

# Towards a Biophilic Design methodology In Search for Health-Inducing Built Environment

[REVISITING SAGRADA FAMÍLIA: AS A CASE-STUDY AND DESIGN CHECKLIST]

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**Abstract-** Special attention had been recently paid to pinpoint the aspects that most affect human satisfaction within the built-environment. Experimental findings demonstrate that compositions that connect people to natural elements and configurations help to increase their sense of wellbeing, with definite and therapeutic consequences on physiology, productivity, and even on stress/pain- reduction. Hence, a set of methodical approaches emerged from diverse domains, initiating a new space of research, i.e. environmental psychology; one of the most tenable theories in this direction is “Biophilia”. This paper accentuates the underpinnings of this theory in the field of architecture, overviewing and comparing the most prominent models in this field, thus the main goal is to conclude a Methodology/Checklist that encompasses all possible criteria for full-biophilic built-environment.

In so doing, the research proposes/suggests a methodology/checklist for evaluating this environment, based on an analytical study through building and site visit. This checklist is then used to examine and evaluate the design of “the Basilica of Sagrada Família” as a suggested model for this environment as a case-study, which represents one of the most iconic international architectural building, with more than (3.5 Millions) visitors a year from all over the world. The proposed model has also further settings and possible characteristics that might help architects and urban designers creating similar “healthy built-environments” to improve users' physical and psychological wellbeing with a positive experience, as found in this building, thus also justified in this study through scientific reasoning, which can be developed as a design guide lines/framework by further adaptation for new (culture/religious/recreational/...) public buildings designs.

**Keywords-** Biophilia – Biophilic design – Sagrada Família – Gaudi – Healthy environment –Sustainable design – Built-environment .

## I. INTRODUCTION

Starting from the mediaeval era, architectural design turned to be not merely the design of a well-proportioned building; but rather the cognitive creation of spatial experience. Unfortunately, the development of all aspects in human life (social- industrial – technological-...) move away gradually architects, urban designers and even planners from this view, proposing an alteration of social reform through buildings that are more economic and basically functional, spreading glass buildings that were stripped of any Nature-cues. Since then, the opportunities for contact with elements of natural environment in the built environment were increasingly reduced. Auspiciously, more attention has been recently paid by theorists, architects and designers to find

ways to regenerate this connection. Biophilic architecture is a step in this direction, paving the way into Nature-based dialogue between architectural spaces and a specific group of human inborn affiliations.

The term Biophilia was coined by the social psychologist Erich Fromm and populated in the 1980s by Edward O. Wilson, who developed it in the field of sociobiology, defining it as “the rich, natural pleasure that comes from being surrounded by living organisms. Not just other human beings, but “a diversity of plants and animals” [1]. Wilson’s theory asserts that “people need to have contact with the complex geometry of natural forms, just as much as they require nutrients and air for metabolism [2].

The goal of incorporating Biophilia in architectural design is to create environments imbued with positive experiences that can promote human health and wellbeing through the contact between people and Nature [3]. It is the missing link in sustainable design that would fill the gap between the functional/material treatments of sustainability, which frequently clashes with buildings' aesthetics, and the core subject of Nature; i.e. its splendor and delight. From this point of view, implementing Nature within our built-environment is not opulence, but has an economic benefit in both :( health and productivity).

According to real physiological and neurological evidences, it was found that certain forms and qualities can endow architectural spaces with certain identifiable “living patterns” [4]. Over the years, designers and professionals published several works that include varying models to objectify the transition of Biophilia from a theory to application in reference to these results.

Therefore, the historical, but still contemporary, building such as “Sagrada Família” is suggested here as a manifestation of a full biophilic design model and a valid source of inspiration for contemporary biophilic design. Measured against the concluded checklist, with special emphasis on exploring its biophilic qualities to conclude further strategies and settings that can be used in other contemporary buildings, the paper comes to the conclusion that this design not only fulfills all the criteria included in the list, but it also presents simple settings and strategies that responds to these criteria and might help bringing life to buildings, as seen in this example.

The different parts of the research are co-related and linked with each other. First part is a theoretical background, part two presents a summarized synopsis for the analytical /experimental findings of environmental psychology and neurology, as well as an overview of the four major Biophilia-theories, which are discussed and compared to draw out a full-model checklist. The brilliant settings for these criteria in the basilica of "Sagrada Familia" are then introduced in section three, where the checklist concluded in section two will serve to evaluate the biophilic quality of the building. Section four will summarize the results and findings of the study, where section five outlines the conclusion.

### 1. Research Problem

Research Problem has many major origins can be summarized as follows:-

- **“Biophilic design” considers an approach to sustainable design:** which incorporates the usage of Natural [Lighting – Ventilation – Thermal comfort – Materials – View– ....], then architects need a suitable design framework based on a “Biophilic criteria” to manipulate with their architectural /urban projects and problems.
- **Distancing from Mother Nature:** due to modernity of current life style and the domination of virtual (not real)/digital technology in: work, living homes and even public built-environments, resulting-in increasing rates of (Physiological – Psychological–Mental) diseases even to youth.
- **Urgent need to reconnect between nature and the built-environments:** to restore the balance with our Eco-system; depending on reconnecting with natural resources.

### 2. Research Goal

Main goal of this research is to: develop/ propose a biophilic design Methodology or design a Checklist/ Matrix that encompasses all possible criteria for a full biophilic-model that may be used as a tool for evaluating/Examine what one may call a "health-inducing built-environment", which can be a design guide line/reference that help:[architects- designers- artists and even urban planners] to enhance their built-environment, research will try to achieve this goal through the followings secondary goals:-

- **Exploring:** various leading models of “biophilia” theory application in architecture design and built-environment.
- **Concluding:** sets of criteria, introduced by leading theorists of biophilic architecture, will be compared to extract the checklist, which the biophilic quality of any building could be measured.
- **Verifying:** of the proposed design Methodology/Model by application the extracted criteria on one of the most worldwide iconic, visited and public architectural sight such as “Sagrada Familia.”

### 3. Research Importance

Consider a serious methodological proposal to Evaluate/Examine and even Measure the Qualitative values of the built-environment based upon application of the new “Biophilic” theory in architecture, searching for enhancement psychological human wellbeing, which reflects positively on (physiological, spiritual, and mental health) then productivity of users.

### 4. Research Methodology

Research methodology comprises among these gradual approaches, (as shown in Fig.1):-

- **Theoretical approach:** this covers the theoretical background and literature review of “Biophilia theory” demonstrating (Concepts – Objectives – Effects – Criteria...) and concept of theory implementation in architecture and design of the built-environment.
- **Comparative analysis and Analysis approaches:** to conclude and extract the most common and suitable sets of design criteria which can be applied as a methodology/matrix for “Biophilic” design for the built-environment.
- **Application approach:** through a case-study building to adapt the indicators and verifying of design criteria effects of the proposed Biophilic Methodology / matrix model.

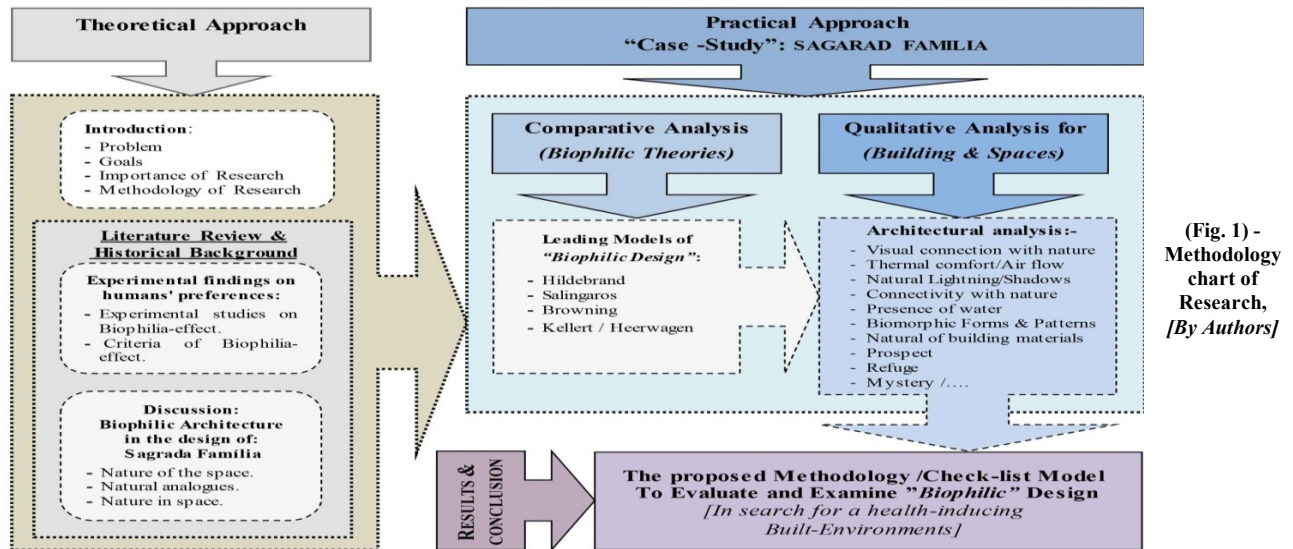
## II. THEORETICAL BACKGROUND: EXPERIMENTAL FINDINGS ON HUMANS' PREFERENCES

Recent researches in the field of environmental Quality of Life indicated that “Biophilia” is an evolving approach to sustainable design strategy, aiming to restore and enhance the relation between built-environment and Nature, which can compromising between the design of the built-environment for human essential qualitative needs [air quality, visual / thermal comfort, and acoustics] with minimum negative impact on nature, with insuring human biological health and wellbeing.

From an architectural point of view, “Biophilic design” patterns have attracted again the attention of Architects’ and even Urban and Interior designers, to link among: [Users, Physiological/Psychological Health, High-performance design of built-environment, and Aesthetics], [5].

Most of recent negative social effects/diseases were related to mental/physical health, Biophilic design especially for public spaces can also encourage social (real) interaction and sense of the real community not a (virtual) limited ones, which become current harmful life style.

In this section, some of these Nature-Health relationships and mind-body systems are briefly overviewed.



(Fig. 1) - Methodology chart of Research, [By Authors]

### 2.1. Experimental studies on "Biophilia-effect"

Over the last decades, several experimental studies were made to record users' preferences in order to apprehend the mechanism of Biophilia-effect and specify the criteria that may trigger it. Research in cognitive, psychological and physiological mind-body systems revealed that strong or routine connections with Nature can provide opportunities for mental restoration, during which higher cognitive functions may take place [3]. Wilson In his study, *"The Economics of Biophilia"*, proves that the more contact with nature the more increase of mental health and learning abilities then improve human productivity, including quality Nature-integration schemes into working spaces can save more \$2,000 per employee/year in working office costs, further more we can save over \$93 million annually in healthcare costs resulting from providing patients with similar qualities [6].

Experimental studies confessed also that, the architectural experiences of natural built-environments support/give greater emotional recovery, with lower cases of (stress, anxiety, tension, fatigue, anger, confusion and total mood disorder than other built-environments with poor/ restricted characteristics of Nature [5]. The conclusion of these researches suggests that people who used to the presence of natural qualities in their environment, not only for the sense of belonging and wellbeing, but equally for existence, as a primal source of "neurological nourishment".

