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BIOMIMICRY: SUSTAINABLE ARCHITECTURE INSPIRATION BY LOTUS

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Abstract: *Sustainability is not merely a style but it is a method of creating a long-lasting and sensible design. Nature is the paramount answer to all the problems which even includes the solution to sustainability. Best design solutions have always been obtained from nature-inspired concepts that are not only creative but also meaningful. Biomimicry is a blessing of nature that can be opted in real-life situations to optimize the design-related issues about sustainability. There are lot many examples as a source in nature. The focus of the study is to explore lotus as an example of biomimicry in sustainable architecture. Lotus Temple in India, The Lotus Building in Wujin, China, Marina Bay Sands- Art Science Museum, Singapore, Gardens by the Bay, Singapore and Motisons Tower, India were studied to understand the various levels of biomimicry and its dimensions which were followed.*

Keywords: ***Biomimicry, Sustainability, Architecture, Nature, Design, Lotus Form.***

1. INTRODUCTION

The concept of using plants and animals to improve the usefulness and sustainability of humanity's creations is achievement ground in today's architectural, design, and engineering industries [1]. Benyus (1997) says biomimicry takes nature's blueprints, recipes, processes, and ecosystem tactics and applies them to our issues, resulting in design concepts [2].

1.1. Biomimetic Approach

The biomimetic approach does not divide defined elements, such as shape, function structure, and substance, but rather unites, describing them as a semi-organic arrangement. It is possible to create conceptual structures that are segregated, flexible, and attached by copying natural models, applying geometric principles, and biological understanding [3].

This biomimetic approach does not distinguish, but unites, fixed entities as a semi-organic composition, such as form, functionality, framework and material. It is possible to generate segregated and variable and related spatial structures by copying natural models, by applying geometric concepts and biological knowledge [3].

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2. Lotus Flower Form

For all Buddhist saints, lotus blossoms are connected with purity, spiritual enlightenment, and truthfulness. Each epidermal cell on the surface of Lotus leaves and flowers resembles wax. Raindrops move dust particles away from the surface and keep them clean as a consequence. The qualities of cleaning surfaces found in plant leaves have paved the way for the development of superhydrophobic paints, glass, and windows [4]. In many faiths and cultures, the lotus species has long been a significant element. It reflects a renewed state of enlightenment from the dirt and swamp of earthly life. The lovely blooms emerge from the turquoise waters as a closed seed, then expand their petals to full bloom and reveal the seed pod. The Lotus building is a three-part construction that resembles any point in the growth of the flower [5].



Figure:1 Lotus Flower

Source: https://www.thoughtco.com/thmb/mik7Z00SAYN786BQbieXWOzZmc8=/2121x1414/filters:fill(auto,1)/lotus-flower-828457262-5c6334b646e0fb0001dcd75a.jpg

2.1. Lotus Temple in Delhi, India

Lotus Temple: The Baha'i House of Worship near New Delhi, known as the Lotus Temple. Baha'i Mashriqul: Lotus Shaped Outline [6].

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Table 1. Lotus Temple Details

S. No.	Title	Details
1.	Architect	Fariburz Sahba
2.	Structural Design Consultant	Flint and Nail Flint and Nail partnership, London
3.	Designed In	1976
4.	Area	24 acres
5.	Built Time	1978-1986
6.	Client	Government
7.	Building type	Worship Place

Biomimicry: The building's form is inspired by the lotus at the organism level.

Concept: The main idea behind the design is that instead of the typical sculptures and carvings seen in Indian temples, two fundamental elements - light and water - have been used as adornment [8]. The concept of the temple differs from temple to temple, yet they all display important and holy symbols that are similar to all Indian faiths. These are the emblems that have been adopted by various nations and faiths. One of these icons is the Indians' scared flower, the Lotus Flower [18]. Fariborz Sahba designed the temple idea based on the notion of a flower, which represents purity. In Hindu culture, cleanliness is very important. The temple's blueprints took two and a half years to finish. Each component of The Lotus Temple is repeated nine times [8]. The Temple of Lotus shows the win for symmetry and self-like (India) [9].



