

'Emergent Architecture: A Resurgence of Natural 'Beauty'.

by

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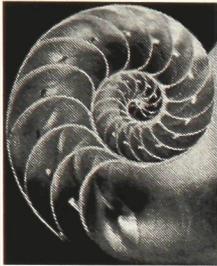
*to all the great friends and precious
memories gained along the way.*

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Emergent Architecture: A Resurgence of Natural 'Beauty'.

Abstract.



**Figure 1: Section
of a Nautilus
Shell.**

*In investigating the notion of 'beauty' in the built realm, this thesis is a study on the **evolution** of architecture and its role in generating equilibrium linking it with and within nature.*

*Consequently, a response to the question of whether architecture can reinstate the **aesthetic experience** of 'beauty' [meaning] in detoxifying the contemporary intoxication and 'anaestheticization' will be presented in the subsequent text. I suggest through utilizing a **mimetic process of form-generation** in designing an*

*Olympic stadium, to reunite the present disjunction disconnecting architecture [built] and the natural realm - designing and realizing architecture as a manifestation and reinterpretation of the **human body**. On framing and focusing the thesis, emphasis will be on the **process** of generating a dynamic architectural structure infused with 'beauty' and 'truthfulness'. With the present shift in balance, this thesis urges for a return to the tradition and wisdom of the ancient world in designing under the delicate guidance of nature - the spring of universal knowledge.*

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Emergent Architecture: A Resurgence of Natural 'Beauty'.

Introduction.

[Excerpt from the motion picture - 'pi']

12:45 ... Restate my assumption.

1. Mathematics is the language of nature.
2. Everything around us can be re-presented and understood through numbers.
3. If you graph the numbers of any system, patterns emerge - therefore, there are patterns everywhere in nature.

i. Role of nature in the design and realization of Architecture.

Architecture is the campaign to design and construct a non-representational organic process - 'meaning' is found within, addressing the question of 'how' form and structure is realized. Architecture being non-representational implies a 'morphogenetic' process [the evolution of form]. As a 'morphogenetic' process, significance is on the duality and interdependency of form and function. Like nature - the manifestation of universal knowledge - humanity must not deny 'beauty' in aspiring to design and construct a unified future. Unfortunately, the logic and 'beauty' of nature is lost in the majority, and complexity, of contemporary design - lost in superficial abstraction [image-making]. Although form and structure inspired and designed in union with nature may create the impression of a 'futuristic' archetype, I suggest that the archetypal manifestation is an illusion fabricated by the primitive condition of the built realm relative to the present ability to understand nature and natural phenomena. In not significantly comprehending the sustainable responsibility of architecture, humanity is continuing to blight the natural world with ugliness and conventional [appendix 1] image-driven design. Nature is a dynamic presence demanding balance and unity. Over the course of history, it is evident

that humanity is persistently in a state of adaptation to ensure continuing existence. With the continuing struggle, humanity is drastically shifting the delicate equilibrium uniting the built with the natural. In preventing this critical shift, humanity must resist the desire to dominate the natural realm and begin resolving the dilemma through the reconciliation and resurgence of natural 'beauty'. Architecture must function on more than a superficial level directed at denying political critique and the quest for 'meaning'. I suggest a **process** of designing and generating form impregnated with content, aesthetic imbued with ethic, and image infused with 'meaning'. Architecture is not a "xeroxified"¹ image of a fabricated nature; it is but an interdependent part of creative nature – a materialization of the invisible pulse and rhythm of life. In defining architecture as the assemblage of a durable 'construct' to resist the test of time,

"... the ultimate test of validity for a work of architecture is for it to be true to nature."²

ii. 'Machine' Metaphor.

In designing a responsible and unified '**machine for living**', the architect must imbue his/her manifestations with the authority to induce and resuscitate critical responsiveness. On attaining this objective, it is imperative to further define and investigate the idea of 'machine' and the role the 'machine' is playing in sustaining, developing, and/or destroying the 'quality' of present life. As humanity is becoming increasingly dependent on the 'machine', the design of architecture is equivalently depending on the 'machine' for the function, construction, and experiential 'quality' of the realized structure. If architecture is a reflection and human extension/manifestation of nature – a **process** of design based on natural '**opportunity**' and '**restriction**'³ – should architecture not embrace the 'machine' for generating the present plethora of innovative and opportune facility? With the constant introduction of high-performance materiality in conjunction with pre-fabrication and mass production, architectural design is progressing

ad infinitum. In addition to influencing architecture through dynamic 'opportunity', the 'machine' is a central figure in inspiring and shaping the aesthetic character of modern design. Although the 'machine' is freeing architecture from a vast array of natural 'restrictions', I suggest that the 'machine' is frequently designed and utilized with irresponsibility and insensitivity. Upon insertion into nature, the 'machine' is often in a state of juxtaposition and opposition. Similar to the majority of human invention and fabrication, the 'machine' is fundamentally designed to serve the human desire for control and domination. If the destruction and annihilation of the natural realm is to halt, then the irresponsible design and utilization of the 'machine' must end. I argue that architecture [the 'machine for living'] is impregnated with the facility to unite and unify the built with the natural in shaping a stable and luminous future.

On further developing the notion of the 'machine' and its impact on the contemporary era, it is evident that the 'machine' is a large factor in creating and sustaining the chaotic tempo and critical 'intoxication' of present-day life. With the aid of the 'machine', humanity is transforming into a civilization infatuated with information and material consumption – "where there is more and more information and less and less meaning."¹⁴ In addition to generating this present state of 'intoxication', the irresponsible application of the 'machine' is playing a large role in the destruction and desolation of the natural environment. With the superfluous quantity of consumption and waste, in conjunction with the constant development and introduction of weaponry specifically designed for 'mass destruction', it is obvious that the present human mentality must change. Humanity must dilute its will for control and domination in designing a balanced and harmonious existence. If the shift in equilibrium is to continue, it will certainly result in the global annihilation of nature and 'beauty'. It is plausible that humankind will perpetually continue to populate the world, but it is evident that the natural realm, in which humanity is dependant, is on the verge of distinction and obliteration. In contrast to deliberating and applying a great sum of energy into building and attaining an alternative nature, should humanity not attempt to sustain and resuscitate the nature that has demonstrated its importance and merit throughout the entirety of human existence? With the present-day restitution and application of 'sustainable technology', architecture

is shifting in the optimistic direction of existing in balance with the natural realm. Within this thesis, I intend to direct the attention on form and structure in generating an architecture [archetype] that is impregnated with sustainable merit – a cultural and **global sustainability** manifested through the aesthetic experience of natural 'beauty'.

iii. A history of 'Mimetic' processes in the design of Architecture.

In the subsequent chapter, titled "**precedence**", an investigation and analysis of past and present architects/designers that have attempted to capture the 'beauty' and unity of nature will aid in establishing a basis for the premise of this thesis. Although many have attempted this feat, I suggest that the following compilation illustrates an extensive range of unique and individualistic **processes**. **Vitruvius** implied that 'mimesis' is a natural mode of evolution and design that involves learning and understanding the physical world and building upon that knowledge to design and construct the built world as – 'it ought to be'.⁵ In addition, he argued that 'imitation' [mimesis in **Greek**] is a natural process of artistic creativity. On further defining 'mimesis', **Vitruvius** stated ...

"... the ancients held that what could not happen in the original would have no valid reason for existence in the copy. For in all their works they proceeded on definite principles of fitness and in ways derived from the truth of Nature."⁶

Architecture is thus identified as a '**second nature**' within the realm of the first. In designing and realizing natural 'beauty' linking the built and natural in equilibrium, a **mimetic process** must transpire. **Cicero**, the Roman orator in 106-43 B.C., first termed the built realm as a '**second nature**', stating that the built realm is an alternative nature in which humanity can control. Within the subsequent chapter, the notions of evolutionary authenticity, architectural 'correctness', and 'truthful' style will aid in presenting and generating a systematic structure [**process**] aimed at attaining natural 'beauty'. In addition, an investigation directed at understanding traditional and 'modular' **Origami** will

assist in presenting and substantiating the *process* utilized in this thesis. Attributed to the present infatuation with deconstruction and irrational image-making, architecture is blighting the natural realm with superficial 'ugliness'. Unlike the transitory character of 'style', nature is timeless. If 'meaning' is to re-emerge in the built realm, architecture must reinstate equilibrium and unity through utilizing a *mimetic and iterative process* directed at re-presenting the beauty of nature.

iv. Natural 'beauty'.

Natural 'beauty' is impregnated with the capacity to generate a balanced and sustainable relationship between the built and natural environment. Architecture must reinstate a logical structure and natural balance to the complexity and 'chaos' that is devastating to the present state of human existence. Architecture is a cultural expression representing the attitudes and values of a given society; a mirror upon which the human ability to understand nature and natural phenomena is reflected. In the manifesto titled "Natural Contract", Michel Serres argued that, "nothing is as beautiful as the world; nothing beautiful comes forth without this gracious giver of all splendor [nature]."⁷ With the continuing development of scientific, technologic, and mechanistic apparatus' [*'opportunity'*] permitting humanity to further understand nature and natural phenomena, current modes of thinking are in constant flux. Architectural design and construction must address this flux. In the **Middle Ages**, the idea of 'beauty' spawned from the internalized notion of 'being' – regarding the human psyche. And thus, in reintroducing a balanced inner 'beauty' vital for the continuing growth and evolution of humanity – the realization of a harmonious experience between the natural realm and the built realm is required. Only in being surrounded by 'beauty' will the psyche appreciate 'beauty', and hence, aspire to embody it. If the shift in equilibrium is to halt and reinstate balance, humanity must find a cure to the predisposition of segregating the built from the natural and align with nature to *detoxify the present intoxication*.

Over the course of history, the universal man [Vitruvian man] has represented a paradigm for universal consistency and harmony – the unique form of the **body** and the formation of identity through the union of separate yet interrelated parts teaches humanity the first rule of composition: unity in multiplicity. Plotinus defined the ‘absolute ugly’ being that which has not been entirely mastered by pattern, and thus identified the fact that only a ‘compound’ is adept in representing ‘beauty’, “never anything devoid of parts; and only a whole; the several parts will have beauty, not in themselves, but only as working together to generate a comely total.”⁸ Unfortunately, architecture is presently ensnared in a state of ‘simulacra’ – a **process of artificial simulation**. On further comprehending this paradigm, Henri Lefebvre argued that the eye of the present architect has developed into a visual space of the blueprint [mere image] – a realm of convention, which is ultimately the “enemy of the imagination.”⁹ In the dictionary, ‘beauty’ is defined as a noun – the combination of qualities [as **form, image, colour, etc.**] that delight the eye. I suggest that ‘beauty’ is a **verb** – the human emotion created through connecting, engaging, and interacting with nature and natural phenomena. In addition, ‘beauty’ is the physical materialization of natural order linking humanity with and within the universe [cosmos]. As humanity is blighting the earth with ‘ugliness’, this thesis argues for a resurgence of ‘beauty’ – a change in the direction of generating a sustainable future and harmonious **aesthetic experience** within the built and natural realm.

v. Application of ‘beauty’ in the process of designing Architecture.

Architecture has a greater responsibility than most to ensure that the built is not fabricated at the expense of the natural. On finding the inspiration to direct and ‘structure’ the **architectural proposition**, I began studying and analyzing the human **body** in dynamic motion. In addition to forming a link with the programmatic function of the stadium and to the natural realm, the **human body** is the principle mode in which humanity

is capable of judging and understanding the physical world. If humanity is to reside in balance within the natural realm, the source of nature's unity must be known so that human fabrication can be designed and realized in union with it. **Stadia** are a select classification of structures designed to unite the world and encourage interaction within a single event. Often, stadia are designed with nothing other than utilitarian function and financial gain in mind – 'beauty', 'meaning', and the present need for equilibrium are ancillary. With the **International Olympic Committee [IOC]** insisting that the design of future facilities demonstrate care and respect for the natural environment,¹⁰ I suggest that an **Olympic stadium** is programmatically and ethically facilitated with the capacity to realize the main aspiration of this thesis. If a sustainable future is to manifest, than humanity and the design of architecture must turn to the **aesthetic experience** of 'beauty' in generating it.

vi. Nature and its relationship to the 'ineffable'.

In clarifying the term nature, it is vital to define the '**ineffable**' and consequently, nature's relationship to the 'ineffable'. As the word 'ineffable' is defined as an adjective for that which is incapable of being expressed and described, I suggest that nature is not ineffable, yet shares the fundamental and infinite **essence** from which 'beauty' and the universal intelligence [structure] of nature inherently resides. In "**Stopping Time: The Photographs of Harold Edgerton**", **Estelle Jussim** defined the 'ineffable' as that which is impossible to see but has forever existed. Although a diverse sum of natural phenomena are experiential through visual observation, the fundamental and dynamic structures [patterns] that generate and transpire during these phenomena lie in a 'microcosmic' realm hidden from the unaided eye. As the term 'ineffable' is commonly utilized in relation to faith and religion defining the indescribable mysteries that touch the heart and spirit of humanity, and as nature is the only true form of God that humanity is capable of experiencing, I suggest that nature and the 'ineffable' are transcendental realms that

*share the same unifying character. As the infinite wealth of wisdom within nature will forever remain a mysterious puzzle in which humanity will perpetually attempt to assemble and understand through oscillating scientific explanations, it can therefore be argued that the **essence** and **phenomenological structure** of nature is ineffable. Yet, as humanity is continuously attempting to further understand nature, it is possible to contend that the distance between our realm of existence and the 'higher' realm of 'reality' is diminishing. Within this thesis, I intend to generate and utilize a systematic **process** of design, capable of extracting the natural logic, balance, and 'beauty' within this realm of the 'ineffable'.*



Figure 1.0: Discussion with Jim Strutt and John Adjeleian.