As for the mechanism of this nourishment, it has been found that humans have an innate craving for certain type of information that is related to the visual complexity of Nature. To impart a healing effect, architects must not just mimic organic form, but rather apply certain guidelines for generating specific characteristics [7]. Neuroscientists found that views of complex, dynamic scenes trigger many more interactions of the opioid<sup>1</sup> receptors in the large rear portion of the visual cortex [8]. In an evolutionary-ecological

approach, it had been found that the incorporation of trees or tree-like forms, actual or symbolic, into the built environment should have a strong positive impact on people [9]. Long misconceived as a copy of natural forms, ornamentation in its deep expressions that directly trigger neurophysiology. For example, fractal patterns were found to have positive effects on neural activity and parasympathetic system mechanisms. [10]. Human body's response to daylight is another important clue in Biophilia-effect. It affects both eye functions and inherent circadian rhythms. [6].

### 2.2. Criteria of "Biophilia-Effect"

Initially, what architects should introduce in biophilic-architecture is not the actual nature, taking into account that it might not have the same effect. As Wilson, It was found that built-environments may possess intrinsic qualities that may allow a connection with nature, and in turn can trigger the sense of wellbeing. Intensive research aided in more and deep understanding for possible start-up reactions to specific shapes in natural forms, detail, hierarchical subdivisions, colors, etc. Several trials were made to develop models and lists that include the main criteria that may trigger the Biophilia-effect. Drawing on the works of several theorists, especially Jay Appleton [12],[13], developed the earliest one of these models, defining six paired elements that reflects human affinity for Nature as:-

- **Prospect and Refuge:** strategies/assumptions to get information about the environment, through providing shelter and protection.
- **Complexity and Order:** complexity is a measure for "how much there is to look at", but "Order" here represents the desire for (patterns- structure- space organization and symmetries) which connects all detailing in one integrated design.
- **Enticement and Peril:** settings that fulfill the desire for (Discovering, Exploring, and Expanding human knowledge, and the passion for risk, challenge and de-realization.

Stephen R. Kellert [3], suggested more extended model, developed from studies by the Psychologists Judith

<sup>1</sup> Psychoactive chemical that resembles morphine or other opiates in its pharmacological effects

Heerwagen and Betty Hase, defining the following qualities as basis for the Biophilia-effect in the built environment:

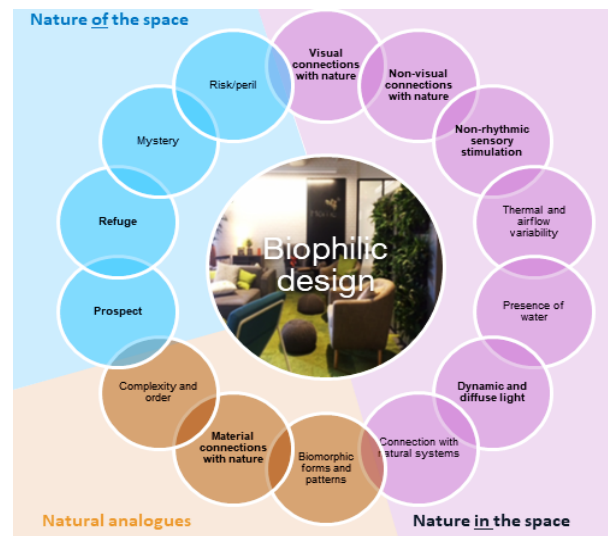
- **Prospect:** brightness, wide horizons, or ability to see into a distance.
- **Refuge:** sense of enclosure and shelter with canopy effect or branch-like forms overhead
- **Livability and movement:** with real moving water or reflecting surfaces.
- **Biodiversity:** vegetation elements or symbolic representation of them.

In its more recent versions, theorists started to promote the incorporation of real Nature into this concept, with three basic concepts as the canons of biophilic design according to the Connection/Experience with nature as follows:-

- **Direct Experience of Nature [Nature (in) space]:** Considers the implementation of (plants, water and animals) into the built environment in a direct connection to Nature.
- **In-Direct Experience of Nature [Natural Analogues]:** Refers to single point away from true Nature, referring to materials and patterns that evoke Nature.
- **Experience of Space and Place [Nature (of) space]:** Based on Man's development in the Savannas of Africa, which keeps him yielding the empathy for similar environments [14].

The "14 Patterns of Biophilic Design", defined by Browning et al.- [5], as shown in (Figure: 2), addresses these three concepts through the following patterns and compositions.

- **Sensory variability (or ephemeral qualities of space):** varieties in (color, temperature, air movement, light, texture...etc).
- **Fractals:** self-similarity, natural patterns or cycles, hierarchal characteristics.
- **Sense of playfulness:** elements that aim at delight, surprise, or dazzle.
- **Enticement:** complexity and richness of details to be seen, or gradual openness of views.



(Fig. 2) – 14 Patterns of “Biophilic design”, [5]

- **Nature in the space:**
  1. **Visual Connection with Nature:** A view to elements of Nature, living systems and natural processes.
  2. **Non-Visual Connection with Nature:** Auditory, haptic, olfactory, or gustatory stimuli that engender a reference to Nature, living systems or natural processes.
  3. **Non-Rhythmic Sensory Stimuli:** ephemeral connections with Nature that may not be predicted precisely.
  4. **Thermal and Airflow Variability:** Subtle changes in air temperature, airflow, and surface temperatures.
  5. **Presence of Water:** Seeing, hearing or touching water.
  6. **Dynamic and Diffuse Light:** Varying intensities of light/shadow changing over time.
  7. **Connection with Natural Systems:** Awareness of natural processes, especially seasonal/temporal changes.
- **Natural analogues:**
  8. **Biomorphic Forms & Patterns:** Symbolic references to contoured, patterned, textured or numerical arrangements that persist in Nature.
  9. **Material Connection with Nature:** Materials from Nature that, through minimal processing, reflect the local ecology or geology.
  10. **Complexity & Order:** Rich sensory information that adheres to a spatial hierarchy similar to those found in Nature.
- **Nature of the space:**
  11. **Prospect:** An unimpeded view over a distance, for surveillance and planning.

12. **Refuge:** A place for withdrawal from environmental conditions or the main flow of activity, in which the individual is protected from behind and overhead.
13. **Mystery:** The promise of more information through partially obscured views.
14. **Risk/Peril:** An identifiable threat coupled with a reliable safeguard.

A more recent model was introduced by Nikos Salingaros, [7], where he defines the following eight points as "the major factors that contribute to the biophilic effect":

1. **Light:** Natural light essential to perceive and evaluate our surroundings.
2. **Color:** As in the transmitted quality of light, or as reflected from pigmented surfaces.
3. **Gravity:** Heavier parts are on the bottom and lighter parts on top. Forced perspective -where scale is deliberately shrunk as ones gaze rises- is recommended.
4. **Fractals:** Well-defined subdivisions of structure in an ordered hierarchy of scales.
5. **Curves:** Natural environment exhibits fractal or curved forms, or a combination.
6. **Detail:** On the most intimate scale -at arm's length and closer- highly organized complex detail is recommended with focus on the smallest detail.
7. **Water:** To see water, and even better, hear it or feel it.
8. **Life:** Enclosing a courtyard, or surrounding a building with trees and shrubs.

(Table: 1) summarizes the criteria in the four previous models and puts them in comparison to each other in lights

of their definitions, as they came in each models, to come up with an extended design checklist, including all possible criteria for biophilic properties/criteria that might be used as

an evaluation/assessment tool for the biophilic attributes of buildings thus, designate what could be called the full-model for Health-Inducing Design.

(Table: 1) - Design checklist for Evaluating Health-Inducing aspects of Built-environment; Comparative Analysis of pioneering Biophilic models), (By Authors)

Comparative Models				Proposed/Deduced Checklist
Hildebrand	Salingaros	Browning (et al.)	Kellert / Heerwagen	
<b>Nature of the Space</b>				
Prospect & Refuge		Prospect. Refuge	Prospect. Refuge	Prospect & Refuge
Enticement & Mystery		Risk/Peril Mystery		Enticement & Mystery
<b>Natural Analogues</b>				
Complexity & Order	Detail Fractals	Complexity & Order	Fractals	Complexity & Order
	Color Curves Gravity	Material Connection with Nature Biomorphic Forms & Patterns.	Biodiversity	Material Connection with Natural Biomorphic Forms & Patterns
			Sense of playfulness	Gravity Sense of playfulness
<b>Nature in the Space</b>				
	Light	Dynamic & Diffuse Light. Connection with Natural Systems.	Sensory variability	Dynamic & Diffuse Light. Connection with Natural. Systems.
	Water	Presence of Water.	Livability & movement	Livability and movement
	Life	Visual Connection with Nature Non-Rhythmic Sensory Stimuli Non-Visual Connection with Nature Thermal & Airflow Variability		Life

### III. DISCUSSION:

#### BIOPHILIC ARCHITECTURE IN THE DESIGN OF: “SAGRADA FAMÍLIA”- [CASE-STUDY]

The “Sagrada Familia” is, indisputably, the world’s most visited construction site, with recorded number over (3.5 Millions) of visitors a year. As listed in year 2007-2008 by survey about the most people’s profound architectural sights and visiting experiences, which proved that, visitors are psychologically composed /synchronized to visit this building more than modern other buildings and structures.

According to David Mackay that refers to a 1965-Declaeration of “Sagrada Familia” against construction completion, that was supported by well-known Modernist Architects, Writers and Artists, including (ironically) Josep Maria Subirachs, who later became the sculptor of the Passion Façade. The result of this declaration /manifesto was a notable huge increase in financial donations (national /international) to complete the building. So, it is clear that people love the “Sagrada Familia”, with donations of over (60.0 Million euros) per year for its completion [15].

Over the last decade, professional construction works grows in site based on the synchronization among all updated digital construction technologies and building master design, in both: (External Facades /Internal spaces) without receiving any formal funds from the state of Barcelona, just donations from faithful and tickets sales with more than (3 million) tourists a year all over the world.

The Economic dimension of “Biophilic” design of such public or even culture buildings has constituted the third pillar of sustainable design, which considers the fuel of this process, the attractive, positive, healthy and influenced experience of visiting such buildings has a great positive free propaganda to be visited more and more times with more

new visitors, resulting in more financial income which insure the services costs and continuous development needed to it.