Figure: 2 Top View

Source: https://architecturever.com/wp-content/uploads/2019/12/Lotus-Temple-Arial-View.jpg

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The Lotus Temple is most known for its distinctive flowerlike shape, which was designed to represent the beauty and symmetry of the lotus flower, which is sacred to many Eastern and Indian faiths, including the Bahá' Faith, Hinduism, and Buddhism. The Lotus Temple

Construction: The lotus temple is built using the arcaded building method. 9 radial grids were used. The Lotus Temple, whose inner leaves form a canopy of intricately patterned crisscrossing ribs and shells that encircle the interior dome. Each layer of ribs and shells hides behind the next, lower layer as it climbs when viewed from the inside [8]. The whole architecture is meant to act as a series of skylights, with glass at the apex of the inner petals, underneath the outer petals, and on the outside side of the entry petals. As a result, light enters the centre hall of the building [7].

Structural Details: Starting from the basement, there are three groups of nine shells springing from the podium, a double-layered Interior Dome, Nine arches, nine ponds and walkways. A building consists of the information center, library, administrative building and restrooms as shown in figure 3. The 54 ribs that make up the double-layered internal dome, which is modelled after the innermost region of the lotus, are separated by concrete shells. The centre hall is 34 metres in diameter and rises 33.6 metres above the podium [7]. Lotus Temple is one of the most well-known instances of biomimicry in modern design. [7].

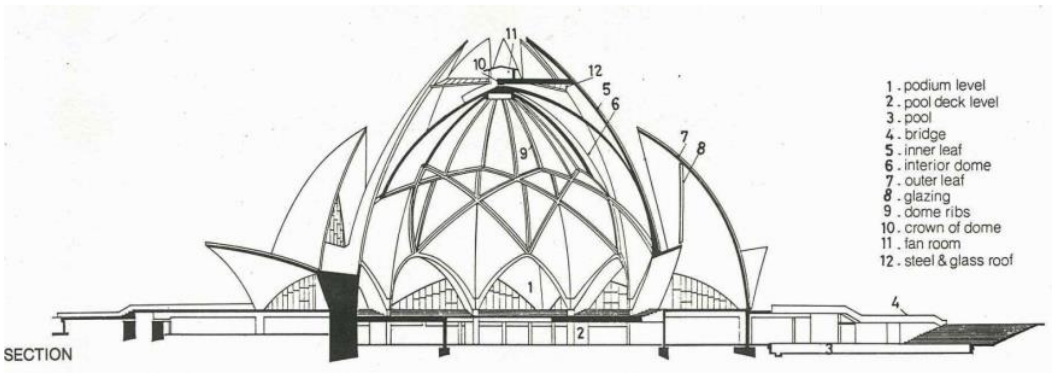


Figure: 3 Elevation of Lotus Temple

Source: https://worldarchitecture.org/cdnimgfiles/extuploadc/b_91copy2.jpg

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2.2.The Lotus Building in Wujin, China

Table 2. The Lotus Building Details

S. No.	Title	Details
1.	Architect	Studio 505
2.	Structural Design Consultant	Studio 505
3.	Area	10,000 m^2
4.	Built Time	2013
5.	Client	Wujin District People's Government
6.	Building type	Exhibition Center and People's Park

Biomimicry: The building's form is inspired by the lotus at the ecosystem level.

Concept: The Lotus Building in China is a stunning public structure with a unique design inspired by a flowering lotus flower. Steel "petal ribs" encircle the structure, evoking from the fresh new bud to the completely grown flower idea to the opening bloom with the seed pod within, there are three phases of a lotus flower. [10].



Figure: 4 Three Stages of the Lotus Flower

Source: https://www.studio505.com.au/admin-resources/image-tools3c58.jpg?w=874&q=95&src=/wujin-centre/1140_Lotus_029.jpg



Figure: 5 Night view of The Lotus Building

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Source: https://laughingsquid.com/wp-content/uploads/2015/03/asdasimage-tools.php_-750x499.jpg

The building is inspired by Lotus Form. The Lotus building is a three-part construction that resembles any point in the growth of the flower. The new Lotus enhancement attempts to combine People's Park with public involvement in a visually and physically focused creative icon. There are Government corporations and Conference centers, Cultural Center Galleries and tourist events [5].