Evolutionary Architecture: A Resurgence of Natural 'Beauty'.

Chapter 1: Precedence.

1.1.1 Leonardo da Vinci.

The air was darkened by the heavy rain whose oblique descent, driven aslant by the rush of the winds, flew in drifts through the air not otherwise than as we see dust, varied only by the straight lines of the heavy drops of falling water. But it was tinged with the color of the fire kindled by the thunderbolts by which the clouds were rent and shattered; and whose flashes revealed the broad waters of the inundated valleys, in the depths of which were seen the bending treetops. Neptune will be seen in the midst of the water with his trident, and let Aeolus with his winds be shown entangling the trees floating uprooted, and whirling in the huge waves. The horizon and the whole hemisphere were obscure, but lurid from the flashes of the incessant lightning. [Human] and birds might be seen crowded on the tall trees which remained uncovered by the swelling waters, originators of the mountains which surround the great abysses.¹¹

- Leonardo da Vinci, The Representation of Deluges - Manuscript G.

Leonardo da Vinci [1452-1519] devoted the majority of his life to studying science in attempt to further understand nature and natural phenomena. In the Middle Ages, the infatuation with religious imagery and symbolism caused a response of 'intoxication' - void of the significance of natural realism. During the Renaissance era, the period of 'rebirth', the focus of studying nature led to the conception and cultural fabrication of art with the objective of re-presenting a superior sense of realism. In addition, the Renaissance was an era of transition desiring to reinstate value and meaning in personal and social thought [imagination]. In this era, the Renaissance leaders attempted to realize the "'promise' inherent in the wisdom of the ancients and in the Christian tradition - to transform this 'promise' from a distant hope to a present reality to be enjoyed by living men and women."¹² Renaissance culture was primarily human-centered - convinced that humanity is simultaneously the child of nature and the creature of God, the leaders of the

Renaissance suggested that in further understanding humanity, it is possible to reach a state of dignity and sympathy. With respect to art and architecture generated during the Renaissance era, the artists/designers found inspiration from uncovering and enhancing the ancient skills that aided in rediscovering, rehabilitating, and re-presenting the 'beauty' of nature. Renaissance artists studied anatomy, botany, and physiology in an attempt to faithfully reproduce/re-present the natural world. As stated earlier, the artists of the Renaissance argued for this 'rebirth' – "a 'new life', an awakening from slumber, the recovery of sight after an age of blindness, and the conquest of darkness by light"¹³ In the present era of intoxicating consumption and destruction, humanity must utilize the teachings of the Renaissance as a muse to generate balance, 'beauty', and a **harmonious existence with and within nature.**



Figure 1.1: Epilogue with 'Deluge'.

Leonardo da Vinci criticized the artistic fabrication of the fifteenth century, arguing that the style of painting was simultaneously unskillful and non-natural. Consequently, **Leonardo** suggested that acquiring complete design freedom is feasible through gaining knowledge of, and reinterpreting nature and natural phenomena – justifying artistic license through scientific explanation and/or exploration. In analyzing and understanding the work created late in his life, the graphic presentation and schematization of extreme natural phenomena expressed a dynamic reality, undermining our sense of

material equilibrium with the force and fury of the imagination. In developing the 'Deluge', he attempted to visually represent the natural phenomena formed by the exaggeration of violent and devastating event, thus formulating a rendering style that

implies a frozen instant in the unfolding of dynamic reality. In understanding the purpose of art being the pursuit of scientific 'truth' – a diagrammatic representation depicting the force of nature – **Leonardo** continually adjusted and invented drawing techniques to better express his evolving understanding of nature.¹⁴ While initial landscape illustrations depicted a stiff and static representation of nature, the 'Deluge' simultaneously represented the natural landscape and the **dynamic movement** of natural phenomena – and therefore, re-presented the perpetual '**chi**' [Chinese term for **energy**] of nature. Although it is difficult to identify a specific historical event that may have inspired the creation of the 'Deluge', the significance is found not in the inspiration, but in the re-presentation of nature through the phenomena of motion – in the re-presentation of the ineffable ... that which is not possible to see directly.

Leonardo da Vinci characterized the task of the designer as the creator of a "**second world of nature**".¹⁵ On analyzing nature and natural phenomena, he argued that every natural form is designed with perfection – "designed perfectly to fulfill its function with no inadequacy or redundancy."¹⁶ In union with the human-centered mentality of the Renaissance, **Leonardo** studied the structure of the **body** and applied the found knowledge to the design and construction of his inventions. In investigating his anatomical drawings generated through the **process** of dissecting the human body, it is evident that **Leonardo** found a vast number of shared similarities within architecture and nature – suggesting that architecture and nature are analogous with respect to the design of form and structure in response to natural law. In addition to finding shared similarities, he regarded the **body** as a machine – exemplified through his engineering. One project demonstrating this notion is the design of his '**bird**'. Unfortunately, like many of his designs, the '**bird**' was never realized. Nevertheless, the carefully designed proportions

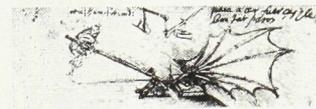


Figure 1.2: 'bird'.

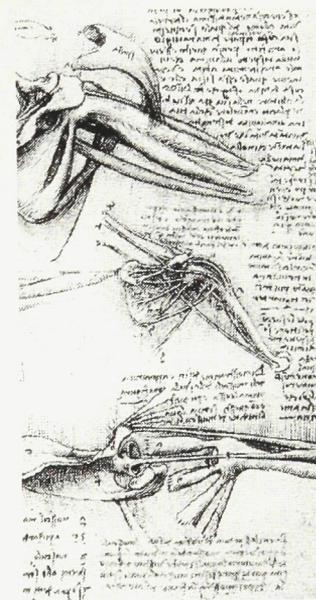


Figure 1.3: Anatomical Study.

established by the wingspan of a bat and the use of materiality based on muscle tendons and nerve-like chords [skin] illustrate an understanding of nature as the perfect teacher of structure and form. **Leonardo da Vinci** regarded nature and humanity as being linked both to each other and to the basic underlying '**restrictions**' and '**opportunities**' of natural law. With this said, it is vital not to misinterpret his understanding of the human-built environment. In the course and duration of his life, he searched and found inspiration from nature and natural phenomena, yet understood the impossibility of human fabrication to achieve the perfection of nature. In spite of this, **Leonardo** continued to emphasize that humanity must strive to achieve a '**second world of nature**' inspired and built from the teachings of the first [nature].



Figure 1.4: Epilogue with 'Deluge'.

1.1.2 Johann Wolfgang von Goethe.

Goethe, the central figure in the Romantic Movement, was among the first to use the term "morphology" for the study of biological form from a dynamic, developmental point of view. [Goethe] admired nature's 'moving order' [bewegliche Ordnung] and conceived of form as a 'pattern' of relationships within an organized whole.¹⁷

- Fritjof Capra, The Web of Life.

Johann Wolfgang von Goethe [1749-1832] suggested that, "beauty is the manifestation of the secret laws of nature which, were it not for their being revealed through beauty, would have remained unknown forever."¹⁸ Goethe, the central figure in the Romantic era, accepted movement as a natural law and set out to capture the constant 'flux' of everyday life. During the birth of Romanticism, a struggle existed in defining the significance of life and art. Nature, which until the birth of Romanticism was regarded as the background against which the human drama of life was enacted, became the mirror in which humanity was given the ability to 'see' - shifting in the direction of understanding and apprehending/comprehending 'experience' rather than scientific explanation. In principle, Romanticism was a reaction against the restrictive monotony and unemotional tendency of the eighteenth century, placing emphasis on the freedom of individual self-expression. A key characteristic attitude of Romanticism included a deepened appreciation of the beauties of nature, a general adoration of senses over reason [intellect], and an emphasis on imagination being the gateway to transcendent 'experience' and spiritual 'truth'. On art, Romantics replaced the 'mechanical' rules of conventional form with the 'organic' principles of natural growth and free development; searching for divinity through nature. Defining and framing Romanticism is difficult as many regard it as completely continuous with the present. With this said, many argue that the Romantic era served as the influential voice of revolution at the beginning of the nineteenth century and the authoritative voice of establishment at the end of it.

Johann Wolfgang von Goethe formed the discipline of 'morphology' in 1827 while studying "the forms of living organisms and the relationship between growth and form."¹⁹ *Goethe* aspired to find a stylistic unity in the complex composition of nature and defined architecture as an 'organ' of a landscape – a process of not simply replicating or imitating organic form but a realization of a 'belongingness' impregnated with the power to create and generate a sense of 'wholeness' to a place. In "Nature and the Idea of a Man-Made World: An Investigation into the Evolutionary Roots of Form and Order in the Built Environment," *Norman Crowe* defined place as being that which the whole of humanity can recognize and share; concerning the need to establish a familiar "landscape as refuge from the unknown, perhaps from the terrifying prospect of being set adrift in what would otherwise be a dimensionless, timeless, and chaotic world."²⁰ Similarly, in presenting architecture as a generated organ with a unique function in the natural landscape, *Goethe* argued that architecture should aspire to create a link "between human society and nature, the point where the evolution of nature and of human society is as one."²¹ *Goethe* regarded all creation in the universe as compositions striving for balance through integration. Consequently, he considered art and architecture as 'spiritual' manifestations "in which the details, as well as the whole, are pervaded by one spirit, and by the breath of one life."²² *Goethe* argued that the perception of 'wholeness' is difficult to grasp with the contemporary 'discursive' mode of thinking – asserting that 'unity' is often confused with 'totality'. Unlike 'totality', 'unity' is not the "whole thing but the formative power or 'breath of one life' that is reflected in all the parts."²³ And hence, only through acquiring balance and equilibrium throughout the entirety of the composition can 'totality' transform and embody 'unity'.

On defining 'beauty', *Goethe* stated – "beauty is related to the scientific enterprise of capturing movement at rest ... beauty is most evident when an animal is at rest but demonstrates an ability or the potentiality at any moment to move."²⁴ In achieving 'beauty', *Goethe* argued that unity and balance is required – a unity and balance spawn from observing and gaining knowledge of natural 'restrictions' and 'opportunities'. *Vitruvius* implied that 'mimesis' is a natural mode of designing that requires learning and understanding the physical realm [nature] and building upon that knowledge to design and

realize the human-made – ‘as it ought to be’.²⁵ Like Vitruvius, Goethe suggested that the artist must “learn to work within certain restrictions and limitations in order to create the most perfect form.”²⁶ It is imperative to understand that he developed his scientific principles not to diminish the realm of nature into a set of laws, but to describe the creativity within nature – emphasizing the importance of studying nature and the need for humanity to cease erroneously placing itself above or outside of it. Goethe’s conception of nature inspired many in the contemporary era to regard the natural and human-made realm as one integrated and **synonymous** [unified] **whole**, illuminating the fundamental interdependence of “all phenomena and the fact that, as individuals and societies, we are all embedded in [and ultimately dependant on] the cyclical processes of nature.”²⁷

1.1.3 Antonio Gaudi.

*'Beauty' is a form of sympathy and consonance of the parts within a body, according to a definite number, outline and position, as dictated by the 'agreement of sounds,' the 'concinnitas' [cosmic balance], the absolute and fundamental rule in Nature. This is the main object of the art of building, and the source of her dignity, charm, authority and worth. All that has been said our ancestors learned through observation of Nature herself; so they had no doubt that if they neglected these things, they would be unable to attain all the contributes to the praise and honour of the work: nor without reason they declared that Nature, as the perfect generator of forms, should be their model. And so, with utmost industry, they searched out the rules that she employed in producing things, and translated them into methods of building.*²⁸

- Alberti, *De re aedificatoria*.

*'Beauty' is the radiance of Truth. Without Truth, there is no art.*²⁹

- Antonio Gaudi.

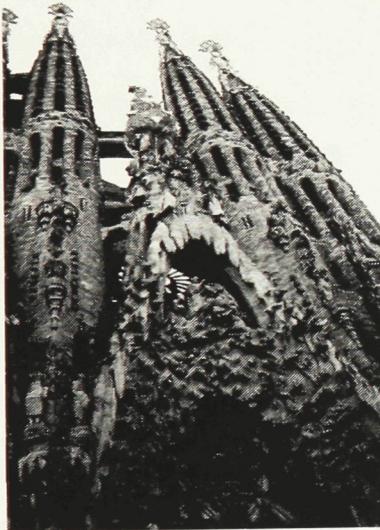


Figure 1.5: Sagrada Familia.