The Selection of “Sagrada Famili” as a Case-study building for this research based on many scientific reasoning, especially based on the great synchronization between a modern technology building with a dream design from history by Gaudi, even seems it was a notable contradiction, thus the driver for selection can be classified into three major dimensions as follows :-

- **Socio-Culture dimension [Community Participation]:**
  - Recorded as a UNESCO world heritage from (2010), which considered one of the most international, Iconic and monumental sights, visited and evaluated from worldwide various cultures (more than 120 nationalities).
  - Construction completion process (will be finished by 2026), and based mainly on donations and the budget entirely through entrance tickets of the visitors (25 Million €/year), that they consider proudly as a contributors.
  - Its distinct site and sky line design with high towers (172.5m), considers the most important landmark of city.
  - Memorial for one of the most famous modernist architect and artist in his time “Gaudi”, where he was buried in his own in-completed work “Sagrada Familia”,then it will be fully completed by 2026 (after 100 years of his buried there).
- **Technological dimension [Evolution over time]:**
  - Represents a great example for successful combination between tradition and innovation; due to the long journey through time for construction completion (from 1882: till 2026), consuming five generations (as

- minimum) of visitors and local citizens as witnesses for the same masterpiece design of Gaudí, which considered a perfect
- Advanced Construction technologies for large/high structural elements helped in completion the symbolic and memorial master design (especially in towers) to be done as Gaudí vision of design.
  - Impeded/hidden advanced technological systems like artificial: (lighting – ventilation – surveilling – sound – security – Follow-up – Control....) enhance the building capabilities.
- **Economic Dimensions / Direct & In-direct economic added value :**
    - Economic direct national added value; with yearly income more than (25 Million €) from visitors tickets only.
    - Economic touristic added value (More than 4.5 Million) visitors/year with all need of a accommodation and complementary touristic tours.

The term *Biophilia* may be relatively new, but the concept is not; designers have intuitively applied it since ancient times. Gaudí was one of those, who accepted Nature as his

Guide; by deep understanding for its principals, basics, natural form generations, in addition to latent forces, creating innovative techniques to mimic its beauty and evoke its stimuli. This section attempts to analyze the architectural configuration of the Sagrada Família in lights of the three pillar concepts of Biophilia, measuring it against the previously concluded checklist, recognizing and observing Gaudí's applications of this, then still unknown theory, in a design that Louis Sullivan described as "a spirit symbolized in stone", [16].

### 3.1. Nature of the space



(Fig. 3) – (Left to right): View to the crossing from the nave and the apse at the end; the difference in heights between the nave and the aisles; View of the transept; and view from the crossing to the apse and the oculus, [46]

#### B. Decreasing lighting conditions along lower sides while increasing it in the center:

For the windows, Gaudí used ruled geometry to create alcove-like windows on the sides of the aisles, enclosed along the lower sides by thicker walls to evoke sheltering effect [18]. Conversely, he increased the lighting levels in the middle area (fig. 4) via the oculus, so that visitors can

This concept addresses peoples' innate longing to cues from the Savanna environment [14]. Wide range of strategies and characteristics were suggested by different theorists, especially Kellert, to summon this environment as in the following.

#### 3.1.1. Prospect and refuge

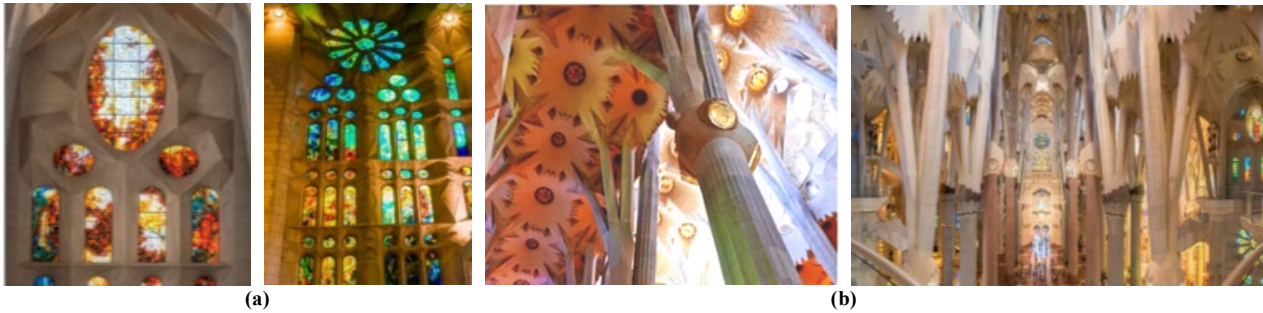
Strategies and settings for evolution of *refuge* include: [enclosure and shelter with canopy effect - reduction of lighting levels-design small window openings- finite space enclosure built with heavy thick walls- ...etc.], while the *prospect* relies on quite opposite characteristics: [brightness-wide horizons- raising of lighting levels- Increasing space dimensions- raised ceilings- panoramic vision on surrounding spaces-, terraces,.. etc]. previous contradictions among the strategies/techniques of the two concepts make this criterion difficult to implement [5]. In the following are some simple settings to overcome this difficulty as found in "Sagrada Família".

##### A. High ceiling in the main area flanked by lower aisles:

"Sagrada Família" is designed based on height being dominant over the other dimensions. Gaudí intended the visitor standing at the main entrance to be able to see the vaults of the nave, the crossing, and the apse; thus the gradual increase in vaults' heights with gradual openness of the view (fig. 3).

Columns rise freely up to (15, 30, or 45m), as they meet the vaults. These, in turn, begin 30m above the aisles, rising to 45m above the central nave, up to 60m above the crossing, and 75m above the apse [17]. Standing in the aisles (lower ceiling), one feels a sense of shelter and enclosure (*refuge*), while looking at the higher crossing area, and the even higher apse, one feels height and openness (*prospect*).

for-face the light (*prospect*), but do not sit in it (*refuge*) [19]. To highlight this characteristic, Gaudí decided that one lantern was not enough; he designed six in order to improve the central space and "let light shine all around the altar" [20]. Large elliptical rose windows in the upper parts of the side walls and clerestory in the upper parts of the wall between the nave and the aisles further intensify the lighting conditions in this area.



(Fig. 4) – Lighting conditions: (a) Alcove-like openings around windows; and (b) the difference in lighting conditions between the sides and the central area of the basilica, [46] & adapted by Authors.

C. Views to a distant scene through columns and interlocking arches or arcade:

In this strategy, prospect is evoked by the distant scene, while refuge is evoked through sheltering arches. Here, Kellert [3] refers to columns and interlocking arches as elements of forest-like environment. In Sagrada Família, the tree-columns are not only meant to transfer load, but also to

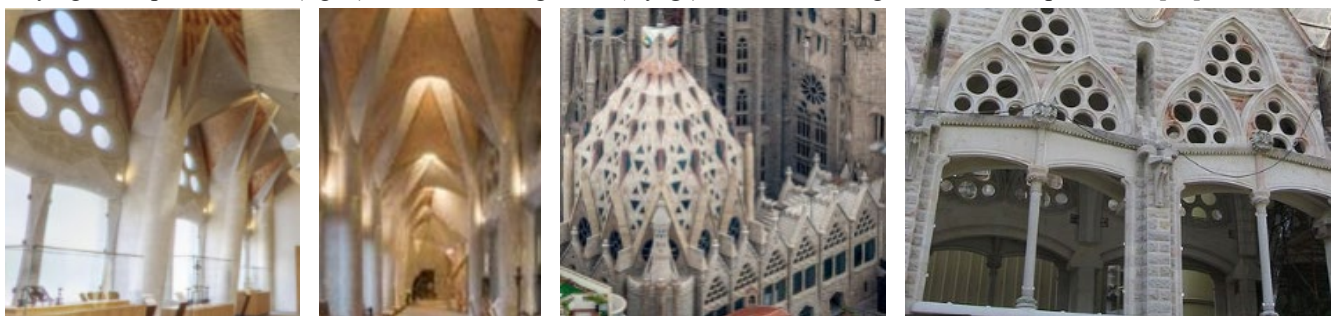
result in beautiful intersections of geometric forms. Viewed from almost any angle, the interior looks like a stone forest rather than a church; the slender, fluted shafts slant gracefully towards each other before branching upward to form repetitive organic catenary arches, supporting vaults covered with floral shapes, and allowing distant views in all directions (fig. 5).



(Fig. 5): Views through arcades: transept, nave, and aisles, [46], and other real by Authors

D. Covered passages:

Design of “Sagrada Família” plan has a non-conventional feature, which the covered passages or Cloisters that enclose the church and pass through the narthex by each of the three portals. Open views (*prospect*) are assured through wide openings varying in shapes and sizes (fig. 6), while sheltering effect (*refuge*) is evoked through the overhead protection [18].



(Fig. 6) – The Cloisters: (from in and out), [46], and other real by Authors

3.1.2. Enticement and mystery:

For evoking *enticement*, building should have chance for testing human imagination in react to details and Variety [3]. *Mystery*, or *peril*, can be done by design of overhanging terraces or upper passages that give a passion for visitors /people to get more experience by walking further more into interior space. These criteria were achieved in “Sagrada Família” through the following strategies/settings:

A. Partially Visible areas:

The Light and shade/shadow influence with various lighting conditions is the most common method for evoking this characteristic. Gaudí was very conscious of lighting atmosphere in the basilica, which he claimed should walk the fine line between meditation and celebration [20]. Integration and harmony between shade/shadow and light were applied to draw intended contrasts of interior space planes, which reflect and refract the lighting effect (fig. 7). None of the interior surfaces is flat; light penetrating through hollows in the vault, alcove-like windows with colorful

glass, clearstory between branching columns, grottoes protecting sculptures, and variety of geometrically shaped irregular surfaces, all contribute to create a light/shadow

influence of sunlight filtering through the leaves of a forest. Similar techniques are used for the façades; with complex geometrical compositions and uneven surfaces.



(Fig. 7) – Partially visible areas: with light/shadow effects, photos [46] and other real by Authors

### B. Details and diversity:

Gaudi's iconic building is known as one of the most astonishingly detailed buildings of its kind. The insurmountable huge building of "Sagrada familia" is full of exterior and interior details (fig. 8a).



(Fig. 8) – Details and diversity: (a) Trencadis and Ornaments of windows' pediments, (b) Festive Nativity Façade (left & middle) vs. austere Passion Façade With chiaroscuro effects, [46], other real by Authors.

We can observe clearly the contrast between the festive, highly decorated Nativity Façade, versus the Passion Façade with its simple, austere and plain design, with ample bare stone, carved with angular harsh straight lines (fig. 8b). Instead of the colorful fruits of the Nativity Façade, crowning the canopy here, there is a row of short bone-like pillars, where Chiaroscuro- effect<sup>2</sup> was used to further evoke the feeling of bleakness.