Figure: 6 The Lotus Building
Source: https://laughingsquid.com/wp-content/uploads/2015/03/zzzimage-tools.php_-750x498.jpg

Structural Details: The Lotus Building lies in the heart of the Wujin District in Jiangsu's eastern coastline province. Studio505, an Australian architecture firm, designed it, and it was finished in 2013 [10]. The Lotus Structure is true, by night and by day, an excellent architectural design. The outside view is characterized by the nearby constructions of this busy area, which are skyscrapers like boxes. In comparison, the Lotus building is round and fluffy which seems floating on the water.

At dark, the structure is pink and purple and graduates at the height and outlines of the petals from light at the base to darker. The illumination is operated by a timepiece, which switches colour schemes every 20 seconds in a fascinating performance [5]. The government headquarters in the Wujin district, which resembles a pink lotus flower, is the large-scale imitative Lotus Conference center.

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Figure: 7 Night View of lighting

Source: https://www.studio505.com.au/admin-resources/image-tools0e1b.jpg?w=874&q=95&src=/wujin-centre/1140_Lotus_024.jpg

A blend of sculpting and a forceful sensual and feminine biological shape characterize the construction. The structure becomes one of the city's most recognizable landmarks. The design is inspired by the blossoming of lotus flowers and is quite beautiful [4]. The rooms of conference centers are elegantly built with lighting ceilings and richly seeded wood. In keeping with the red floral shape, the seating is oval. As an integral component of planning thoughts, tourists, officials and civil servants are an influential part of creative aesthetic beauty [5] as shown in figure 8.



Figure: 8 Conference Room

Source: https://lh5.ggpht.com/-vtcn-41EU5c/VP6bmEC-REI/AAAAAAAABAJI/X-6PH3GtBNc/lotus-building-wujin-7%25255B5%25255D.jpg?imgmax=800

Construction: The building has cathedral-like ceilings, meeting rooms, exhibition halls, and offices on the inside. Ecological preservation is an essential feature as functionality and aesthetic design are in line with the three levels of growth of the lotus flower. Geothermal pre- and pre-heating utilizing more than 2500 array pilings are being implemented in the project using the water and soil of the artificial lake. Evaporative cooling from the lake surface is employed to power a thermal chimney within the main flower pod, which is also mixed-mode and naturally ventilated [5].

The building's temperature is controlled with minimum energy consumption thanks to a system of geothermal piles that utilize the nearby lake. At night, a lighting system bathes the building in colourful lights providing a stunning appearance [10]. All external and internal surfaces are covered in hand-laid and varied white, beige, and stainless steel

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hexagon mosaic tile finishes, which blend seamlessly to create a continuous form with studio505's bespoke 7m high suspended chandelier at the apex, which becomes the centre of attention, both inside and out [11] as shown in figure 9 and 10.

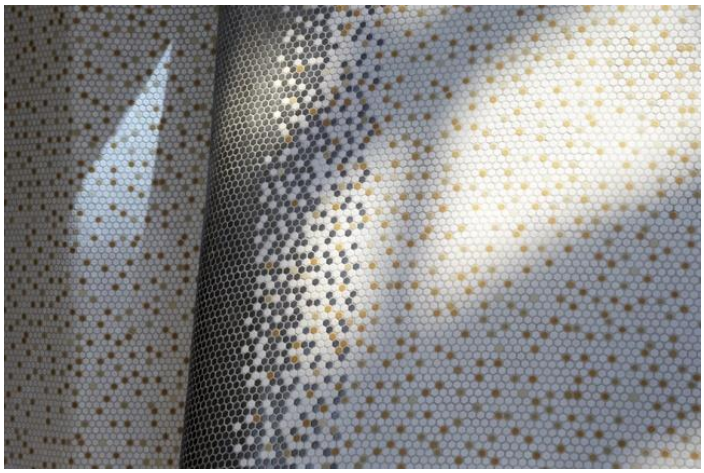


Figure:9 Mosaic Tiles wall

Source: https://www.studio505.com.au/admin-resources/image-tools235f.jpg?w=874&q=95&src=/wujin-centre/1140_Lotus_013.jpg



Figure: 10 Chandelier

Source: http://ift.tt/2dDj97H

2.3. Marina Bay-Art Science Museum, Singapore

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Table 3. Art Science Museum Details

S. No.	Title	Details
1.	Architect	Moshe Safdie
2.	Structural Design Consultant	SkyPark, Arup
3.	Designed In	2011
4.	Area	6000 m^2
5.	Building type	Art Science Museum

Biomimicry: The building's form is inspired by the lotus at the behaviour level.