On investigating the architecture designed and realized by Antonio Gaudi [1852–1926], it is evident that the manifested forms and structures transcend the notion of time and style. Gaudi found inspiration from nature, and through observation and comparison, he found 'regular' forms fabricated through conventional practice to juxtapose the **geometric logic** and unifying 'beauty' found within nature. Gaudi argued that design aspiring for function will ultimately result in 'beauty'; and in contrast, design aspiring for 'beauty' is adept of reaching only the realms of aesthetics and philosophy. Within this frame, he sought to utilize and implement the functionality of natural form and structure into the arena of building. Gaudi suggested that the underlying 'composition' of natural structures originate from 'fibrous' geometric form – exemplified by the 'helicoid', the 'hyperboloid', the 'conoid', and the 'hyperbolic paraboloid'.³⁰ In implementing the 'fibrous' forms found in the microcosmic structure of nature, he suspended lead weighted string from the load-bearing positions of a 1:10 inverted plan mounted on the ceiling of his workshop. Upon

photographing the **inverted model**, the photograph yielded the absolute precise and exact form of the structure with no additional need for mathematical calculation and with no possibility of error.³¹ As a direct manifestation of tension and gravity, the inverted photograph maintained the natural distribution and lines of stress situated on the anticipated structure. In generating and constructing architecture with this intuitive and elemental system defined above, **Gaudi** attained and realized '**beauty**' through equilibrated forms *mimetic* to those found in nature.

Antonio Gaudi found in nature the key to artistic restitution – progressing past **Romanticism** and the aberration of the '**Modern Style**'. **Gaudi** utilized a naturalistic return to the source of universal knowledge [nature] – “projecting his spirit onto nature so that nature, in turn, is captured in a new way.”³² In addition, he argued that architecture is the creation of an organism, which therefore must be governed by a law in consonance with the laws of nature, arguing that architectural design without observing and implementing that law will result in oddity rather than art. On arguing against conventional practice and the utilization of 'simple' geometry based on abstract forms nonexistent in nature, **Gaudi** designed and realized architecture through a *process* of three-dimensional experimentation [**modeling**]. Disliking the abstract and unrestrained character of drawing, **Gaudi** established freedom through the physical investigation and re-presentation of natural phenomena. Similar to **Leonardo da Vinci**, he acquired complete design freedom through the acquisition of knowledge and by reinterpreting nature – justifying artistic license through scientific inquiry. I suggest that the most significant message is not that of imitating the architecture designed and realized by **Gaudi**, but that of turning to nature as the source of inspiration for form-generation.



Figure 1.6: Inverted model [string and lead weights].

Within nature lies infinite and universal knowledge, as stated in the introduction. Unlike the transitory character of 'style', nature is timeless.

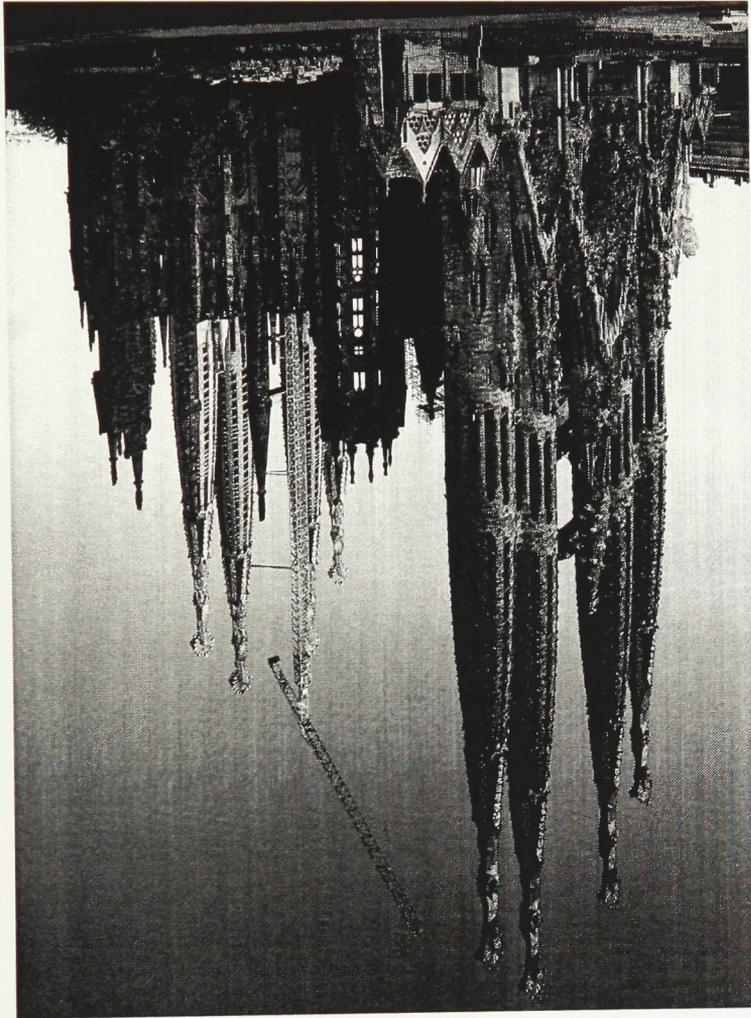


Figure 1.7: Inverted Photograph of Sagrada Família.

1.1.4 Le Corbusier.

You employ stone, wood and concrete, and with these materials you build houses and palaces. That is construction ... but suddenly you touch my heart ... 'this is beautiful.' That is Architecture. Art enters in. My house is practical. I thank you, as I might thank Railway engineers, or the Telephone service. You have not touched my heart. But suppose that [form and structure] rise toward heaven in such a way that I am moved. I perceive your intentions. Your mood is gentle, brutal, charming or noble. The stones you have erected tell me so. You fix me to the place and my eyes regard it. They behold something which expresses a thought. A thought which reveals itself without word or sound, but solely by mean of shapes which stand in a certain relationship to one another. These shapes are such that they are a mathematical creation of your mind. They are the language of Architecture. By use of raw material and starting from conditions more or less utilitarian, you have established certain relationships which have aroused my emotions. This is Architecture.³³

- Le Corbusier, Vers une architecture.

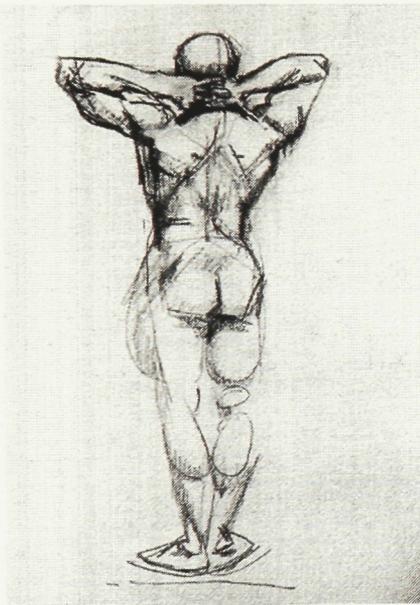


Figure 1.8: Study of male nude figure [Le Corbusier].

In 1908, upon reading "Les Grands Initiés"

[trans. the Grand Initiatives], written by Edouard Schure,

Le Corbusier [1887-1965] began to regard the world

in terms of **patterns** - "lines and geometry that

would, ideally, be linked together in a cohesive

whole ... [a] unity that he perceived in nature."³⁴

During approximately the same time, he found

inspiration from the teachings of **Pythagoras** -

leading him to the realization that through

mathematics, a link could be generated between the

human realm and the natural. Although many

regard the architecture designed and built by Le

Corbusier as a 'machine' above a naturally inspired

manifestation, the use of geometrical composition evident throughout his life work

exemplifies his interest and underlying respect for the unity within nature. In stating that

architecture is primarily a 'machine' for living in "Vers une Architecture," Le Corbusier

suggested that architecture must **mimic nature** in striving for maximum efficiency. In

addition to finding inspiration from the mathematical teachings of **Pythagoras**, the central

vision of his architecture was highly influenced by the early twentieth century **Orphism art movement**. 'Orphic' artists alleged **Orpheus'** ability to create **harmony** through music as the epitome of artistic achievement. Correspondingly, the Orphic artists aspired to achieve a similar sense of harmony through painting. On utilizing this Orphic tradition, **Le Corbusier** stated that he "then recognized that art ... is the means by which the individual may count completely. [On] realizing how much our world was convulsed by the birth pains of the machine age, it seemed to me [Le Corbusier] that to achieve harmony ought to be the only goal."³⁵ Clearly, the notion of nature played a large and inspirational role during his early development, leading **Le Corbusier** to link and equate the **process** of designing architecture to the **process** utilized by nature, which designs "from the inside outwards, uniting, in the three dimensions, all the diversity, all the different intentions in perfect harmony."³⁶



Figure 1.9: Abstract pattern based on pine [Le Corbusier].



Figure 1.10: Study of landscape and lizards in motion [Le Corbusier].

Le Corbusier argued that creativity is a reflective rudimentary function "animating even the 'lowest' cell of organic life."³⁷ As stated above, he focused throughout his life on re-establishing harmony between humankind and the natural environment. In accomplishing this task, he spent many years attempting to devise "a cellular housing unit

suitable for mass production, large numbers of which could then be brought together to form a community."³⁸ With his investigation into nature, **Le Corbusier** realized the importance of perfecting the individual unit, stating that in nature, "the smallest cell determines the validity, the health of the whole."³⁹ With the development and realization of 'modular' housing, **Le Corbusier** aspired to generate a cohesive built environment in harmony with the natural – a harmony that he termed '**radiant**'; the presence of **energy**. In addition to believing that this was a suitable 'ideal' for architectural development, he understood nature as being the central inspiring element for the act of creativity. Although the means by which nature inspired his architecture may not be directly obvious, nature and its re-presentation encompassed his life and played a large and significant role throughout his entire career. Whether he was successful in re-establishing a sense of harmony between the built and the natural environment is debatable. Nevertheless, the importance lies not in triumph or failure, but in viewing architecture and nature as one synonymous whole. Importance lies in his perception of nature as the proprietor of universal intelligence – the key to **sustaining the equilibrium** between 'man' and nature.

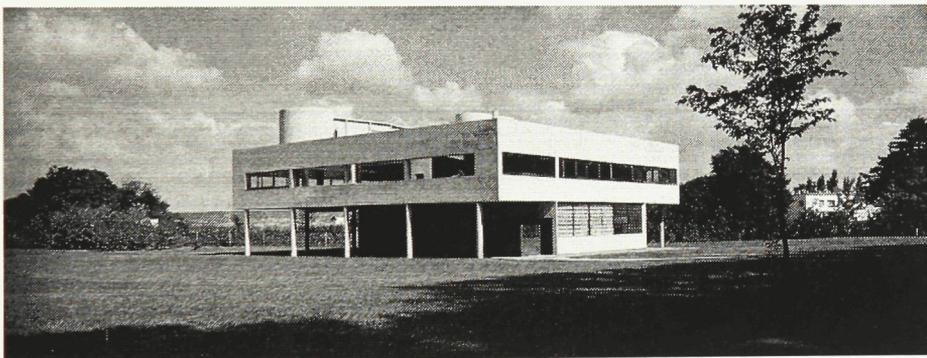


Figure 1.11: Villa Savoye.

1.1.5 Frank Lloyd Wright.

A child is first taught to take the cube out of the box undivided in order to inculcate alike the sense of order and the idea of completeness ... In life we find no isolation. One part of the cube, therefore, must never be left apart from or without relation to the whole. The child will thus become accustomed to treating all things in life as bearing a certain relation to one another.⁴⁰

- Froebel [kindergarten] Manual.

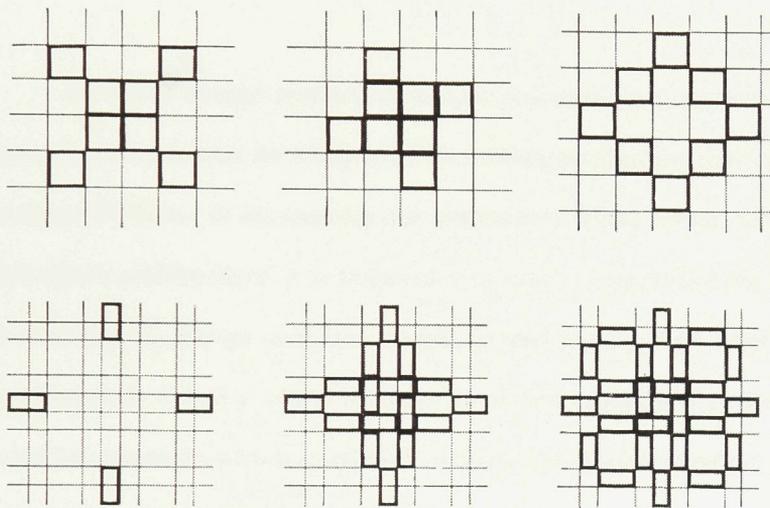


Figure 1.12: Froebel Investigation Studies.