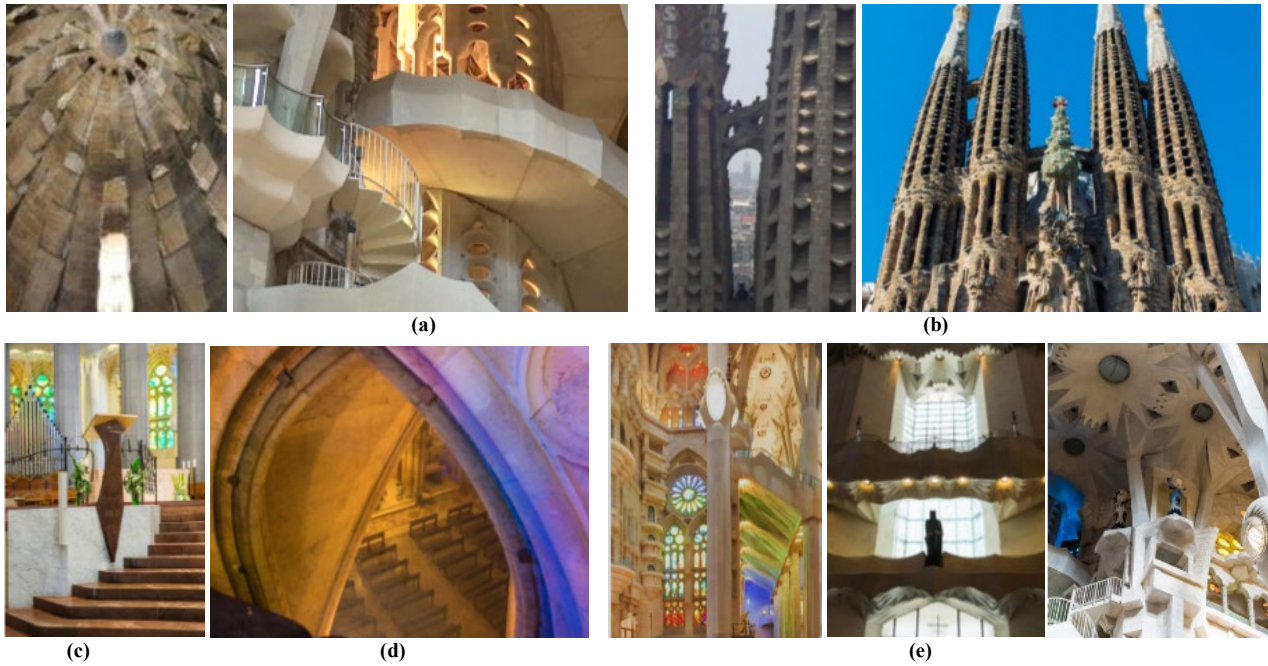
Entering the basilica, the interior appears even more majestic and mysterious. Ornamentation is comprehensive and rich, combining smooth curves and jagged points, with huge variety of colors and lights, the ample use of irregular shapes, the prodigious slanting columns, differing in colors and shapes, and the overwhelming vaulting-system, with endless mini stalactites and leafy canopies that render the arches almost unrecognizable, are some examples.

### C. Topographic variations:

The "Sagrada Familia" is granted one of the most interesting topographical compositions among all churches/cathedrals. From outside, the main entrance will be through the Glory Portico; a large staircase over an underground passage overflowing the street will lead to it.

<sup>2</sup> Dark angular shadows contrasted by bright rigid light





(Fig.9) – Topographic variations: (a) access to towers, (b) bridges between the tower, (c) the podium and the marble lectern, (d) View of the crypt, [21], and (e) Triforia, [46] other real by Authors).

Each façade has four towers accessible via spiral staircases (fig. 9a). At the point of transition, where each tower turns from square to circular cross-section, a balcony is made. Grouped in pairs, accessible bridges are instated between the towers at different heights. The most important one is the one behind the *Tree of Life* portico, topped by a covered gallery (fig. 9b). From inside, along and around the apse, there is a podium with a tier to accommodate the choir (fig. 9c). The altar lies over the crypt about 2m higher than the general level of the basilica, with large gaps around the apse to provide view down to the crypt (fig. 9d). At both ends, the stairs to the crypt are visible, with a triforium at the top and several series of triforia and balconies along the lateral walls (fig.9e).

### 3.2 Natural analogues

This concept addresses organic, non-living and indirect evocations of Nature. This can be characterized in architecture and design as artwork, ornamentation, furniture, decor, colors, patterns, sequences, or materials that manifest analogues found in Nature [14].

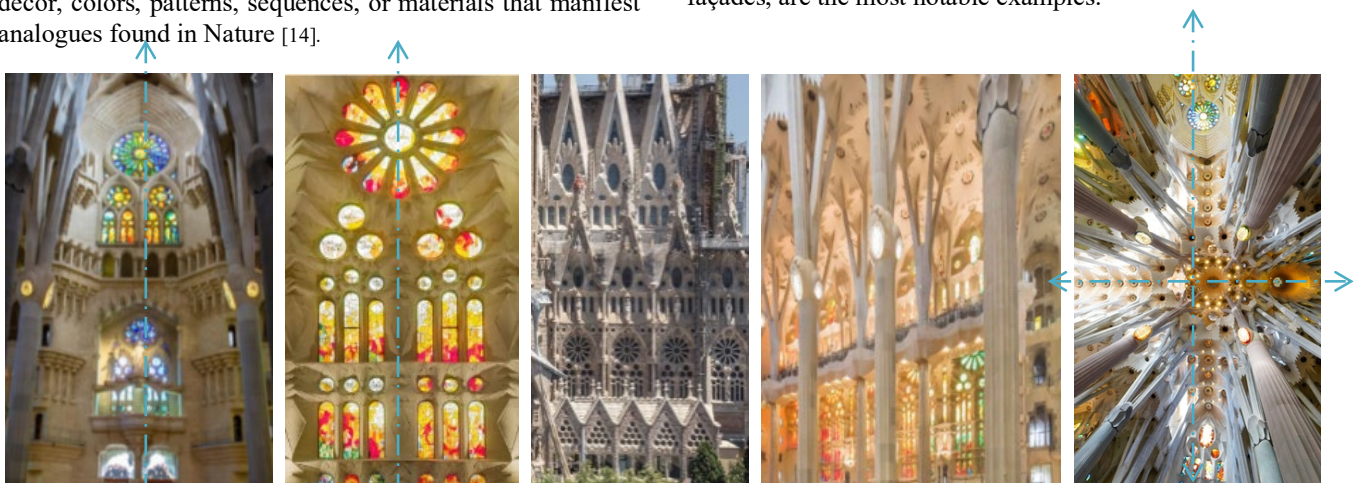
#### 3.2.1. Complexity and order:

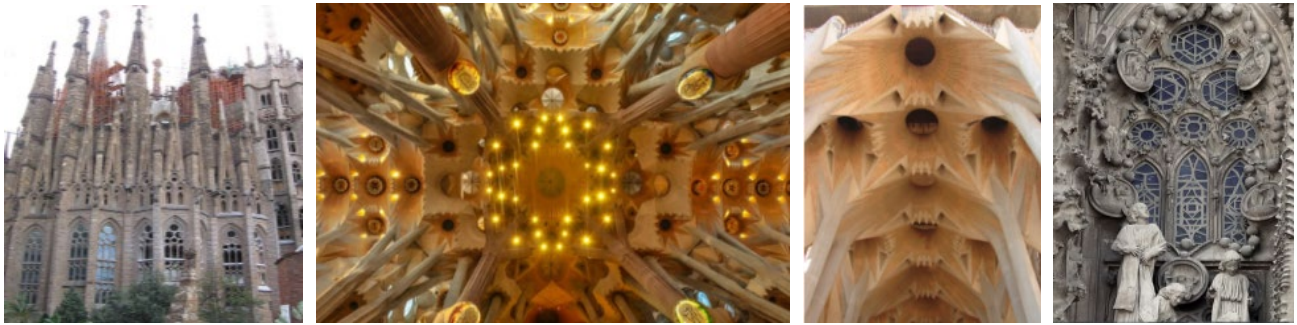
Complexity is the degree of details and variety that "enables one to make comparisons and/or choices" [22], while *order* is characterized by rich sensory information that is configured with a coherent hierarchy. Combining Gothic and Art Nouveau styles, the "Sagrada Família" has great complexity of forms.

The following are some applications from Sagrada Família for the strategies that Salinger suggested for attaining what he called "ordered complexity".

#### A. Connective symmetry/hierarchy:

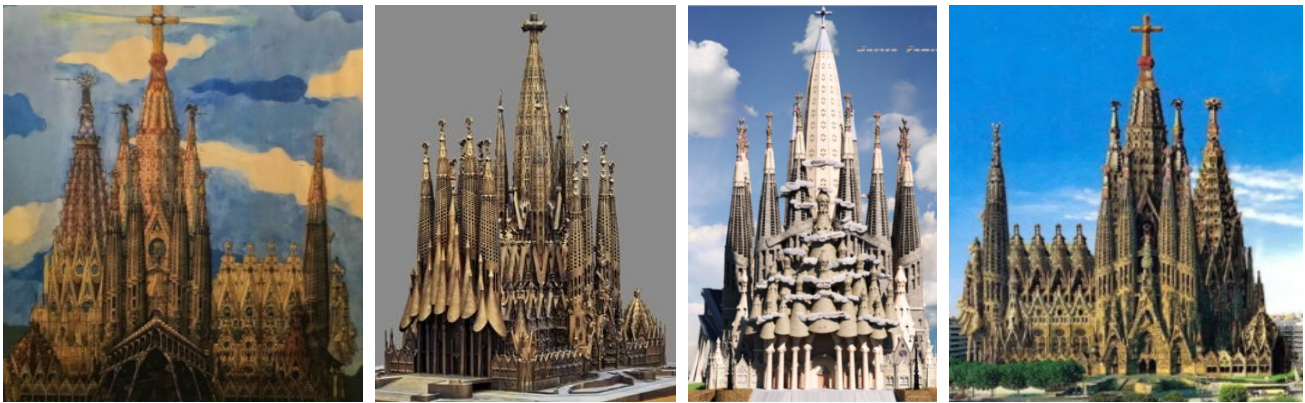
Visualizations for this conception are strongly existent in several settings in "Sagrada Família", where different levels of symmetry are composite with each other as seen in (fig. 10). The hierarchical geometric compositions of the vaults and the windows, the hierarchical repetitive pediments, as well as the series of gables, pinnacles and flashlights in the façades, are the most notable examples.





(Fig. 10) – Connective symmetry and hierarchy: hierarchical repetitive elements, [46].

*B. Universal scaling:*

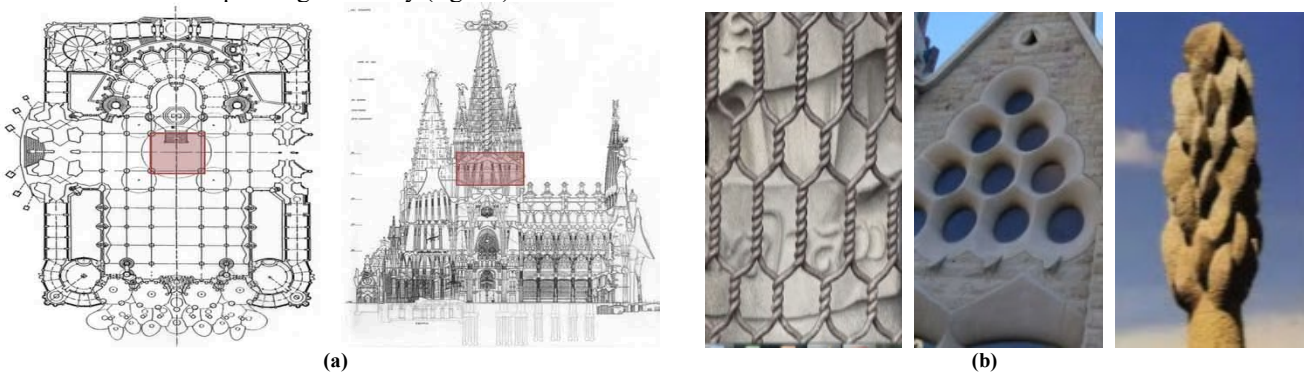


(Fig. 11) –: Facades: (From left: Passion, Sanch, Glory, and Nativity facades) Variation of tapered triangular shapes on different scales, all pointing to the sky [21], [27].