Figure: 11 Top View of Marine Bay

Source: https://safdie-staging.imgix.net/dbc37648-cf90-4ace-9ed9-63fe1146ff18/01_B-F_MBSIR_2016Aerials_4_4x3.jpg?q=50&ixlib=imgixjs-3.4.2

Concept: The Artscience Museum, which is located on the Marina Bay Sands beachfront, contains exhibitions that connect the arts and sciences. The museum is divided into two main exhibition halls that are connected by a central open-space atrium. The initial exhibitions float over the promenade in a sculpturally structured form, while the second collection of gallery spaces is hidden behind a vast water lily garden [12].

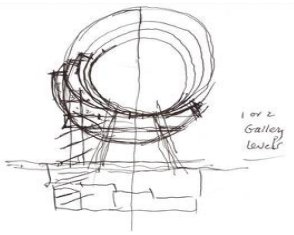


Figure: 12 Rough Draft

Source: https://safdie-staging.imgix.net/dd416d65-94df-4c56-81b8-419733242b93/01_A_MBS-ASM_SKETCH.jpg?ixlib=imgixjs-3.4.2&w=282

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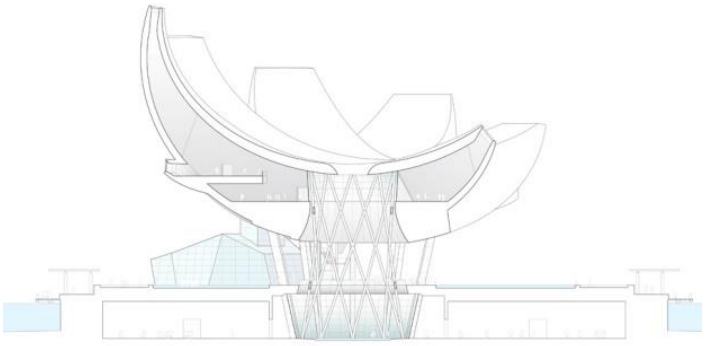


Figure: 13 Building Section

Source: https://safdie-staging.imgix.net/1b9bc8ad-8967-4740-ba60-afeec7ecb4c5/02_2_MBS-ASM_Section_16x10.jpg?ixlib=imgixjs-3.4.2&w=1246

Construction: According to Peter Bowtell, Buildings Leader for Arup in Australia, "trying to make a building stand upside down was a problem." Because one side of the 'lotus flower' is larger than the other, the construction will naturally fall to one side." To get around this, we needed to come up with a logical and straightforward technique to keep the galleries in the air. The ultimate solution required balancing the structure in space as well as dealing with extremely intricate geometry.

Structural Details: A steel lattice diagrid framework and ten steel columns support the structure, creating a sculptural centrepiece that allows it to hover above the ground. The shape is encased in fibre-reinforced polymer (FRP), which is often utilized in high-performance racing boats and has a lotus-like geometry. The building's eco-friendly features include rainwater collecting for household use, which is channelled through the bowl-like roof and cascades into a central pond in a beautiful waterfall as shown in figure 15.