Frank Lloyd Wright [1868–1959] praised the Froebel kindergarten system, where children are given ‘gifts’ consisting of geometric blocks and coloured cardboard shapes with which they form patterns and constructions on a squared grid. Upon ‘mastering’ the potential of the first ‘gift’, consisting of a single cube, sphere, and cylinder, children are given additional ‘gifts’ to increase the complexity of the pattern. Significance of this process is the pure “geometric forms and the abstract, symmetrical patterns they produce upon the grid.”⁴¹ Similarly, an equivalent fractal-like pattern is visible in Wright’s characteristic ‘style’. A fractal is defined as a dynamic pattern that contains self-similarities at infinite levels of observation – natural proportion is continuous through the process of graphing and visualizing a fractal equation; thereby, presenting a logical

structure and natural balance even within the complexity of 'chaos'. **Wright**, a former student of the **Froebel** system, delighted in the resemblance between his architecture and the figures created by the 'gifts' – and hence, it is evident that **Froebel** presented him with the central philosophy and design discipline to realize his architecture. **Wright** regarded these repetitive **fractal-like patterns** as the "instrument of a system of education based upon a pantheistic conception of nature."⁴² In investigating geometric pattern, **Wright** developed an ability to create and convey a sense of harmony and order found within 'God', stating that "God's works reflect the logic of his spirit and human education cannot do anything better than **imitate** the logic of nature."⁴³

With this design technique, **Wright** presented a comprehensive vision of the 'organic', within which he integrated and amalgamated aesthetics with the universal principles of form. In illustrating the similarities found when comparing **Froebel** patterns and **Wright's** architecture, it is important to first comprehend the core governing principle that directed his design process. **Wright** strived to establish a harmonious relationship throughout the entirety of the realized structure, arguing that the design of architecture should be complete within itself and regarded as a unified whole – stating that perfect correlation and "integration is life. It is the first principle of any growth that the thing grown be no mere aggregation ... integration means that no part of anything is of any great value except as it be an integrate part of the harmonious whole."⁴⁴ In developing this notion, it is evident that the exteriors of his constructed structures reflect internal spatial qualities. Unlike **conventional** and traditional design, **Wright** revolutionized architectural design through realizing the exterior of a building not as a disconnected entity surrounding the plan, but as an integrated part of the unified whole – a manifestation of the various components which formulate the interlocking interior volume. In addition to integrating the exterior with the interior, the fractal-like repetition of geometric form is visible throughout the whole of the building – visible in the construct of the realized structure, furniture, and detailing. With the application of a fractal-like system, it is possible to argue that **Wright** presented a **process** of generating a unified architecture with the facility to sustain the vital balance between the built and the natural.

A process made possible through translating and utilizing the patterns learnt from Froebel investigations into a dynamic three-dimensional system for form-generation.

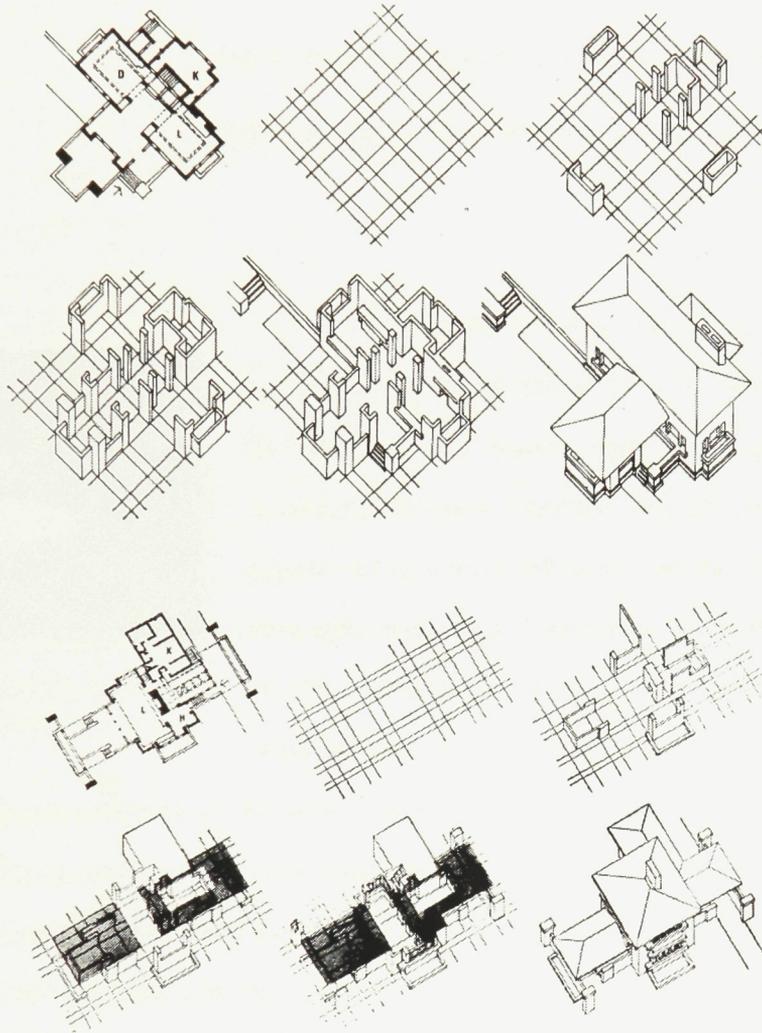


Figure 1.13: Barton house [top] and Robert Evans house [bottom], both designed by Frank Lloyd Wright. This sequence of diagrams are an example of Wright's design process as it relates to the Froebel system.

1.1.6 Pier Luigi Nervi.

*Seek not to imitate nature's appearance but, instead, to imaginatively apply its profound principles. Nature is alive with God's thoughts. Know nature and you shall know God.*⁴⁵

- Eugene Tsui, Evolutionary Architecture: Nature as a Basis for Design.

*Nothing is better than this earth, nor more excellent and beautiful.*⁴⁶

- Cicero, De Natura Deorum.

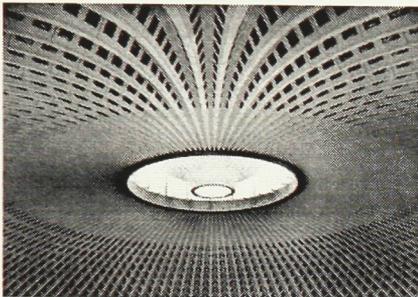


Figure 1.14: Stadium roof structure.

Pier Luigi Nervi [1891–1979] aspired to design and realize architecture with what he referred to as an “authentic” and ‘truthful style’. In developing this ‘truthful style’, Nervi searched for a **process** to apprehend maximum efficiency through form and structure. Nervi found inspiration from nature and natural phenomena – stating that the manifestations of nature are universal forms capable of satisfying and moving the human collective in the same manner.⁴⁷ Nervi defined architecture as the only form of art that is dominated by laws independent of the designer and found ‘beauty’ in the construction and aesthetic expression of structure determined by natural law. Nervi’s structures are “intricate, and often decorative, [but] never arbitrary or obscure ... the power and grace of these extraordinary shapes and **patterns** stem directly from their structural logic.”⁴⁸ Consequently, he found inspiration in Gothic architecture, where ‘beauty’ is revealed through structure and the mode in which the structure expresses the distribution of natural force – exemplified by Gothic vaults and flying buttresses. Clearly, Nervi stressed the importance of **technical ‘correctness’** as the principle ingredient of his authentic or ‘truthful style’, arguing that designing under the guidance of this ‘style’ will manifest an “ordered and attractive public and private environment.”⁴⁹

Throughout history, the nature and role of architecture has been widely debated. Vitruvius wrote that architecture must “take equal account of strength [structure], utility [function], and grace [art].”⁵⁰ In reuniting the division between substance [meaning] and appearance [image], **Nervi** re-established architecture as a form of structural art – leading to the radical change and acceptance of undisguised structure and thus a radical and unfamiliar ‘**beauty**’. In contrast to the superficial image-making plaguing contemporary architecture, **Nervi** stated that the role of architecture is to create a “stable, unified, enduring organism, in accordance with its surroundings and the functions that it must satisfy.”⁵¹ Additionally, he argued that architecture must be “balanced in all of its parts, sincere in its supporting structure and technical elements, and at the same time capable of giving that indefinable emotion that we call beauty.”⁵² A ‘beauty’ that **Nervi** found in observing and gaining knowledge of nature – a ‘beauty’ attainable through a process of designing in union with the [authentic] ‘truthful style’. **Ada Louise Huxtable** suggested in “Masters of World Architecture Series: Pier Luigi Nervi,” that the architectural “fusion of structural function and abstract form creates a kind of building that is so fundamentally ‘right’ that most other architecture seems superficial beside it.”⁵³ **Nervi** established and developed a system of attaining ‘beauty’ and ‘meaning’ through pragmatic structural form while simultaneously embodying artistic merit. I suggest that the importance and principle message left by **Nervi** is in his ability to re-unite the realms of architecture and nature – in his ingenious ability to design under the delicate guidance of natural law in realizing form and structure, as ‘it ought to be’.⁵⁴



Figure 1.15: Stadium exterior [exposed structure].

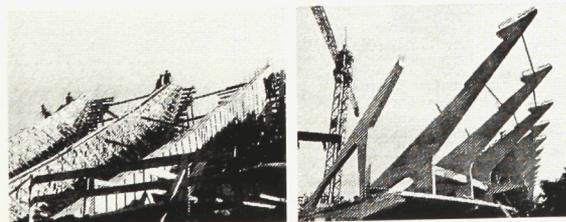


Figure 1.16: Construction Documentation [Concrete Structure].

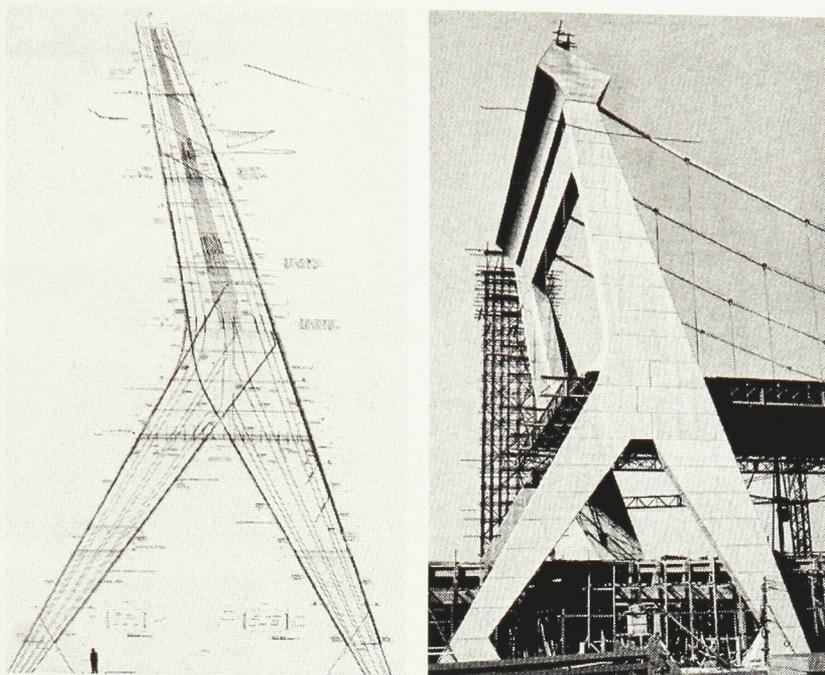


Figure 1.17: Burgo Paper Mill, Mantua [Concrete Structure].

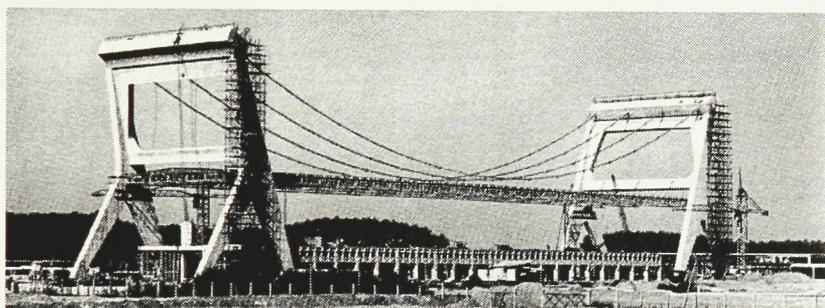


Figure 1.18: Construction Documentation [Concrete Structure].

