2o.com

	Improving Aid Equipment efficiency	• Designers study the anatomy of cold-weather birds to learn more about efficient heat exchange patterns in order to maximise HVAC efficiency. Other ways animals inspire heating and cooling product innovation include the study of natural moisture absorption by ticks to pull humidity from interior spaces and improving fan efficiency by studying whale flappers. Figure 10.  Fig. 10: whale flappers.to improve fan efficiency. Source: Biomimicry « Randy Topp | Business Improvement (rt-bi.nl)
Sunlight and natural light	***Building and Skin design***	• Lighter, stronger building materials are inspired by bird skulls. "Skulls in general are extraordinary impact-resistant structures that are extremely light while protecting the most important organs of an animal body, and this performance and physical property can be applied in structure or architecture design," says architect Andres Harris. Figure 11.  Fig.11: a) Bird skulls. Source: (102) Pinterest b) Biomimetic approach shelter. Source: Brilliant Bio-Design: 14 Animal-Inspired Inventions - WebEcoist (momtastic.com)
Materials	***Materials that reduce infection***	• Shark skin is an evolutionary trait that increases speed and prevents microorganisms from adhering to the skin. This antimicrobial film is also being used in hospitals to prevent bacteria cross-contamination. Figure 12.  Fig. 12: Antimicrobial material inspired by sharkskin. Source: Y Studios — INSIGHTS | Passion | Y Studios — Biomimicry Design: Mother Nature's Influence on Products and Design • The paint is inspired by the lotus flower that appears clean from the swampy water, and this product is the design creation as detailed by Baumeister. The lotus leaf is known as one of the most waterproof materials. This is because its surface is hydrophobic and cannot absorb water to a large degree. Figure 13.  Fig. 13: Lotus Inspired lotusan paint. Source: (Pedersen Zari M, 2022)

Materials that change colors

- Cephalopod-inspired camouflage: Squids can change the colour of their skin to protect themselves from predators. Researchers have created a device that can detect its surroundings and blend in. These light sensors can generate a type of artificial skin that adapts to its surroundings and changes with them. Figure 14.

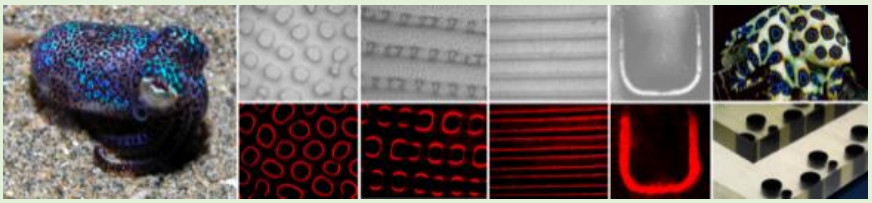


Fig.14: Camouflage inspired by cephalopods. Source: Y Studios — INSIGHTS | Passion | Y Studios — Biomimicry Design: Mother Nature's Influence on Products and Design

8. Conclusion

- Biomimicry enables all types of innovators and problem solvers to create more intelligent and sustainable designs by mimicking nature. Designers and architects stand to benefit greatly from incorporating biomimicry into their design processes.
- Biomimicry can serve as a springboard for considering a design approach that combats the coronavirus while also meeting the design requirements deduced to reduce infection. Biomimicry can also help with sustainability, disease prevention, creating safe and comfortable environments, and lowering energy consumption. By studying organisms and examining their behavior to overcome the conditions of their surroundings and achieve survival, all of the elements required in the building can be achieved through ventilation, natural lighting, and materials.
- During the design or the redesign to reduce the coronavirus it is important to Concentrate on the organism and behavioral levels, as well as sub-levels that specialize in the organism's form and construction, behavior, and organ function.
- According to a solution-based approach applications, the base's work prefers biomimicry balance data and design in the coronavirus era from the crescent of the required elements in design. Biologists and botanists work together to ensure that we have easy access to immediate solutions to design and environmental issues.

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