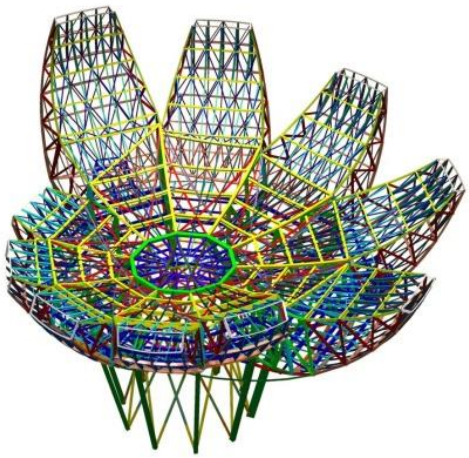


Figure: 15 Steel lattice Framework

Source: https://safdie-staging.imgix.net/111d0fa4-4cb3-416c-8f67-7aa303252e98/Picture3.jpg?ixlib=imgixjs-3.4.2&w=1946

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2.4. Marine Bay-The SuperTrees, Singapore

Table 4. The Supertrees Details

S. No.	Title	Details
1.	Architect	Wilkinson Eyre Architects
2.	Structural Design Consultant	Grant Associates, Atelier Ten
3.	Designed In	2006
4.	Area	600 m^2
5.	Built Time	2012
6.	Client	National Parks Board (NParks)
7.	Building type	Garden

Biomimicry: The building's form is inspired by the lotus at the ecosystem level.

Concept: Within the site, they mix a variety of functions. They serve as exhaust chimneys for biomass furnaces and as a steam outlet for dehumidification steam. They give a spot for solar energy collecting, solar heat collection, and water collection while also providing shade to the area.

The canopy skin and the trunk skin are divided into two zones, each characterized by a set of radial and diagonal elements (CHS). These resemble branches sprouting from the ground, increasing in quantity as they progress from the trunk skin to the canopy skin's outer border. The surface's form is what gives it its strength. A conic shape is used in the light upper canopy, which is quite frequent in membrane constructions. The surface, on the other hand, is inverted to function in compression rather than tension. The structural frame is made up of a two-layer lattice with the inner and outer layers offset to increase stiffness out of a plane [14].



Figure: 16 Gardens by the Bay, Water Lily Pond with Supertrees

Source:https://i2.wp.com/www10.aeccafe.com/blogs/arch-showcase/files/2012/07/107.jpg?w=1000&ssl=1

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Structural Details: Concrete and steel constructions combine up the supertrees. They have a hollow concrete core with a semi-transparent steel cladding system around them. A 'head' at the top of the core is covered with membrane material and provides a nearly flat surface. While the best angle for a solar collector in Singapore is horizontal, any panel put in the pure horizontal plane would require a significant amount of cleaning. As a result, the head of the core was inclined slightly downward to allow for drain-cleaning [13] as shown in figure 16. A concrete core cantilevers from the ground, supporting each tree. Each has a central 'head' that controls all of the environmental equipment. This core head also aids in the support of the canopy of the supertree [14].



Figure: 17 Supertree

Source: https://laughingsquid.com/wp-content/uploads/DSC_0503.jpg

The Supertrees have an Aerial Walkway that is intended to resemble the treetop walkways that are so popular in Australia. It is distinguished by the fact that it is hanging from the Supertrees by exceptionally thin and delicate skins. The walkway was created with extremely particular parameters in mind; because of the sensitivity, it is only intended for a restricted capacity and usage [14] as shown in figure 18.



a **b**

Figure 18 The Aerial Walkway

Source: a). https://www.gardensbythebay.com.sg/content/dam/gbb-2021/image/things-to-do/attractions/supertree-grove/gallery/supertree-grove-main.jpg,

b). https://i1.wp.com/www10.aeccafe.com/blogs/arch-showcase/files/2012/07/192.jpg?w=1000&ssl=1

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The 123-meter aerial walkway is 22 metres above ground and arcs out from one 42-meter Supertree to the other, winding around one side of the 50-meter tree. The structure is supported by wire rope cables that are set at 1 m intervals and link to the 42-meter trees as well as three smaller surrounding trees, one 37-meter tall and two 30-meter tall constructions. The walkway is made up of 140 mm steel tube stringers that support rectangular hollow section cross beams of varying depths that are located at 1 m intervals and support the steel coated platform [14].

Construction: These metal-framed constructions, totalling 18 in number, are vertical gardens with heights varying from 82 to 164 feet. The restaurant is at the top of the main Supertree [15] Grant Associates' 18 Supertrees range in height from 25 to 50 metres, with a focus on creating a "wow" impact with a vertical display of tropical flowering climbers, epiphytes, and ferns. Lights and projected media bring these canopies to life at night. Visitors may get a unique view of the gardens from an aerial walkway strung from the Supertrees. The Cooled Conservatories are cooled using sustainable energy and water technology built in the Supertrees [16].