This strategy is identified as "very many identifiable components on the smaller scales, several on the intermediary scales, and another a few with the largest scales" [11].

The façades of "Sagrada Família" are obvious application to this strategy. Harmonized elements with varying sizes are arranged to compose a balanced whole. For example, the "many" pediments and torches, the "several" lanterns, and finally the "only" central tower, all are variation of tapered conical elements on different scales, that makes a "whole" the looks like a shaft pointing to the sky (fig. 11).

Modularity is another technique for achieving universal scaling [4]. In Sagrada Família, all dimensions are designed with a modular system, which has a main span of 7.5m in both dimensions (the distance between main columns). Selection of this module refers to the dimension of the highest point of the "Montjuïc" hill, setting his highest point at 172.5m (23 modules; one module less than the hill) [17]. From the scale of the hill to the scale of the building's superstructure, reaching to the details and the ornaments (fig. 12 a, b), all are subject to the same module, [18].



(Fig.12) – Modular system in: (a) Plan & section, (b) Details: railing in the Nativity Façade, honeycomb pattern in the cloisters' openings, And lavender sculpture in the apse façade, [46].

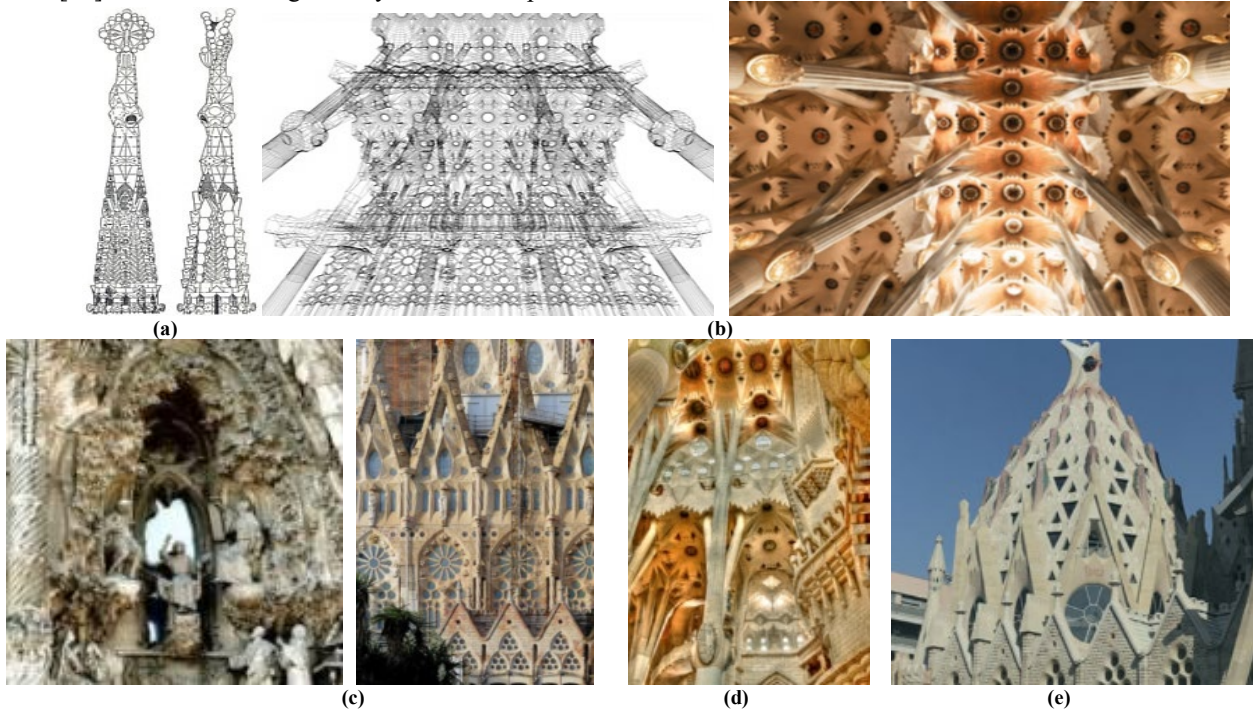
*C. Fractals<sup>3</sup>:*

For several Biophilia-theorists, fractals are essential characteristic of biophilic design; strict interpretation of fractal mathematics or infinite repetition is not demanded here. Only a scaled self-similar pattern is enough [15]. It is

<sup>3</sup> A Fractal: is a pattern that repeats itself at different scales to an infinitely small scale (like cauli flower)

actually impressive how Gaudí was able to imitate the varying complexity of Nature by a clever use of Euclidean Geometry with intuitive fractal processes. From the branching of the columns to the ceiling that is boasting floral patterning spreading across the whole space, all are fractal patterns [18]. Elements that "grow" by means of repetitive

patterns of different sizes can be easily perceived all over the building, with profusion of organic figures surrounded by exuberant, repetitive vegetative forms that weave their way between the sculptures covering every inch of the Nativity façade (fig. 13).

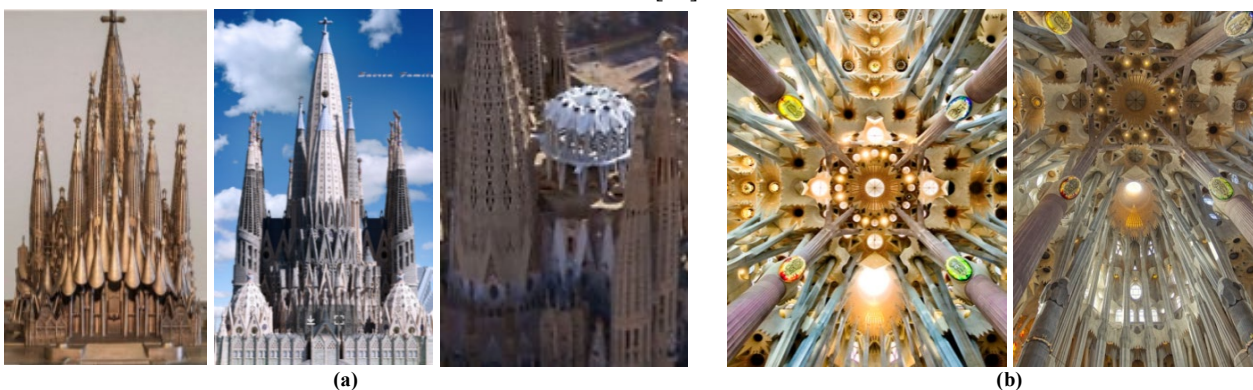


(Fig 13) – Fractals: (a) Pinnacles, (b) Vaults and ceiling (based on Cerebrovortex, 2013), (c) Façades, (d) Ornaments, and (e) Cupola, [24]

#### D. The theory of centers:

According to Salinger, the generative cipher of the Universe/Creation is "identifying and strengthening centers", where many smaller centers focus upon larger center [11]. In Sagrada Família, the image of the structure, tapering to a single point (fig. 14a), was Gaudí's illustration of his faith in the single, omnipotent God.

With the grouping of pediments, torches, and towers, the overall pyramidal shape of the building is further accentuated. Upon finishing the building, the tallest tower will be situated over the crossing, falling over six porticos with a height of 172.5m, led by a cross of four branches 15m high that will be covered by Venetian glass, with searchlights focusing on it, making "the sun shine at night" [25].



(Fig.14) – Centers: (a) Models of Sagrada Família show how it will look upon completion, and (b) The cimborio and the oculus over the altar, ([21], [26])

The same sense is conveyed upon entering the basilica. By following the axis of the church main entrance, the main altar is displayed with five porticos on the front end of the Gloria. Hung from the center of the apse are a large flashlight and a cimborio, the height which is 65m. An

oculus showers the focus on Christ with a single beam of sunlight (fig.14b).

#### 3.2.2. Material connection with Nature:

This criterion refers to the use of materials that reflect the local ecology or geology or create a distinct sense of place. This could be achieved through accent details made with natural wood grains, leather, stone, bamboo, rattan, etc., with natural color palette [5]. This idea was presented in “Sagrada Família” in the following settings:-

#### A. Variety of natural materials:

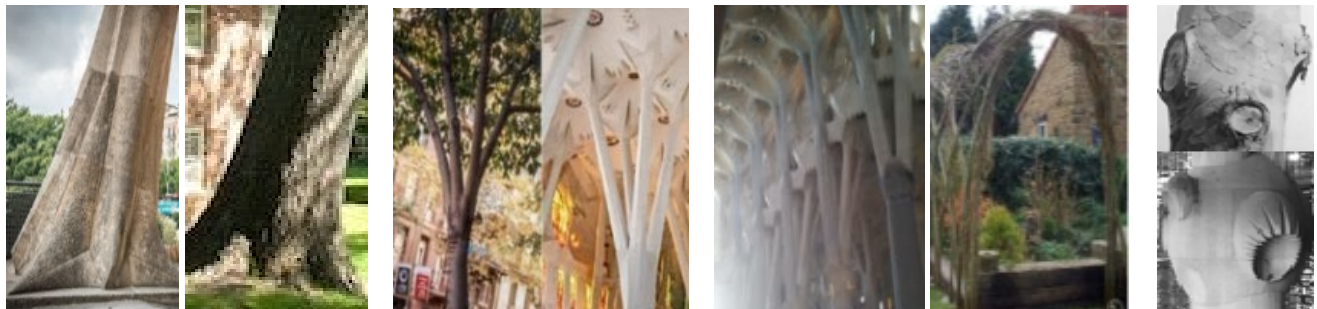
As in natural trees, with the concept of bearing loads, and resistance of each column, and heavy loads will be received, Gaudí built his stone-trees with various stone types, differs in (patterns - colors, and textures). The strongest stone, the “maroon-tinted porphyry”, is used for the twelve-pointed main hall columns of the crossing; otherwise the ten-pointed columns under the towers were made of black basalt stones;



the eight-pointed columns constructed of grey granite; and the six-pointed ones are yellowish sedimentary sandstone from the Montjuïc Mountain [20]. For the façades, he switched from inner materials to another interesting choice of a natural material, although not Gaudí's choice was the use of cork for flooring.

#### B. Petrification:

*Petrification* in architecture refers to replacement of natural wooden materials/structures with fabricated stones, but scrupulously preserving the natural wooden appearance on the stone fabric [27]. In “Sagrada Família”, Gaudí took this technique to a new level, producing an effect of a beautiful architectural forest from natural stones (fig. 15).



(Fig.15) – Stone-Trees: (above) general views of the interior, (below) structural elements and their roots in Nature (Leaning columns, arborescent columns, reed-like arches, and knots at branching points) [24], [46]

The Passion Façade with the leaning stone columns, Gaudí simulated design of large trees that broaden their base for better balance. For the interior, he created reed-like arches and arborescent columns with new geometric structure [28]. The columns have different cross sections, varying between (four: twelve) initial sides, turning their shafts in two directions (double twisting of square cross section), imitating the three-dimensional growth of trees [29]. For more natural look, as well as structural necessity<sup>4</sup>, he even added knots at branching points like in real trees.