1.1.7 *Santiago Calatrava.*

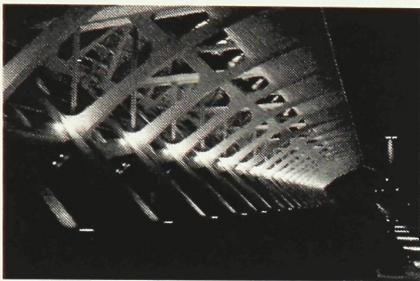


Figure 1.29: *Ciudad de las Ciencias.*

Originating from the logic of natural phenomena, the architecture designed by Santiago Calatrava is considered exemplary in providing structural solutions through the utilization of logical [meaningful], adaptive [dynamic], and beautiful [natural] form – minimizing resource while maximizing performance. In parallel with Pier Luigi Nervi, the core belief and ‘meaning’ of the designs originate from the ‘beauty’ and knowledge gained from studying nature and natural law. Upon realization and insertion into the built environment, the designs encourage the observer to question the origins of

the structural form as the re–presentation of natural ‘beauty’, illustrating why understanding nature is vital to humanity. In developing a ‘morphology’ of motion, the structural ‘beauty’ and natural proportion evident in Calatrava’s architecture are generated by analyzing the dynamics of a body in motion. Once placed into the natural landscape, the architecture “enhance[s] the landscape’s uniqueness rather than subjugate its character.”⁵⁵ When placed in forgotten peripheral areas of a city, his architecture generates hope and rehabilitated desire. In re–presenting motion through adaptive functional structure and form, the architecture realized exemplifies the flow and materialization of natural phenomena. In utilizing the process of sculpting, Calatrava is capable of understanding and manipulating nature and the body through mapping and matching form and idea in reframing the body and applying it in a metaphorical design scheme. Furthermore, the process of sculpting is a tool to aid in understanding and realizing the nature and ‘morphology’ of motion manifest by the concrete body through

the abstract combination of form. In understanding nature through the metaphor of a **body**, the structural systems designed,

“arouse wonder, renew human curiosity, and engage humanity in the collective quest to repair the disorder of the world.”⁵⁶

*Santiago Calatrava draws upon various paradigms of nature and highly articulate forms that offer a dynamic symbiosis exemplifying the active flexibility and ‘movability’ of form. An example of this interest in dynamic form is evident in his postgraduate doctoral thesis where he explored the geometric and trigonometric expansion of structure through space in developing new forms of foldable construction.⁵⁷ Calatrava has developed a mode of architectural exploration and structural investigation capable of merging and transforming construction into a mesmerizing **experience** directed at the realization of natural phenomena. Calatrava’s ‘foldable’ and static designs are simultaneously optimal [logical] and poetic [representational].*

*‘Morphological’ investigation is reflective of the ‘**homo universalis**’ tradition of **Leonardo** and **Goethe** – desiring to understand the structure of organic life and natural phenomena through abstract form and structural movement. In accordance with the work of*

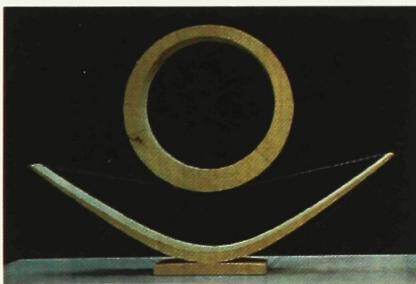


Figure 1.21: ‘Discerning Eye’ sculpture.

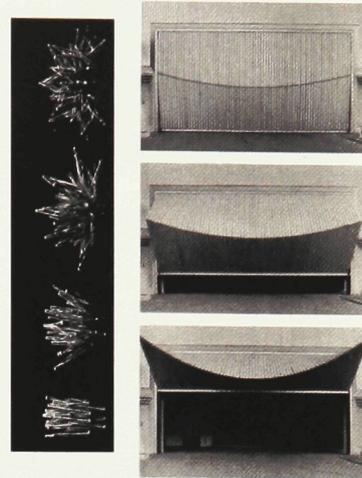


Figure 1.20: Postgraduate doctoral thesis.

*Calatrava, a successful structure must function dynamically through the generation and inspiration of dynamic natural motion. In understanding and applying the logic and ‘**beauty**’ of natural phenomena, Calatrava [like **Nervi**] has demonstrated a capability of transgressing the artificial distinction between art [representation] and science [logic] – architecture and technology. Designing under the*

delicate guidance and knowledge of nature, the architecture realized resurrects a sense of natural 'beauty', linking the built and the natural in equilibrium.

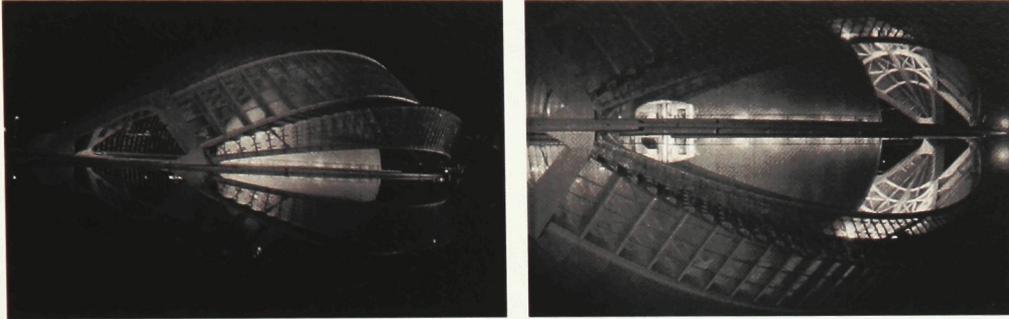


Figure 1.22: Planetarium in half-open and open position.



Figure 1.23: Study of the human figure in dynamic motion.

1.1.8 Eugene Tsui.

It is the birthright of every human being to live in a world of beauty: a world that is concordant with the needs and aspirations of the innermost and highest elemental power in humankind and is expressive of the supreme intelligence and spiritual power manifest in nature.⁵⁸

– Eugene Tsui, *Evolutionary Architecture: Nature as a Basis for Design.*

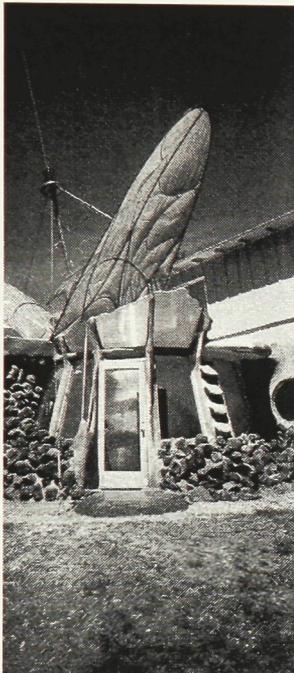


Figure 1.24: Solarium Addition.

In “*Evolutionary Architecture: Nature as a Basis for Design,*” written by Eugene Tsui, the architect is defined as being “more than a designer of buildings, an organizer of space or the interpreter of utilitarian function. An architect is a poet of the human heart.”⁵⁹ Tsui argued that a responsive and poetic heart is capable of generating a naturally vigorous and original ‘beauty’ – shining forth an internal vitality and vision. While the pursuit of an occupation is noble and necessary in sustaining life, it is through creativity, love, and ‘beauty’ that humanity is capable of experiencing life. Tsui declared that the need for ‘beauty’ and concern for the welfare of all living things is fundamental in sustaining a sense of well-being, suggesting that humanity must elevate above the commonplace built environment into the rightful capacity of

designing ‘beauty’ and dignity – “a world where beauty of the human environment and the study of nature go hand-in-hand down the inevitable path of creative freedom.”⁶⁰

Architecture is not a “xeroxified” image of a created nature, in reality it is but one interdependent part of creative nature – the materialization of the invisible pulse and rhythm of life, giving natural pattern to structure and a logical structure to pattern.

Architecture is the physical manifestation of the human desire for the invisible to be made visible – a process of organization and composition of various interrelated forces into a unified whole. In referencing Tsui, dreaming and making a visible reality out of the invisible in thought is the great attribute revealing the uniqueness of humankind. During

a speech that critically evaluated the state of humanity and the human-made environment, **Tsui** argued that the post-modern attitude is generally shaped by destruction, confusion, disregard, and chaos – postulating that the present is the time where humanity must lunge in taking an **evolutionary risk**; a risk in the direction of working with nature not against it – “[humanity] must break the chain of hate, arrogance and conformity in this world.”⁶¹

Eugene Tsui suggested that the mind of **God** is the essence where humanity is capable of learning and gaining knowledge to generate order and responsibility in the built environment. In addition, because nature is the only true **body of God** that humanity is capable of experiencing, humanity must design in **unity** [harmony] and in **symmetry** [equilibrium] with nature and natural phenomena. Nature is the universal force of intelligence – “revealing the solutions to problems that have plagued mankind since the beginning of time. A force that can inject new life and meaning into the vein of humanity.”⁶² On critically investigating the architecture designed and realized by **Eugene Tsui**, I argue that the literal appearance and character of the structures degrade and diminish natural ‘beauty’ into a the realm of superficial image. Although the principle intention is that of creating a harmony to unite the built and the natural, I suggest that **Tsui’s** architecture is aiding in generating and sustaining the present disjunction and lack of criticality. Unquestionably, there is a need to resuscitate the equilibrium. Nonetheless, if architectural design and construction continues with just the image of creative nature, than the ‘beauty’ and ‘meaning’ of nature will remain subsidiary to the superficial. Consequently, I argue for the **process** in which **Gaudi**, **Santiago Calatrava**, and **Pier Luigi Nervi** design and realize architecture. I argue for an architecture impregnated with natural ‘beauty’ without surrendering to the ‘meaningless’ realm of the image.



Figure 1.25: Butterfly Structure.

1.1.9 *Muybridge and Harold Edgerton.*

*'Beauty' is the accord and harmony of parts in relation to the whole to which they are linked, based on number, delimitation and place, as required by the concinnitas, the basic and most exact law in nature.*⁶³

- *Plato, The Republic.*

Visually capturing the experience of time and sequential phenomena in the dimension of time has been made possible through the implementation of 'modern' photographic invention and practice. In 1876-81, **Eadweard Muybridge** developed and realized a variety of devices and 'modus operandi', giving the camera the capacity to 'instantaneously' photograph and capture the invisible phenomena and poetry of motion. In presenting the 'instantaneous' sequential photography, **Muybridge** invented the **zoopraxiscope**, a device designed for the repetitive projection of consecutive images - a device proficient in re-presenting the 'appearance' of motion.⁶⁴ On the basis of the



Figure 1.26: Multiple-flash photography [Edgerton].

zoopraxiscope, **Muybridge** is credited with inventing the motion picture. Yet, the system of sequential photography realized by **Muybridge** is restrictive in that it is only capable of portraying a specific fragment of the whole action - constraining the observing eye from one specific frame to the next in a linear fashion. In reality, the phenomenon of motion is dynamic, and in revealing the true invisible structure and pattern generated through motion, another technique needed to be introduced. In 1932, **Harold Edgerton** revolutionized photography through utilizing and combining a long exposure with a

'stroboscopic' light, facilitating the capture of high-speed motion and multiple-action sequence on a single plate with incredible exactitude. **Stop-motion** [multiple-flash]

photography exposed a 'truth' of natural phenomena never before visible.⁶⁵ In addition, the photography generated by Edgerton significantly influenced the fabrication of art during the early twentieth-century as exemplified by the stylistic representation depicted in Cubism and Futurism. Although visually similar, **photography** differs in that it is non-representational, the capture of reality ['truth']. Via 'magically' shattering and capturing the notion of linear time through the application of stop-motion or multiple-flash photography, the spectator is presented with the totality of the event [phenomena]. Similarities established in analyzing early twentieth-century art illustrate and exemplify the universal intrigue, admiration, and desire to capture time in re-presenting the phenomena of motion. Quintessentially Germanic in origin, *Die Neue Sachlichkeit* – translated the *New Objective Vision* – inspired a new realism and a clinical examination of the 'everydayness' of life, delighting in that which the unaided eye is unable to see, but forever exists. With the continuing advance and meticulous search to capture and observe motion, further knowledge of form and natural phenomena are being exposed – the form underlying the '**phenomemo-logical**' world and natural law made visible that contribute in changing and enhancing the experience of human existence. Understanding and delegating to the New Objective Vision is to simultaneously delight in the **physical world** containing infinite '**beauty**' and the **technology** that makes capturing the infinite '**beauty**' possible.⁶⁶



Figure 1.27: King and Queen Surrounded by Swift Nudes [Marcel Duchamp].

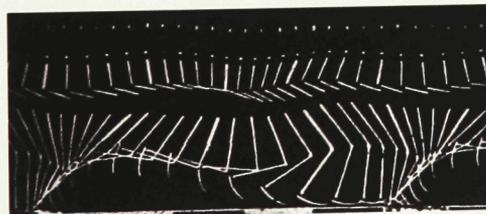


Figure 1.28: Man Running Chronophotograph [Etienne-Jules Marey].



Figure 1.29: Nude Descending a Staircase [Marcel Duchamp].

1.1.10 *Origami and 'Modular' Origami.*

*To the paper-folder, the square is the origin of all form. Geometric shapes, animals, objects, and human beings arise from the square and then, unfolded, dissolve back into it ... In Taoist philosophy, the square is the First Form, the undifferentiated void from which the opposing Yin and Yang forces arise.*⁶⁷

– Peter Engel, *Origami: from Angelfish to Zen.*

*[Origami] is a tender attempt to accomplish something possible in this impossible thing we know as life ... it is moral geometry, inasmuch as it defines our sense of proportion to the universe.*⁶⁸

– Okakura Kakuzo, *The Book of Tea.*



Figure 1.30:
Origami 'dragon'.

Originating in China and designated 'Origami' by the Japanese in approximately the sixth century, paper folding is an artistic process with the ability to sustain the natural logic, simplicity, unity, and 'beauty' of nature. Historically, due to the fact that paper was a rare and costly commodity, Origami became a significantly ritualistic figure in the ceremonial life of Japanese nobility. Samurai exchanged gifts adorned with 'noshi,' a luck token of folded paper with abalone or dried meat while Shinto noblemen celebrated a wedding with sake wrapped in male and female paper butterflies. Origami simultaneously developed in North Africa where the Muslims and Moors, internationally respected for their extraordinary comprehensive skill in math and astronomy, led to the investigation of the vast folding properties of the 'geometric square' – exemplified in traditional architectural ornamentation [Alhambra]. Muslims and Moors presented a universal order in paper folding through the application of the natural principles of geometry. In relation to mathematics, the 'beauty' of Origami is found in geometry and its inherent purity – folding techniques are often unexpected but never arbitrary; the highly ordered process of folding Origami is a method of apprehending nature in a systematic way. In examining the unfolded square, a successful figure is constructed with regular angles and simple proportions – the folded pattern is clean and more beautiful than in those generated in failed figures. Natural systems and structures function and evolve

through intrinsic '**restrictions**' and '**opportunities**' – the beauty of natural pattern is a direct manifestation of the logic and simplicity found in nature. **Origami** is simultaneously representational and logical, "designed with proportion, crafted with sensitivity, and charged with life."⁶⁹ A finished **Origami** figure is successful if it is adept in depicting the creature's true form [**structure** and **proportion**], natural motion, and character [**spirit**]. In traditional **Origami**, the entire square of paper is utilized and given function – nothing is wasted.