Figure: 19 Restaurant on the top

Source: https://laughingsquid.com/wp-content/uploads/DSC_0681.jpg

2.5. Motisons Tower, India

Table 5. Motisons Tower Details

S. No.	Title	Details
1.	Architect	Kothari Associates
2.	Structural Design Consultant	V S Kukreja Associates Pvt. Ltd.
3.	Designed In	2013
4.	Area	50000 ft^2
5.	Built Time	1 year
6.	Client	Motisons Jewellers
7.	Building type	Jeweller Showroom

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Biomimicry: The building's form is inspired by the lotus at the organism level.

Concept: The building is inspired to look like a blooming lotus. Each leaf may be controlled separately, and at night, each leaf can change colour to any chosen hue. To generate varied "crackling effects," a central computer controls LED veins that are affixed to the glass surface. The colour altering may be programmed to produce certain effects, and it changes every day. The lighting system can be operated from mobile phones (Motisons Tower, 2013).

Structural Details: The structure has a square layout that is symmetrical on all four sides. The lotus flower's leaves sprout from the structure. Coloured glass is used to form each leaf, which has an exceedingly intricate geometry. Each leaf is capped by moulded fibreglass in a gold tint.



Figure 20: Motisons Showroom

Source:
https://images.adsttc.com/media/images/5180/1c29/b3fc/4b38/3400/009b/large_jpg/STILL_2.jpg?1367350298

Based on parameters given by the client, where the architect was suggested to make a unique design, Design should be worldwide, eye-catching, the buzz of the town, and a prospective tourist attraction, rather than 'regional.' The architect was given the leeway to create something unique in India that has never been attempted before. The design is made with glass as semi-open petals. The colour of the petals changes every few seconds.

Construction: The design's brilliance lies in the choice of glass and its installation technique. The all-glass exterior acts as a second skin to the primary structure, which is supported by SS spiders, resulting in an insulated structure. The area in between is ventilated mechanically. From the variety of hues accessible in natural gemstones, a total of 9 distinct colours were chosen. At night, LED wall washers wash the inside of the glass and produce millions of colours.

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Figure: 21 Night View

Source:
https://images.adsttc.com/media/images/5180/1bc6/b3fc/4b19/c700/00a1/large_jpg/1_S7A4275.jpg?1367350200

3. CONCLUSION

The lotus temple structure is classic and simple. The structure is innovative and the use of natural lighting and ventilation is solved as a sustainability solution [8]. The iconic building is a pride of Wujin and fulfills the expectations of the city itself as an iconic landmark and attraction. Humans have long labelled architecture on time. By integrating nature as an inspiration for architecture, the Lotus Conference Center will lay a lasting mark via an underwater tunnel from the property visitors are incorporated in the flowering sculptures. In the light of the domed, clear atrium of glass put in the metal "venues" that form unopened petals, they seem like a bud, like a lotus. A chandelier at the top draws attention to heaven. The middle portion is the "bud," which has open flower and seed pod divisions on either side [5]. If biomimicry of motisons can be noted aesthetically the design is good and innovative where the architect has used different lights to change according to the requirements whereas functionality is missing as lotus do not change its colour. This is not called biomimicry. The marine bay art science museum is the only place in the world where you may learn about the creative processes in art, science, technology, and culture, as well as their impact on society. The marine bay garden supertrees, on the other hand, function as an energy conservation system, with solar panels on the canopies capturing and converting solar energy to electricity, which is then used to illuminate the supertrees. There is a newly constructed Guangzhou Evergrande Football Stadium in china. The architect behind the project is Hasan A.Syed. The structure is inspired by the lotus flower petals. It was started in April 2020 and claims to open the stadium in December 2022 which will be the world’s biggest football stadium. Interior Designers should also pay attention to the concept of biomimicry. The contribution of interior designers is very little in the innovation towards nature-inspired concepts and designs.

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