#### 3.2.3. Biomorphic forms & patterns:

Browning defined this criterion as "references to contoured, patterned, textured or numerical arrangements that exist in Nature". This may include: designs based on Golden Mean; ornaments and moldings, glass color, texture, mullion

design, free-standing sculptures, etc. [5]. In the following are some settings of this criterion as seen in Sagrada Família.

#### A. References to elements that exist in Nature:

Gaudí was a sculptor as much as an architect, possessing the ability to imbue structures with qualities of Nature that can be experienced visually and tactually, where walls would be covered with crowded and cluttered stone sculptures teeming with life. In its entirety, the Nativity façade presents an allegory of the constant change of Nature and existence. The organic design aspects which appeared in (curvature, colors, undulating walls...) all reflects the impact of Mediterranean Nature. The portico in the middle of the desert-plant-looking towers is topped by a representation of the “Tree of Life” (fig.16.a), The cloisters are also decorated with abundant sculptures of flowers, palms, olive branches, etc., with more than 30 different animals,(fig.16.b) brilliantly distributed over the façades, [30].

Gaudí's tendency to decorate and design using natural imagery is continued in the interior with a richness of foliage decoration and colors. Even for lighting units, small units are

<sup>4</sup> Gaudí was interested and believe of the importance of curves at joints to prevent cracks

sprinkled in the ceiling like stars (with figures of stars on them) to emerge the forest-like effect (fig. 16.c), while shell-

like units were installed in the capitals of the pillars [12].



(Fig.16) – Biomorphic forms: (a) Plants, (b) Animals, and (c) Star-like units, [46]

### B. Decorative gardens:

Decorative gardens are original strategy in this basilica. The matchless colorful bronze gates of the three portals of the Nativity Façade, full of metal leaves, flowers and insects, are

the most direct application of it (fig. 17.a). In fact, Gaudí wanted the whole façade to be polychrome, for each figure to be tinted as in these gates [31].



(Fig.17) – Decorative Gardens: (a) The gates of the Nativity Façade, (b) The pinnacles that finish off the apse, and (c) The pediments on the windows of the aisles, [21], [26]

Another application is seen on the upper parts of the apse façade, where he created a garden surrounding the tower of the Virgin Mary, with leaves from cypress, palm, olive and rose bushes, etc. (fig.17.b). It is the fruit of these plants that will be on the top of the apse pediments.

Gaudí organized these fruits by the natural course of the seasons, for example, the eastern Nativity Façade, there are spring fruits (loquats, cherries, plums, peaches and pears) and so on (fig.17.c).

### C. Geometry of Nature:

In Sagrada Família, Gaudí's employed uncommon geometrical forms to imitate the geometry that he found in Nature; he studied their geometries and the logic behind

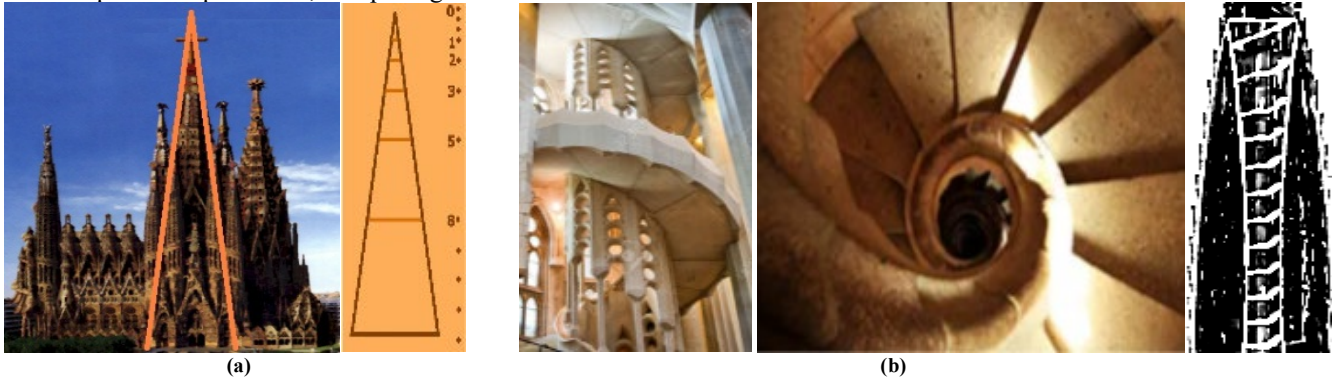
them, and tried to incorporate them into his design [18]. In the following are some examples; from these only the Golden Mean was suggested by Browning, where the others are Gaudí's original applications.

#### • Golden Mean:

Adrian Bejan the professor at Duke University and the author of *Constructal Law*, based on her studies, states that "the façades of the Sagrada Família are based on the Golden Ratio" [32].

The Golden Triangle is a derivation of the Golden Ratio with set of its essential qualities. According to Rojas, the main tower of Sagrada Família is designed according to this ratio, (fig.19a) [33].

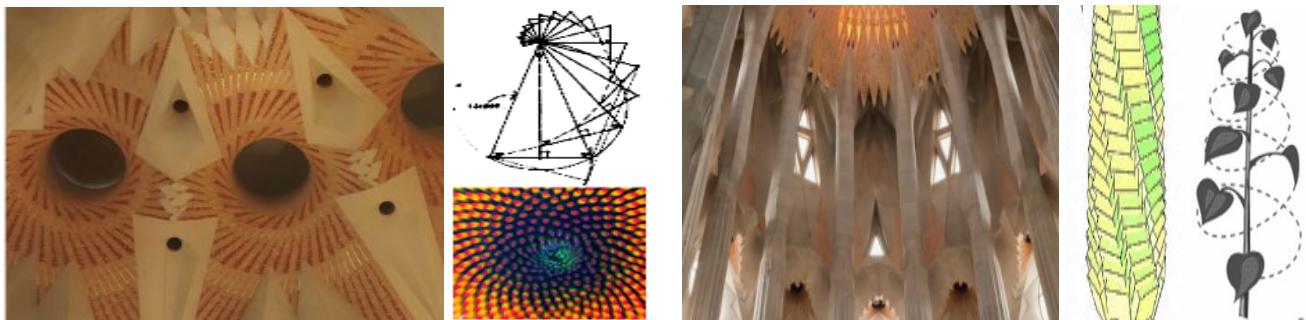
The spiral stairs of “Sagrada” towers are also modeled after their movement as they rise (fig.19.b), [34]. the Perisphinctes spiral shell, comprising a Golden Ratio in



(Fig.19) – (a) Golden Triangle in the Tower of Jesus (based on Rojas, 2008) and (b) Golden Ratio in the spiral staircase of the towers, [33]

• **Dynamic (Philotaxian) symmetry:**

The term “dynamic symmetry” was coined by Jay Hambidge, who found that the synchronicities of Nature express themselves in certain “patterns and cycles”. Of these, he determined two types of symmetry: static symmetry, such as that in a snowflake (fractal); and dynamic symmetry with continuous movement, such as in sunflower-disk [4].



(Fig.20) – Design based on dynamic symmetry, (Philotaxian patterns - [35])

Based on this natural dynamism, he discovered the *Phyllotaxis Phenomenon* in botanicals, such as the arms in daisies, the sequence of leaf patterns as they twist around a branch, etc. [35]. Applications of this kind of geometry appear in “Sagrada Família” in, for example, the crisscross patterns of the vaults, and the aforementioned double twisting movement of the columns (fig.20).

• **Quasicrystal line patterns:**

Quasicrystal line structures<sup>5</sup> are another type, which the universe's patterns and cycles are expressed. These types of patterns that fill the whole space, but do not have the translational symmetry that is characteristic of true crystals or fractals. Discovered in the 1980s, these patterns were not known for Gaudí. Nevertheless, similar arrangements could be seen in some patterns in “Sagrada Família”, such as those of the stained colored glass windows and the various compositions of the vaults and ceiling, (fig.21).



(Fig 21) – (left to right) Atomic model of Al-Pd-Mn quasicrystal surface,(public domain,2023), (Up) window and ceiling from Sagrada Familia, electron diffraction pattern of Al-Cu-Fe icosahedral, and a vault in “Sagrada Familia” quasicrystal, [36]



<sup>5</sup> A crystallic structure that is ordered but not periodic.

- ***Ruled surfaces:***

The use of ruled surfaces in architecture, which comprises the greater part of the elements, from windows to roofs, it was a totally original contribution of Gaudí. He realized that Nature can be expressed by the family of ruled geometrical forms. Gaudí had designed the Passion Façade columns,

depending on hyperbolic paraboloids, while in the Nativity façade the helicoid was used in the pillars, and ellipsoid for the knots of the interior columns. Solid or hollow, hyperboloids are used in the openings of the windows and the transparencies that pierce the vaults, using paraboloids to connect successive vaults (fig. 22).

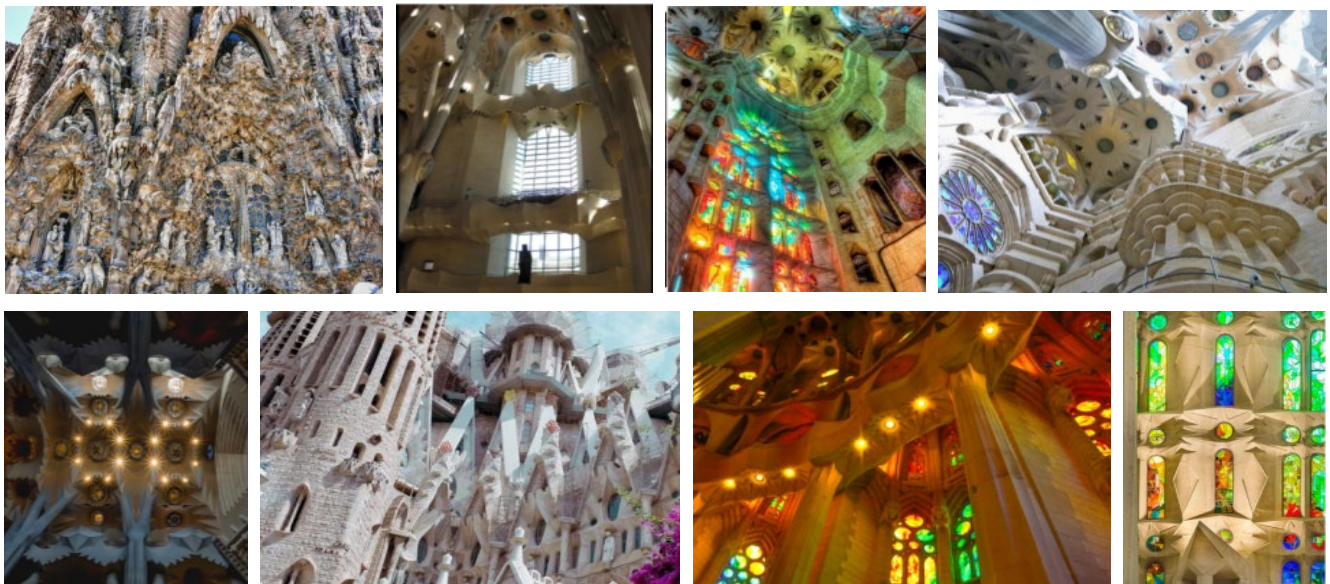


(Fig.22) – Ruled surfaces: windows, roof, stair, vaults, and columns, [46]

- ***Non-Rectilinear Geometry:***

In keeping with Gaudí's observation that God did not "build" in straight lines, there is not a straight line anywhere in the basilica. And since Nature was neither uniform nor monochromatic, Gaudí avoided regular

shapes and right angles with variety of geometric techniques, as mentioned before, incorporating an abundance of colorful natural geometric motifs in reference to the structure of trees, flowers, fruits, leaves, fungi, etc.,(fig.23).