Originating from nature as a re-presentation of nature, a successful work of **Origami** must satisfy and exemplify 'beauty' for both the artist [representational] and the mathematician [logical]. This fusion of logic and representation generated a new systematic **process** in paper folding classified as '**Modular Origami**'. In observing and understanding nature's iterative **process**, it is evident that the origin of **Modular Origami** is found in the mimetic manifestation and combination of multiple folded figures into a unified whole. In, "**On Growth and Form: Volume II**" [1942], **D'arcy Wentworth Thompson** postulated that the "heavenly host [nature] must be determined by observation and elucidated by mathematics ... we dwellers in the world and this world wherein we dwell are bound alike by physical and mathematical law."⁷⁰ As stated above, within the 'beauty' of nature lies infinite universal intelligence and the key to progressive knowledge. **Origami** is fundamentally a unique mode of re-presenting, understanding, and realizing this universal and **progressive intelligence** – a mode of apprehending 'meaning' through the embodiment of natural 'beauty'. "Like the patterns of nature, the **Origami** model is a skillful accumulation of simple elements ... its **beauty** is its **simplicity**."⁷¹

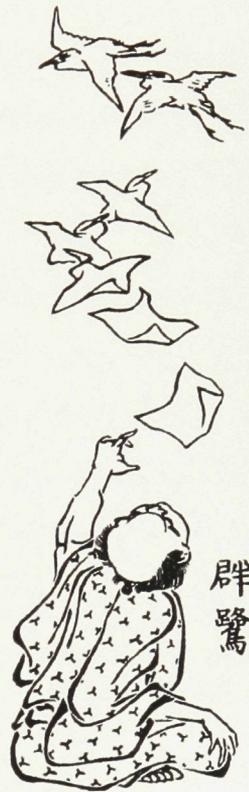


Figure 1.31: Origami.

1.2 Summary.

Architecture is a cultural expression presenting the attitudes and values of a community; a mirror reflecting the human capacity to understand nature and natural phenomena. As a tool with the ability to inspire change in the world, architecture supplies shape and 'meaning' to our experiences by constructing and framing events and rituals. Architecture, like culture, is imperative in providing humanity with a sense of 'place' throughout history and in the diverse complexity of the modern era. As the physical manifestation of the human desire for the ineffable to be made effable – it is a **process** of organizing a **composition** of various interrelated forces into a unified whole. Infused with the facility to bring hope and renewed desire to forgotten peripheral areas of a city, architecture is impregnated with the gift to stimulate wonder, revitalize human curiosity, and “engage humanity in the collective quest to repair the disorder of the world.”⁷² Designing under the delicate guidance and knowledge gained in understanding nature and natural phenomena, architecture is capable of transgressing the artificial distinction between art [representation] and science [logic]. Within the mind of 'God' [analogous to **Eugene Tsui**], humanity is presented with the knowledge to generate order and a responsible **sustainable** future. As nature is the only **body** of God that humanity can truly experience, the design of architecture must progress in unity [**harmony**] and symmetry [**balance**] with the natural realm. As the universal spring of intelligence, nature is impregnated with the aptitude to inject new life and 'meaning' into the vein of humanity. Unfortunately, in the present era, 'meaning' is substituted with the belief that the material world is a mere collection of inanimate substance [**image**] – substituted with the absurd assumption that 'meaning' is an abstract fabrication of the mind that can be manufactured a priori. Architecture is more than a construct of programmatic space for utilitarian function, it is a construct designed and realized to inspire change. Architecture is infused with the facility and responsibility to guide humanity in the direction of forming a **balanced union** with nature – a relationship built on the logic and structure of 'beauty'.

Evolutionary Architecture: A Resurgence of Natural 'Beauty'.

Chapter 2: Paradigm.

The heavenly host [nature] must be determined by observation and elucidated by mathematics ... this is the teaching of Plato and Pythagoras, and the message of Greek wisdom to mankind ... we dwellers in the world and this world wherein we dwell are bound alike by physical and mathematical law.⁷³

- D'arcy Wentworth Thompson, On Growth and Form: Volume II.

2.1.1 Philosophy.

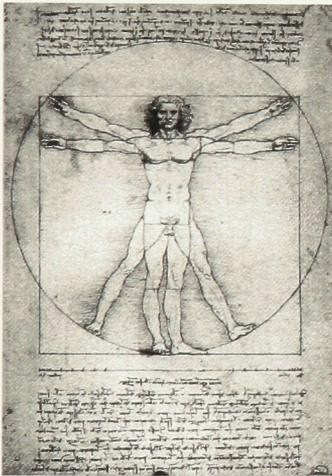


Figure 2.1: 'Vitruvian Man'.

As stated in the introduction, *Vitruvius* implied that 'mimesis' is a natural mode of evolution and design that involves learning and understanding the physical world and building upon that knowledge to design and construct the built world as 'it ought to be'. Over the course of history, the universal man [*Vitruvian man*] has represented a paradigm for universal consistency and harmony – the unique form of the **body** and the formation of identity through the union of separate yet interrelated parts teaches humanity the first rule of composition: unity in

multiplicity. *Galileo* implied that the world is read through mathematical systems, suggesting that everything in the physical realm can be represented and understood through numbers. Via graphing the numbers of any mathematical system, patterns emerge, and therefore, **patterns** are a visual materialization of the underlying structure and construct of nature. Although principally differing in their theoretical approach, *Plato* and *Aristotle* shared the notion of art being a form of *techne*. Where *Plato* argued that

human manifestation and realization originate from an abstract mental construct built on subjective interpretation, **Aristotle** argued for empirical knowledge [experience] – an ultimate reality realized through the observation of nature. In understanding nature, humanity is given the facility to experience ‘beauty’ through **sensory-based** interaction – **Aristotle’s** concept of structured knowledge. If architecture is to reinstate ‘meaning’ into the built realm, the infusion of ‘beauty’ must commence. Unfortunately, with the present disarray of ‘**homo aestheticus**’, the meaningless and superficial are equivalently fashioned and defined ‘beautiful’, destroying the true quality and character of ‘beauty’. If the present desire and infatuation with ‘**beauty**’ is to manifest in the built realm, humanity must turn to nature in generating it.

Hegel argued that architecture [**hylomorphic form**] is unable to engage in representation.⁷⁴ As a hylomorphic form, the ‘crystallization’ of architectural ‘meaning’ is dependent on subjectivity [**human interpretation**] and hence, is vulnerable to an end. As a **morphogenetic process**, the significance is placed on the duality and interdependency of form and function – ‘**beauty**’ and ‘meaning’ are infused in the tradition and **process** of realization. In addition, as a **morphogenetic process**, ‘meaning’ in architecture is self-referential and non-representational. As a hylomorphic form, architecture is reduced to a representational and meaningless image. Unfortunately, architecture is presently ensnared in a state of ‘**simulacra**’ – a **process of artificial simulation**. As stated in the introduction, **Jean Baudrillard** suggests that the present era is inundated with “more and more information, and less and less meaning”⁷⁵ – the world is being “**xeroxified**” to infinity. **Baudrillard** argued that the inundation of the image has generated an alternate reality where the image itself is reality – “a virtual world floating above the real world in its own sealed-off hermetic envelope.”⁷⁶ In addition, he argued that the image is the ultimate form of **seduction** – a purely visible enchanting form, extracting ‘meaning’ from discourse and detracting ‘truth’ from critical inquiry. If humanity continues to champion seduction over critical discourse, all ‘meaning’ will ultimately be vanquished. In the present state of ‘**hyperreal**’ existence, architecture is falling prey to the seduction of “**anaestheticization**”. Architecture must not subscribe uncritically to abstraction and

*superficial representation in designing and realizing a **sustainable** future. In designing and realizing 'beauty', architecture must reinstate a **morphogenetic process**.*

*In the present, a large quantity of architecture is designed primarily for profit and self-prestige. Image and the infatuation with the 'self' are generating a state of life that is simply 'lived' and not experienced. **Walter Benjamin** argued for a resurgence of **experience**, stating that experience is impregnated with 'aura' – the built up collection of a balanced and unified transmittable wisdom supplying uniqueness and distance from the 'xeroxified' realm.⁷⁷ With the continuing pursuit and systematic quest to study and comprehend nature, knowledge of the '**phenomeno-logical**' structure of nature is infinitely **progressing** – enhancing the health and experience of human existence. Suggested in this thesis, 'beauty' is a manifestation and re-presentation of the logic and unity within nature. Architecture is the ultimate manifestation of human expression and significance, a '**second nature**' [Cicero] designed as an alternative to living entirely within the first. As the emergence of architecture originated not from 'style' but from intrinsic 'meaning' in response to a consciousness of the **human body** and nature, I suggest that the present design of architecture must revisit its origin in denying 'style' and reinstating 'meaning' – as humanity is blighting the earth with 'ugliness', this thesis argues for a resurgence of natural 'beauty'. Summarizing this section, the **Darwinian theory** illustrates and demonstrates the search for order in the environment as a mechanism that has evolved to ensure survival within the unpredictable realm of nature. With the present design of architecture being driven by a search to perfect a system of freeing humanity from the unpredictability, an alternative realm of imbalance and 'ugliness' has spawned. As a result of the mutual dependency and ultimate interdependency linking the built with the natural, architecture must be designed and realized with the '**beauty**' and unity of nature. As stated in the introduction, architecture is infused with the facility and responsibility to instigate change in the world; to guide humanity in the direction of restoring a lasting equilibrium with the natural and the built through the assemblage of a progressive, adaptive, dynamic, and unified future.*

2.1.2 *Vitruvius.*

Vitruvius, author of "*De Architecture libri decem*" [trans. *Ten Books on Architecture*], the solitary treatise on architecture to survive from classical antiquity, was born in approximately c. 80/70 B.C. in Rome. *Vitruvius* argued that all building must attain validation through nature and history. And in implementing an *Aristotelian* aesthetic principle, he suggested that imitation [*mimesis*] is the natural human ability to envision things 'as they ought to be' – stating that, "the ultimate test of validity for a work of architecture is for it to be true to nature."⁷⁸ In addition, *Vitruvius* argued that tradition and science represent the cumulative result of a progressive unveiling of natural order, which is to be guarded carefully, but extended continuously, by invention and good judgment. Hence, the underlying message is in regarding architecture as a complex art that requires the control of a "rich tradition" [nature] – an intricate art that must advance through innovative personal talent and intelligent application.⁷⁹ Although the notorious conflict in architectural theory between absolute 'beauty' and arbitrary 'beauty' [image] is fundamentally absent in his text, *Vitruvius* has presented the ancient and the present with a system of attaining and generating order in architecture through informed creative intelligence. *Vitruvius* suggested that expertise of the architect is born from 'practice' and 'reasoning' – where practice is the constant exercise of the hands by which the work is brought to completion, and reasoning is the skillful and systematic demonstration [explanation] of the completed work. In addition to gaining skill in geometry, history, music, medicine, law, and astronomy – *Vitruvius* argued that philosophy completes the character of the architect by instilling a loftiness of spirit, so that the architect can deny and surpass arrogance in becoming fair, trustworthy, and most importantly, free from greed.⁸⁰ In the quest for unity, the vital objective is the achievement of a unified and all-inclusive existence. If humanity is to reside harmoniously within nature, then the design of architecture must bring a conclusion to the infatuation with profit and self-prestige.

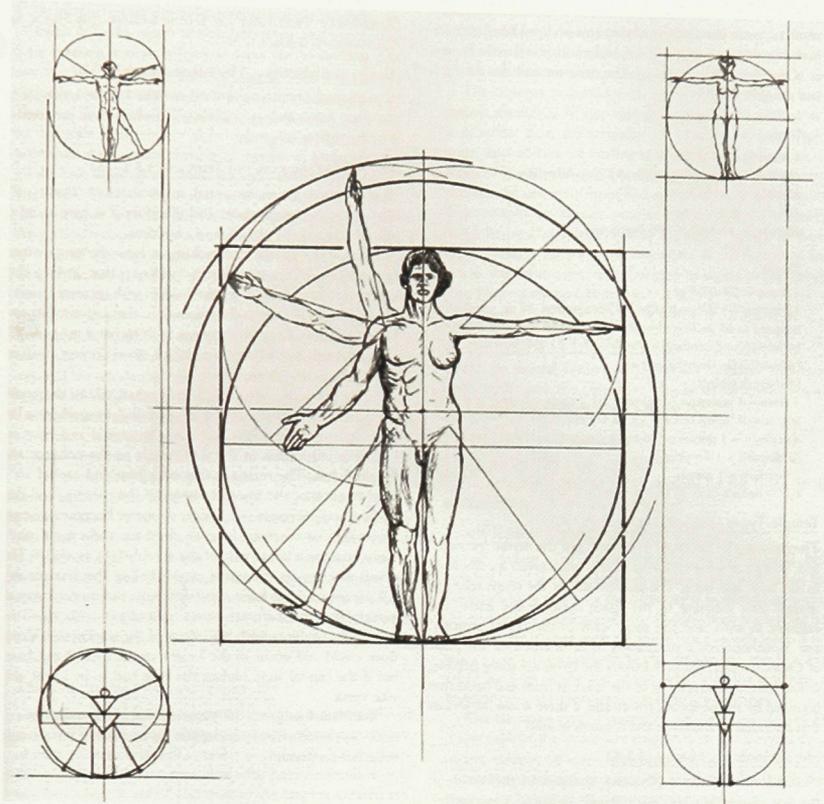


Figure 2.2: 'Homo Bene Figuratus' [Vitruvius].