(Fig.23) – Non-Rectilinear geometry in "Sagrada Família", [46], other real by Authors

### 3.2.4. Gravity:

According to Salingeros, [7] "All objects in Nature exist in *gravitational equilibrium*, and this informs humans' mental reverence for stable structures". In Sagrada Família, Gaudí refined the aesthetic tricks of Gothic Architecture to create a building that looks as if it is being pulled upward. He employed not only "visual" equilibrium, but rather "structural" equilibrium as it is in Nature, where he got rid of the buttresses, calling them "the crutches of a cripple" [37], and created an equilibrated building that stands on its own and looks like as if growing out of earth (fig.24.a).

"Forced perspective" as suggested by Salingeros, reassures people of the gravitational balance around them [7]. For him, a tree is anti-gravity creature that grows in strength as the roots, the stem, and the crown widens; a column with a base,

a stem and the crown, reflects this strength; pillars with no base or crown do not do this [38]. In his design, Gaudí used *tree-like columns*, several years before this concept was suggested by Salingeros. Gaudí's columns, not only have base, stem and crown, as Salingeros suggests, they rather resemble real tree trunks, with shafts that spread into branches to meet the vaults.

Exactly as in Nature, their cross sections decreases as they rise (forced perspective), increasing in number of vertices from polygonal to circular, forking then into smaller branches for even lighter appearance.

The double movement of the columns represents, Gaudí said, the "rising movement of transcendence" [39]. The catenary arches of the interior and the towers of the exterior both seek the same lines of ascension. The tapering towers and the

vaults containing the flashlight are also forced perspective- elements that shrink as they rise (fig.24.b).



(Fig.24) – Gravity elements: (a) A structure growing out of earth, and (b) forced perspective-elements, [24]

### 3.2.5. Sense of playfulness:

The “Sagrada Família” is at once surprising, unusual and exuberant. Gaudí proposed for this basilica the reinterpretation of the Gothic style that may establish a relationship between heaven and earth by means of height and light. Standing alone in the area between Gothic style and Art Nouveau, the uniqueness of its design makes it one of its kinds.

Delight, surprise, and dazzle are found in almost each and every element of the basilica with tremendous details all over the building inside and outside. Its overall look is like a hill of sand or melted wax. As one steps inside, one sees the space no less than a kaleidoscope stone forest, the beauty of which is breathtaking with variety of colors, shapes, geometry, details, reflective surfaces and diffusing lights, all are rather imposing and may take some time to take in. Its profuse sculptural decoration and its magnificence and solemnity make this structure a genuine Bible in stone or a "spiritual forest" [40], that exercises one's imagination for clues and meanings. Intending to illuminate it at night, it is as if Gaudí wanted his building to be prophetic, turning it into a lighthouse to "proclaim the Exceeding God" [25].

### 3.3. Nature in space

This concept addresses the direct, physical presence of Nature. Its criteria and the possible strategies related to them are dependent, not only on architectural elements, but rather on connections to elements of real Nature.

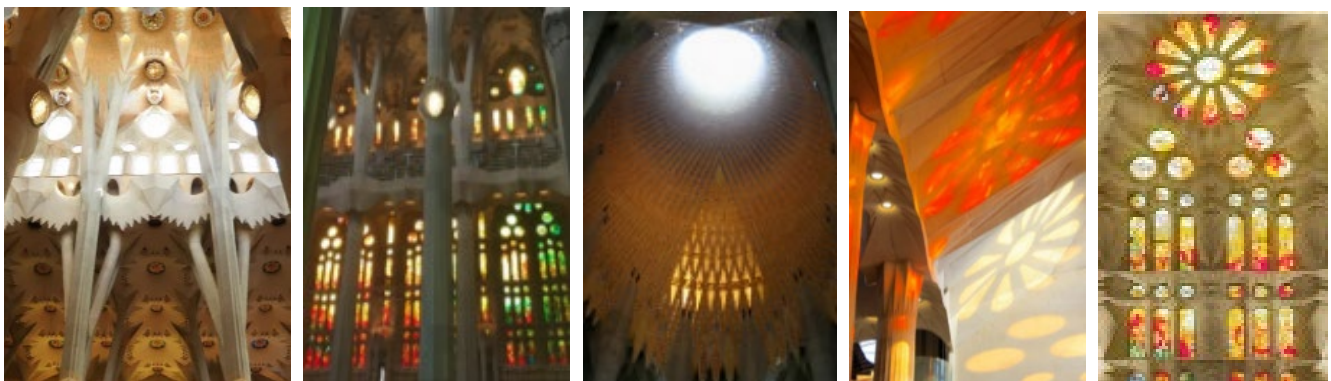
### 3.3.1. Dynamic and diffuse light.

Possible strategies for this criterion that would allow for light to penetrate at variable levels of diffusion are: differing orientations of windows, clerestories, skylights, a large central atrium, etc. [5].

“Gaudí” was very interested and conscious by the vital role of natural lighting in space; he analyzed and measured its effect with great care to be sure that, all interior spaces of the basilica will be enjoyed by proper natural lighting as possible (fig.25).

The vibrant windows with colored stained glass give the building its main source of light and life with specific rhyme and reason behind their placement: large clerestories with transparent glass were used to insure high illumination in the upper part (*prospect*), while deeper hues work their way down to create a forest-like lighting effect (*refuge*). Stained glass in the apse features the same plan of graduated tones with a beam of sunlight from the oculus on top. To sway the intensity of light that diffuse through, Gaudí invented a new technique for making stained glass, using three glass planes of the three primary colors with varying thickness [41].

“Gaudí” used ruled surfaces throughout his design to trap natural light and defuse it within the windows and the roof, the light diffusing and reflecting through apertures in the vaults, windows, and between the branching columns gives the influence of sunlight infiltrating through the upper sleeves of a canopy.



(Fig.25) – Natural Lighting in “Sagrada Família”: (left to right) Clerestory with clear glass, graduated tones for stained glass,



The oculus above the altar, and ruled surfaces to trap light and diffuse, [46], *other real by Authors*

### 3.3.2. Connection with Natural Systems (Sensory Variability)

Browning et al. (2014) define this criterion as "Awareness of natural processes, especially seasonal and temporal changes". The varying light conditions throughout the day are the most notable of these changes. In "Sagrada Família", windows have varying colors, based on (as previously described) their vertical location, as well as their solar orientation. To virtually introduce Nature and its colors, so it appeared in eastern façade glass windows which have cold colors, but west façade was by warm ones [25]. As the sun moves around the building throughout the day, the mode of the building changes from the warm celebrative mode of the morning (Nativity) to the cold gloomy mode of the dusk (Passion).

Around the winter solstice, when the sun sets before reaching the west, exceptional phenomenon occurs: as the rays become horizontal at sunset, they stream into the nave almost perpendicular to the windows; each of the rose windows projects its light onto the opposite section of the vault, creating a perfect reflection of each window in colored light on stone (fig.25).

Simultaneously, the nave becomes inundated with the reds of the sunset. The scenario is dynamic and progressive, where the red rays are first projected on the floor; then, little by little, they move up the columns, like flames, then rising little by little to reach the upper vaults of the choirs, [42]

### 3.3.3. Livability and Movement.

Factors of this criterion are real water, reflecting surfaces, or bearing resemblance to water or clouds [5]. In "Sagrada Família", in addition to the reflections of the stained glass surfaces, the circular apertures in each of the vaults are finished in Venetian glass tiles of green and gold. For more reflective surfaces, certain parts of the floors are marked with shiny red granite, while the rest of them are made of cork, finished in reflecting high traffic varnish. The subtle play on reflecting light in the interior is developed more expressively on exterior façades through Gaudí's technique of *Trencadis*, where the top (17m). Of the spires are covered in Murano glass [34].

Gaudí also gave them openings, where searchlights are to be installed, focusing on the huge cross on the central tower, covered in Venetian glass, reflecting lights that will be seen in the whole vicinity [25].

Reference to water elements or clouds is present in the basilica in the window of *Water of Life* in the Passion Façade and the monument to *Fire and Water* in the terrace in front of the Glory Façade. Above the Glory Façade (fig. 9), clouds in the form of construction will rise by four towers along the torches (fig.11), carrying characters of great dimension Creed "*Credo in unum Deum Patrem Omnipotentem, creatorem coeli et terrae.*"<sup>6</sup>

As for real water, a huge fountain will launch four streams of water in front of the baptistery, the height of which is 20m, going down to a system of cups and gutters. Another water feature in the façades is the gargoyles. Not only they drain water, they also symbolize it, as Gaudí gave them the shapes of Mediterranean animals, (fig.17b).

### 3.3.4. Life

This criterion, with its suggested settings (which came in the model of Browning et al. as separate criteria), has little to do with architecture and it is not among the elements of a building, but serves to encourage users to interact with natural built-environment [7]. Yet, one can still find brilliant applications for this criterion in Gaudí's design that offer a good precedent for understanding how design can functionally and beautifully connect people with Nature.

#### A. Visual connection with Nature

When referring to this notion, most theorists talk about actual Nature, although Christopher Alexander calls "living structure", making distinction between ornaments that look organic and those that look abstract [43].

In "Sagrada Família", in addition to the aforementioned decorative gardens, there is also a real garden (fig. 26). Hidden behind the upper narthex of the Passion Façade, behind the triangular pediment and between the two central towers, is a fairly large garden that should symbolize the garden, where Jesus was buried. It will be visible from the Passion narthex and, from below, the rose window of the resurrection, [42].



(Fig.26) – (UP), The garden behind the Passion Façade, [46], Authors

<sup>6</sup> Meaning: "These clouds will surround an image of God"

The bridges of the towers of the Nativity Façade and the openings of the cloisters are overlooking another park with a pond across the street.

### B. Non-Rhythmic Sensory stimuli

Browning defines this characteristic as "Stochastic and ephemeral connections with Nature that cannot be predicted precisely". He gives examples of its applications of changing light and shadows by the act of time, or people movement, or rainwater management that leads to ephemeral experiences of swaying grasses, falling water,... etc." [5].

Gaudí wanted the finished "Sagrada Família" to be a structure of unlimited permanence. Growth and movement are two characteristics of living things that Gaudí made visible everywhere in the basilica. The fact that the building itself is still "growing" for more than a century is evidence of this [18].

The aforementioned changing lighting conditions over the course of the day (3.3.2), and the gargoyles all over the façades are further applications of this characteristic. In rainy days the system of the gargoyles is drained, where the thin trickles of water coming from sculptural zoological figures reflects light and weather conditions and invite passersby to touch water.

### C. Non-visual connection with Nature.

According to Browning, "The integration of water and natural ventilation with the architecture is vital to the non-visual experience". He refers to water fountains, solar heat, fragrant plants,

or sounds of Nature and people as possible ways to evoke this characteristic [5].