2.1.3 *Plato and Aristotle.*

The chief forms of beauty are order and symmetry and definiteness, which the mathematical sciences demonstrate in a special degree.⁸¹

– Aristotle, On Beauty from “Metaphysics”.

As mentioned earlier, **Plato** and **Aristotle** shared the notion of art being a form of *techne*. Where **Plato** argued that all human manifestation and realization originate from an abstract mental construct based on subjective interpretation, **Aristotle** argued for empirical knowledge [*experience*] – an ultimate reality realized through the observation of nature. In understanding nature, humanity is given the ability to experience ‘beauty’ through sensory-based interaction. **Plato** suggested that among the arts, the highest is that of the divine maker – the *Demiurgos*. Consequently, **Plato** argued that the world which humanity experiences through sensory-based interaction is fundamentally not real but a copy. Unlike **Aristotle**, he believed that the ‘real’ world exists in the realm of the mind [“Ideas”], stating that the ideal tree in which all trees are derivative manifestations and the idea of all things in the universe reside in this realm. In contrast, **Aristotle** suggested that the ‘real’ and ‘meaningful’ are not outside and above the natural world in which humanity experiences – ‘beauty’ is not a transcendental idea, but a unifying spirit within the form and matter of nature. Unlike **Plato**, suggesting that the sculptor is independent and free from his marble, **Aristotle** argued that the sculptor is dependent on it. Where **Plato** regarded the ‘true’ universe as a pure, changeless, and motionless entity, **Aristotle** regarded motion and change as the demonstration and explanation of the union between form and matter [universe] – nature referred not to the physical things around us but to the “active forces of the universe.”⁸² Consequently, **Aristotle** argued that understanding natural order requires dealing with the behaviour and properties of the tangible universe rather than the abstract ideals [**Plato**]. On the notion of unity and ‘beauty’ in art and architecture, **Aristotle** turned to nature in attaining a basis for generating a balanced composition. And hence, unity and ‘beauty’ in art and architecture

is regarded as yet another reflection of nature's infinite paradigm. I postulate that natural and universal 'beauty' is comprehensible and attainable through understanding and utilizing Aristotelian philosophy. On arguing against the Platonic notion of segregation being a rational system liberating architecture and humanity, I suggest that segregation is leading humanity on a path of natural destruction. If the shift in equilibrium is to halt and reinstate balance, humanity must find a cure to the predisposition of segregation.

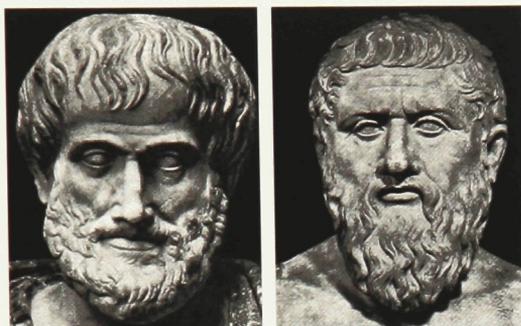


Figure 2.3: Aristotle [left] and Plato [right].

3.1.3 Plotinus.

On further understanding natural and universal **'beauty'**, it is imperative to identify and define the three fundamental characteristics of **aesthetic experience** – **'isolation'**, **'unity'**, and **'significance'**.⁸³ On developing this notion, **'isolation'** implies that the experience is complete within itself and that **'meaning'** is non-representational [**morphogenetic**]; **'unity'** is the harmony of parts within the whole; and **'significance'** is that which is valuable. **'Isolation'**, **'unity'**, and **'significance'** are independent yet interrelated in aiding and supporting the other. On expanding this notion, it is important to discuss **Plotinus'** contribution to the philosophy and metaphysics of **'beauty'**. As stated in the introduction, **Plotinus** argued that the amalgamation of **'unity'** and balance is vital in generating **'beauty'** and aesthetic experience. **Plotinus** defined the **'absolute ugly'** being that which is not entirely mastered by **pattern** – identifying the fact that only a compound is adept in representing **'beauty'**, "never anything devoid of parts; and only a whole; the several parts will have beauty, not in themselves, but only as working together to give a comely total."⁸⁴ Consistent with this notion, **Plotinus** suggested that **'creation'** is a fall from God – in parallel with **Plato**, he regarded the nadir of **'creation'** as the manifestation of pure matter. Consequently, **Plotinus** argued that the **'beauty'** of art and architecture is a demonstration of the unity of **'being'**, stating that the **'beauty'** of a human-made object is an imitation of **'beauty'** and ultimately of the **Good** of the intellect [**psyche**].⁸⁵ I suggest, in agreement with **Eugene Tsui**, that nature is the only true **body of God** that humanity is capable of experiencing – and hence, humanity must design in unity and in symmetry [**equilibrium**] with nature and natural phenomena. Unlike **Plato** and **Plotinus**, I suggest that **'beauty'** is not a manifestation of the mind but a unifying essence within nature that is understood and received by the mind. If the shift in equilibrium is to halt and reinstate balance, humanity must cease segregating the built from the natural and align with nature to detoxify the present **'intoxication'** of the human psyche. If a cultural and ethical **sustainability** is to manifest, humanity must return to regarding the built and the natural as a **synonymous and interdependent whole**.

3.2 Summary.

If the decay of 'meaning' and 'beauty' [aesthetic experience] is a result of the present state of "aestheticization", should not humanity cease desiring to commodify nature, and begin to align with nature to overcome this desolation? **Descartes** emphasized the dualistic idea of separation from mind and nature in declaring that because the human mind is able to contemplate nature, the natural realm must reside outside of thought, and is therefore separate. As the built realm is indisputably a second nature built within the first, architecture is a large and integral factor in sustaining environmental balance. If architecture is infused with the facility to create a balanced and integrated link between the built and the natural, it must therefore be infused with the facility to destroy it. I suggest that architecture must return to the teachings of the ancient world in amalgamating and building in balance with nature. As stated earlier, in the present state of 'hyperreal' existence, architecture is falling prey to the seduction of "anaestheticization". If architecture is to reinstate 'beauty' linking the built and the natural, it must not subscribe uncritically to abstraction and superficial representation. As mentioned earlier, **Aristotle** argued that the 'real' is not outside and/or above the natural world in which humanity experiences – 'beauty' is not a transcendental idea, but a unifying spirit within the form and matter of nature. In harmony with **Aristotelian philosophy**, I urge for a resurgence of 'beauty' – unity and equilibrium. In conclusion, I leave the reader with a passage from an ancient myth describing the origin of the eight basic generative figures that have given birth to **Chinese calligraphy**,

When Fu Xi governed everything under the sky, he looked upward and admired the splendid designs in the heavens, and looking down he observed the structure of the earth. He noted the elegance of the shapes of birds and animals and the balanced variety of their territories. He studied his own body and the distant realities and afterwards invented the eight trigrams in order to reveal the transformations of nature and understand the essence of things.⁸⁶

Evolutionary Architecture: A Resurgence of Natural 'Beauty'.

Chapter 3: Architectural Proposal.

3.1 Re-presenting the Body.

*The machine is the architect's tool – whether he likes it or not. Unless he masters it, the machine has mastered him.*⁸⁷

– Frank Lloyd Wright, *In the Cause of Architecture*.

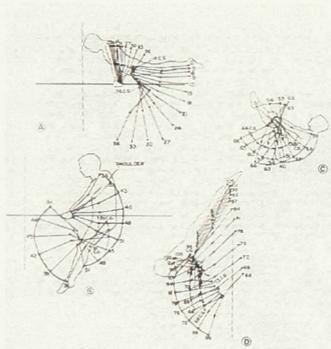


Figure 3.1: Study of the phenomenological patterns created by a gymnast in motion [parallel bars].

On searching for the initial inspiration to direct and 'structure' the architectural proposition, I began studying and analyzing the human **body** in *dynamic motion*. And in implementing the realized structures and forms manifested through the investigation of the **human body**, I propose to design an Olympic stadium. In addition to forming a link with the programmatic function of the Olympic stadium and to the natural realm, the **human body** is the principle mode in which humanity is capable of judging and understanding the physical world. Since the beginning of humankind, the

body and its **proportions** [dimensions] has commanded a large and governing role in the design and construction of architecture. In "Nature and the Idea of a Man-Made World: An Investigation into the Evolutionary Roots of Form and Order in the Built Environment", Crowe suggests that humanity is capable of understanding the world from a referential structure of bodily associations, and "it is from this natural characteristic of our perception of the world that geometry is born."⁸⁸ On the notion of balance and unity, the drawing of the 'Vitruvian man' by Leonardo da Vinci is universally established as representing the

harmonious link connecting humankind and nature. As the **human body** is fundamentally a manifestation created in the image of **God**, should the design of architecture not utilize the human body in generating balance and 'beauty' in uniting the built and the natural in equilibrium? Historically, the 'universal man' represented a valuable and rational approach to architectural design via presenting a mode of natural compositional arrangement with the intuitive sense of balance and architectonic form that arise from bodily perception. Vitruvius defined the drawing of the 'universal man' as representing a "paradigm for proportional and **compositional consistency**."⁸⁹ As stated in the introduction, if humanity is to reside harmoniously within the natural realm, the source of nature's unity must be known so that human fabrication can be designed and realized in union with it.

Understanding the **process** that directed and aided the shaping of this architectural thesis is imperative in comprehending the 'meaning' and significance of the design. Illustrated above, the design began by studying and analyzing the human body in **dynamic motion**. In the film "**π**", directed by **Darren Aronofsky**, the main character [Maximilian Cohen] hypothesizes that **patterns** will irrefutably emerge upon graphing the numbers of any system. Consequently, upon graphing the vector-lines generated by a gymnast, a pattern emerges. After investigating and analyzing the pattern, the challenge became that of transforming the two-dimensional pattern into a three-dimensional structure. In attempting to transform and realize the pattern, I utilized the art of **Origami** with the optimistic confidence that this **process** would maintain the natural 'beauty' and optimal simplicity of the manifested pattern. In addition, through studying the folded-patterns generated by **Chuck Hoberman** and upon 'truthfully' finishing and judging the initial three-dimensional structure appropriate, the next challenge centered on further understanding the aptitude and 'flexibility' – **dynamic character** – of the manifested form. With the alteration of varying degrees in combination, the curvature of the spiral was found to be adjustable. After exhausting many plausible

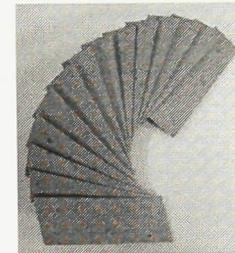
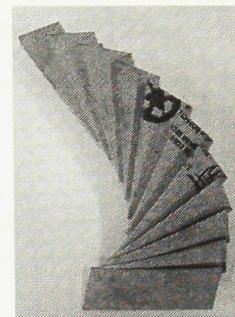


Figure 3.2: Folded Pattern [paper].

combinations, I began combining the single 'module' to create a larger structural system. As stated earlier, *Plotinus* defined the 'absolute ugly' being that which has not entirely been mastered by pattern. Subsequently, after analyzing the 'modular' structures, I desired to further investigate the dome and spiral manifestations, regarding these folded structures as having great architectural potential – ultimately leading to the design of the *dynamic roof*.

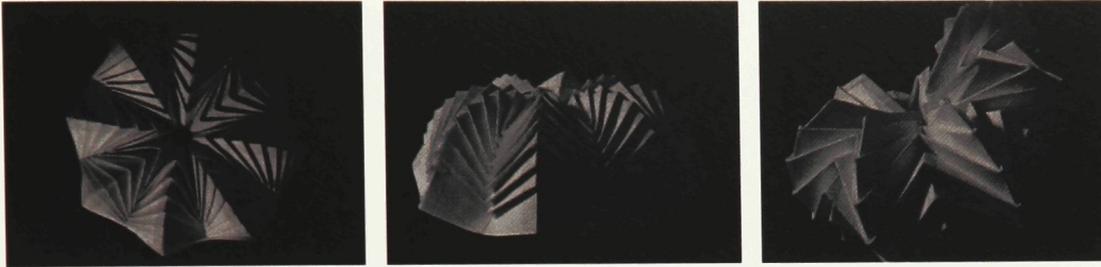


Figure 3.3: 'Module Origami' [paper].