In "Sagrada Família" the spires will have twelve bells (only one is installed at the moment) that will be heard inside and outside the building. Gaudí chose for his building tubular bells for softer and more diverse sounds [18]. In addition to the gargoyles, the aforementioned huge fountain (3.3.3) that will launch four streams of water, both will contribute to create the connection with water. On the other side, in front of the *Capilla del Sacramento*, a huge project called *pebetero* (censer) is being built [45]. From where the natural fragrance of incense will rise.

The symbolic garden and the semi-open cloisters are both places, where solar heat is to be felt and sounds of Nature and people are to be heard.

### D. Thermal & Airflow variability

A façade/layout designed to enhance daylight and light/shade variability, while reducing glare and elevated exterior walkways providing access to breezes, shade, and solar heat are possible application for this characteristic [5]. The discussions in (3.1.1-B and 3.3.1,2) demonstrated some of Gaudí's strategies and settings regarding natural light/shade variability. As for providing access to breezes and solar heat, when Gaudí started working in the basilica, the crypt was already partially built, Gaudí's insistence on adding a ditch around it, so that it could have direct light and natural ventilation [45]. shows his great concern to insure these qualities. The aforementioned elevated exterior walkway, in the form of the cloisters around the building, is another element that assures this fact [18].



(a)

(b)

(Fig.27) – Thermal & Airflow variability: (a) (18) Towers, and (b) Sided Lower & Upper windows permit a continuity of Air flow and Natural lighting  
For all parts of space, [24]

## IV. RESULTS

In (Section 2) of this study, by overviewing four different models for evoking the health-inducing aspects of Biophilia-effect, suggested by leading theorists of the field, an extended checklist that encompasses all possible criteria of biophilic built environment, including 11 criteria, had been concluded. And although the model of Browning et al. included 14 criteria, it will be noticed that the last four criteria in his model had been comprised as strategies for the comprehensive criteria of "life" as it came in the later model

of Salingeros, especially that the settings for applying them are so conjoint, as shown in the discussions in (3.3.4). Applying this Checklist on the design of "Sagrada Família", it has been found that the visual performance, pursued by biophilic design, is at its best in this design, where Gaudí's interpretation of movement and growth in Nature, helped him to produce a built environment that is "fully biophilic", fulfilling all the points of the extended checklist, as

demonstrated in the previous discussions and as summarized in the following (table: 2).

(TABLE:2) – Applying the Proposed Methodology/Design Checklist on the design of the “Sagrada Familia”, (By Authors)

CHECKLIST for “Sagrada Familia”			
Pillar concepts	Criteria	Strategies/Characteristics	Applications /Settings in the basilica
<b>1- Nature of Space</b>			
EXPERIENCE OF SPACE & PLACE	<b>I. Prospect &amp; Refuge</b>		
	a) High ceiling in the main area flanked by lower aisles		Clerestory windows - Lanterns
	b) Decreasing lighting conditions along lower sides while increasing it in the center		Alcove-like with ruled surfaces around the windows and multiple lanterns in the center
	c) Views to distance through interlocking arches		Repetitive (catenary) arches, branching columns, floral shapes
	d) Covered passage **		Cloisters
	<b>II. Enticement &amp; Mystery</b>		
	a) Partially visible areas		Strong contrasts of planes Hollow spaces in the vault with clerestory between columns Uneven surfaces, and grottoes protecting sculptures Colorful finished surfaces of Trencadis
	b) Details and diversity		Festive N. Façade vs. austere P. Façade (Chiaroscuro-effect) Irregular shapes of vaults, endless stalactites & leafy canopies Smooth curves and jagged points
	c) Topographic variations (Overhanging balcony, elevated passageway, or grand staircases)		Portico with large staircase and underground passage Accessible towers with balconies and bridges between them Gaps in the floor of the apse providing view to the crypt Triforia
	<b>2- Natural Analogues</b>		
IN-DIRECT EXPERIENCE OF NATURE	<b>I. Complexity &amp; Order (Biodiversity)</b>		
	a) Connective symmetry /hierarchy		The geometric composition of vaults and windows Repetitive pediments on different scales in façades
	b) Universal scaling		Variation of tapered triangular shapes Twofold modular system
	c) Fractals		Complexity of geometry and richness of details Elements that <i>grow</i> by means of repetitive patterns
	d) The theory of centers		Mary tower surrounded by lower towers & <i>cimborio</i> underneath Window focusing on Christ with single beam of sunlight
	<b>II. Material Connection with Nature.</b>		
	a) Variety of natural materials		Materials according to function
	b) Petrification **		Leaning columns like large trees Arborescent columns with fluted shafts Reed-like arches Knots at branching points
	<b>III. Biomorphic Forms &amp; Patterns</b>		
	a) Symbolic references to arrangements of Nature		Walls covered with crowded and cluttered sculptures Desert-plant looking towers More than 30 different animals Elements of vegetative and tree-like structures
	b) Decorative gardens **		Metal leaves, flowers and insects on the portals Stone garden surrounding the tower of the Virgin Mary
	c) Geometry of Nature **		Golden Ratio Dynamic (Philotaxian) symmetry : Ruled Surfaces Non rectilinear geometry Quasicrystal line patterns
	<b>IV. Gravity</b>		
	Gravitational equilibrium		Equilibrated structure (getting rid of buttresses)
	Branching columns **		Columns like trunks with shafts spreading into branches Cross sections decrease as they rise, forking into branches Roofs formed by sunflowers shapes with weightless petals and light penetrating them
	Forced perspective		Tapering elements
	<b>V. Sense of Playfulness</b>		
	Elements that aim at delight, surprise, or dazzle		Outer look like a hill of sand or melted wax Inner space like kaleidoscope stone forest Bible in stone or a "spiritual forest" A lighthouse
<b>3- Nature in Space</b>			
<b>I. Dynamic &amp; Diffuse light.</b>			
	Clerestories, skylights		Vibrant stained glass windows Clerestories with transparent glass and deeper hues down

DIRECT EXPERIENCE OF NATURE	Differing orientations of windows,	Oculus showering the central point with light Ruled surf. to trap/diffuse light and shiny surf. to reflect it Light diffusing and reflecting through apertures in the vaults, windows, and between the branching columns A new technique for stained glass, using 3 glass planes
	<b>II. Connection with Natural systems</b>	
	Connection to natural processes and seasonal changes	Different tones for stained glass based on solar orientation
	<b>III. Livability and Movement</b>	
	Real water Reflecting surfaces	Fountains and gargoyles Vaults finished in Venetian glass
	Bearing resemblance to water or clouds	Floors covered with shiny red granite and cork finished in reflecting high traffic varnish Window of "Water of Life" Monument to fire and water Clouds in the form of construction
	<b>IV. Life (non-architectural elements)</b>	
	a) Visual connection with Nature	Symbolic garden Bridges and openings overlooking a park with a pond
	b) Non-rhythmic sensory stimuli	Growth and movement in architectural expression Gargoyles with biomorphic shapes
	c) Non-visual connection with Nature	Tubular bells Gargoyles and huge fountain The <i>pebetero</i> (censer) The symbolic garden and the semi-open cloisters
d) Thermal & airflow variability	See 3.1.1.b and 3.3.1, 2 A ditch around the crypt Elevated exterior walkways (cloisters)	

\*\* New strategies for biophilic design inspired by "Sagrada Família"

(Table: 2) demonstrates the applications/settings of these criteria/strategies, as they are found in Gaudí's design for the building. Results show that, by analyzing the components of Nature and applying its principles to his design, Gaudí could intuitively come up with a design that is, by all measures, fully biophilic.

In addition, and by referring to the definitions of the three basic concepts and the neurological findings related to them, which show that the positive effects of *Biophilia* relies on certain qualities; and by exploring Gaudí's design in Sagrada Família in search for these qualities, further strategies and settings that might stimulate these positive effects have been suggested.

Through this survey, (30) strategies/characteristics for applying the criteria of biophilic architecture had been identified, (9) of them were originally suggested by the design of the basilica itself, including: covered passage, petrification, decorative gardens, geometry of Nature (with (4) different kinds and geometric patterns as applications), and branching columns; all of them with the potentials of: [dynamism - hierarchy - complexity - visual richness-opportunities for exercising imagination], all of them are of the major attributes of "*Biophilia*" qualities and effect.

## V. CONCLUSION

This paper addressed the assumption that the great admiration that people have for the "Sagrada Família", as one of the most visited sites in the world, somehow aspects to the biophilic qualities of its design. The research proved some of these qualities, which extend the logic of Nature into the built-environment to provide the beholders with the neurological nourishment they need. The paper revisited Sagrada Família, with the lenses of the twenty-first century, to examine its aptitude to fulfill the qualities of biophilic

design, where the design of the basilica has been evaluated by means of an extended checklist of biophilic design qualities (table:1), that was Concluded/Extracted from the works of four prominent theorist of this novel design approach. Finally, The results of the study (as summarized in Table: 2) show that:-

- The architecture of "Sagrada Família" manifests a successful full-model of "Biophilic" design, that fulfills all patterns of "Biophilic design", addressing direct, physical and ephemeral presence of Nature, as well as organic, non-living and indirect evocations of Nature, through (Forms, materials, colors, shapes and proportions) found in Nature, are present in the building of basilica as geometric compositions, ornamentations, lighting conditions, and unique structural system; each providing a connection with Nature.
- This design of "Sagrada Família" had been more examined and investigated for more new [strategies-settings -design techniques], which had not been formerly indicated by *Biophilia* theorists, where nine (9) new strategies were recognized and discussed as shown in (Table:2).
- The research demonstrates that: although Biophilic design is a new design approach/concept, "Gaudí" intuitively applied all its assumptions, criteria, even principles, as defined by its leading theorists, creating a diversity of strategies and settings of these criteria.
- Considering these results, it is not anymore surprising that in "Sagrada Família", visitors experience reached a high level of mental and spiritual stimulation, which was justified in this study through scientific reasoning for answering and explaining the question of "why the contemporary (plain, minimal, abstracted) sacred or public buildings, fail to attract and integrate with thier

users in such way"? Accordingly, this would also reflect and proof the expected effect/role of the architectural design approach (manipulation) of “Sagrada Família”, and similar buildings, on the health and wellbeing of its visitors/users in reference to the discussion in (2.1).

- The proposed Biophilic “Check-list”, could be useful for (Planners, Architects, Urban designers) by implementing these strategies/settings into their design to improve users' physical needs and psychological wellbeing, which is essential to human survival. Maximal benefit from these potentials could be insured by means of new design software and building construction technologies.

This research does not acclaim conventional construction techniques or traditional building-process; that needs several decades to be completed, meanwhile advanced construction materials, digital CAD/CAM/BIM techniques, and 3D printing technologies had simplified both construction and fabrication of such sophisticated patterns into a systematic, cost-effective process. Furthermore, Light-projection, hologram, and Trompe-l'œil techniques are extra tools that may facilitate such applications with minimum costs and efforts with maximum values.

**Funding:** The authors should mention if this research has received any type of funding.

**Conflicts of Interest:** The authors should explicitly declare if there is a conflict of interest.

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