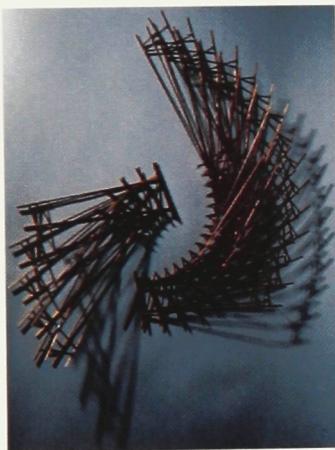


Figure 3.4: Foldable Structure [metal].

On realizing the 'modular' structure and assigning it materiality, I transformed the folded paper pattern into a metal skeletal structure. In maintaining the dynamic qualities of the folded pattern, the joints had to be designed with the capability of facilitating the natural motion of the realized pattern. After constructing a single 'module', the challenge again was that of combining and joining the 'module' into a larger 'modular' system. Subsequently, the question turned again to selecting the materiality for the sheltering membrane of the stadium. With the vast quantity of innovative materials in the present discipline of construction, I decided to utilize *ETFE* [ethylene tetrafluoroethylene] membrane for its environmental and aesthetic quality [appendix 3]. In designing a structure with the capacity to facilitate motion, it was obvious to exploit and take full advantage of the dynamic and adaptive character of the foldable structure. I propose that architecture aspiring to exemplify *evolutionary capacity*, must be designed with the capability to adapt to the environmental flux of nature. And thus, in

designing the Olympic stadium with this **adaptability**, I utilized the dynamic foldable pattern to generate a retractable roof structure. In addition to facilitating adaptability, it is imperative that **sustainable technology** be implemented to ensure that the built and the natural physically exist in equilibrium [appendix 3]. In spite of this, due to time and the fact that this thesis is predominantly centered on the **mimetic/morphogenetic process** of generating form and structure, the traditional notion of sustainability will not play a large role in the final design. Yet, with the contemporary shift in balance, it is vital not to disregard the evolutionary significance of environmentally sustainable development [ESD] and to incorporate these issues into the design through further iteration.

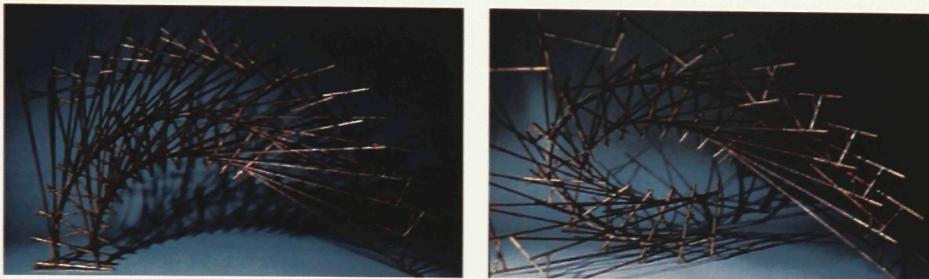


Figure 3.5: Foldable Structure [metal] in half-open and open position.

With regards to designing the structure to support the three-tiered seating area with a maximum capacity of 50 000, I again drew inspiration from the human **body**. In contrast to the prior mode of utilizing the body to generate form, I investigated the natural **process** in which the body transfers and distributes gravitational force. Similar to **Pier Luigi Nervi** and **Santiago Calatrava**, I implemented a **process** of abstracting the human form to create a structural system embodying natural logic. Staying true to maintaining an affiliation between form and function, I investigated the natural structural form of a sprinter in the 'set' [starting] position. Consequently, the natural form in which the hand and the leg carry and distribute the weight of the body was utilized to generate the structural



Figure 3.6: 'Modular' Foldable Structure [metal].

form of the stadium. In designing the structural system to support the weight of the stadium, it was imperative for the design of the structure to simultaneously exemplify 'beauty' through aesthetic experience and efficiency in construction. With this in mind, I designed a repetitive structural system that would utilize the innovation of pre-fabrication and mass production. On assigning materiality to the organic form of the structure, I decided to utilize pre-cast and site-cast concrete. As stated in the introduction, with the perpetual opportune introduction and innovation of high-performance materiality and building technology, architectural design and construction is progressing 'ad infinitum'. Subsequently, in demonstrating and facilitating 'evolutionary' authority [appendix 1], architecture must utilize these 'opportunities'.

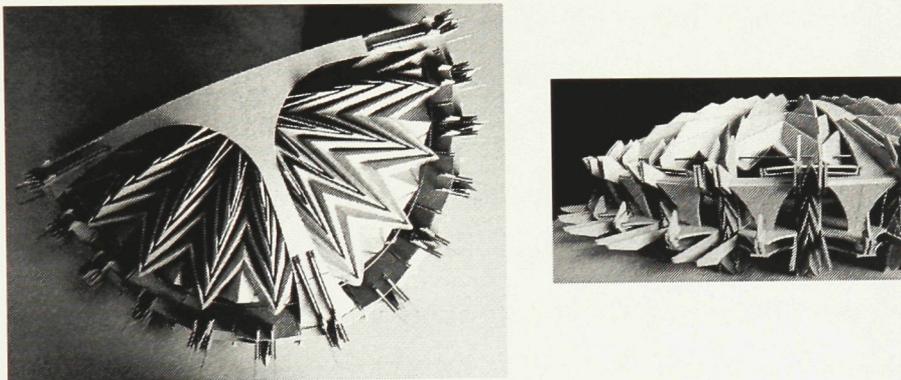


Figure 3.7: Proposed Stadium [first iteration].

3.2 Machine.

'Beauty' – a word much avoided in this late mechanistic era, conveys an inexplicable sense of harmony and wholeness ... it touches a higher sense than the emotions alone. Out of the most ordinary circumstance a transcendental experience is distilled.⁹⁰

– Arthur Erickson.



Figure 3.7: Machine Study.

*In the mid-nineteenth century, the proliferation of the machine-driven culture began, and thus, art and architecture reflected the proliferation and increase dependency on the machine. In the **Modern Style**, which became an iconic emblem of Capitalism, architecture advertised and delighted in the 'promise' of a machine-made future.*

Armed with the plethora of innovative design

*'opportunities', the **Modern Style** encouraged the experimentation and stylistic utilization of the machine in the built realm. Although the machine has inspired and aided in generating a large quantity of the irresponsible and insensitive construction criticized in this thesis, it has in contrast, aided in freeing architecture from a vast quantity of evolutionary 'restrictions'. With this in mind, it is imperative that the machine be utilized with care and the utmost responsibility. With the present state of 'intoxication', there is no end to the ability that the machine-driven culture has to completely substitute the real for the unreal – and consequently, there is no end to the sum of destruction and segregation that is denying 'beauty' and equilibrium between the built and natural realm. Architecture must return to the teachings of the ancient world in building in harmony and unity with nature. If architecture is infused with the gift to increase the human consciousness of its existence in time, and thus, if a sustainable future is to manifest, then a change in attitude is clearly required. I urge for a termination of the human desire to oppress, dominate, and segregate itself from nature. If a stable and healthy future is*

truly desired, then humanity and the design of architecture [the '**machine for living**'] must turn to the **aesthetic experience** of natural '**beauty**' in generating it.



Figure 3.8: Machine Study [details].

As the machine is aiding in the '**progression**' of architecture, I initially desired to exploit and take full advantage of the present design '**opportunities**' that exist in the disciplines of design and construction. On developing this desire, I began investigating the mode in which the machine is influencing the shape and character of contemporary architecture. In addition to presenting a vast sum of inventive building '**opportunities**', the machine has played a considerable role in shaping the aesthetic '**quality**' of modern and post-modern design. And thus, in addition to utilizing the machine during the anticipated **process** of construction, I initially aspired to exploit the **machine aesthetic** in an attempt to create a stable and unified dialogue between the built and the natural realm. After investigation and critique, I established that the machine aesthetic diminished the natural '**beauty**' and logic of the anticipated structure – in contrast to generating a unified dialogue, it camouflaged the authentic '**truthfulness**' infused through the **process** of reinterpreting and re-presenting the human **body**. Hence, in not contributing to the '**meaningless**' abstraction and superficial image-making that is plaguing the built realm, I decided not to utilize the machine on an aesthetic and superficial level. Although not immediately visible, I suggest that the unifying dialogue is fundamentally impregnated within the design through the **process of construction and experiential realization**. Without the application and diligence of the machine, the function and construction of the structure would evidently be unfeasible. As stated in the introduction, in designing a responsible and unified '**machine for living**', the architect must imbue its manifestations

with the authority to induce and resuscitate critical responsiveness. If the destruction and annihilation of the natural realm is to halt, then the irresponsible design and utilization of the machine must end. If architecture is to reinstate 'beauty' in the built environment, it must not subscribe uncritically to the realm of the image – the enemy of the imagination.



Figure 3.9: Machine Study [sculpture].

3.3 Stadia.

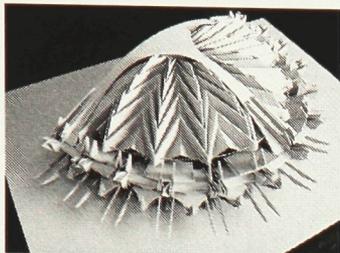


Figure 3.10: Proposed Stadium [first iteration].

In presenting a general history of modern stadia, it is imperative to present the **'generational' progression** that led to their design. Historically, the first 'generation' of stadia, although often stylish and articulate, developed a reputation for being uncomfortable and dangerous.

Although the great **Roman Coliseum** is generally not regarded as being a stadium, I argue that it exemplifies the

mode in which stadia are capable of unifying a nation through generating a shared sense of **'community'**. With the design of stadia continuing relatively unchanged in the second 'generation', the design did advance in the direction of supplying the spectator with a higher level of comfort and a larger variety of amenities. In the second 'generation' of stadia, the design anticipated a multiplicity of athletic functions, sanctioning a perpetual utilization of the realized stadium.

Unfortunately, in the third 'generation', stadia became restrictive single-function facilities. Outside of the limited duration of a weekly or monthly sporting event, stadia were 'dead' structures in the environment. Luckily, due to the competition created by the introduction of the television, the contemporary design of stadia has had to adapt to satisfy the voracious appetite of the spectator. With the design of

the **Houston Astrodome** in 1960, stadia began reintegrating a multi-functional program to attract a larger audience. Nevertheless, the majority of stadia remain vacant for most of the year, and of the vast sum of modern stadia, only a few are truly multi-functional. In designing a multi-functional stadium, I proposed a permanent Olympic gallery to celebrate the athletic history of all participating countries. Additionally, the majority of the ground floor will remain open for public use - a sheltered space that could be utilized as a public market, urban park, and/or temporary exhibition site.



Figure 3.11: Interior of the Roman Coliseum.

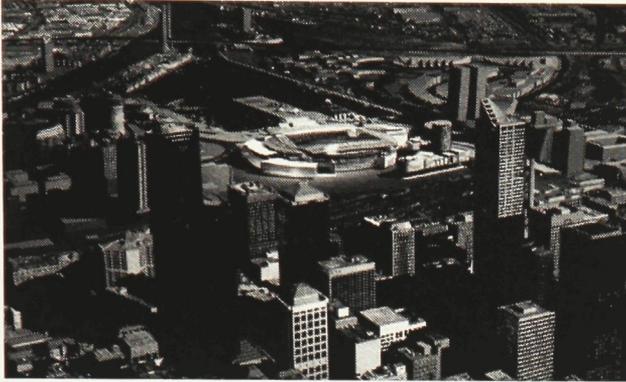


Figure 3.12: Colonial Stadium.

Often, the only site within the present urban context available for stadia are abandoned heavily contaminated industrial areas – therefore, stadia can and should offer ‘ecological benefits’ via cleansing and detoxifying the contamination. In addition to benefiting the natural environment,

stadia are catalyst, instigating change in the built realm – the *Colonial Stadium* in Melbourne exemplifies of this notion. *Colonial Stadium* is the pivotal and integral ingredient of a radical renewal and transformation plan for Melbourne’s abandoned railway and dockland area. Sited at the center of the 220–hectare area, *Stadium Park* is a deliberate attempt to emulate the established example set by *North American* cities that have effectively revitalized a redundant inner city area with an urban strategy centered upon the design and realization of a new stadium. As ‘magnetic’ structures with the facility to attract a large audience, stadia are infused with the ability to instigate change and rehabilitated desire. It is the fundamental importance of all humanity to build upon natural inheritance and remember that humanity is ultimately dependant on nature. Architecture has a greater responsibility than most to ensure that the built environment is not created at the expense of the natural. As stadia are designed and realized with the principal function of housing and commemorating human triumph, should they not therefore reflect the fact that the elite level of competition is dependant on the balance and health of the environment? Like the *Renaissance* cathedral, the design of stadia must learn from nature in generating equilibrium through embodying ‘beauty’.

As stated in the introduction, stadia are a select classification of structures designed to unite the world together and induce interaction, linking spectators and the spectacle within a single event. Stadia are often designed for nothing more than utilitarian function and financial profit – situating ‘beauty’, ‘meaning’, and the present

need for equilibrium between the built and the natural ancillary. Without a doubt, there is a higher quality of personal comfort and amenity in the average living room – but the vital difference between the lived experience and its televised ‘replica’ is the “sense of ‘community’ a stadium creates, that gathering of people, focused, as one, upon a single transient show of human endeavour.”⁹¹ With the ability to generate this sense of ‘community’ through uniting the world under a single roof, I argue that the stadium is infused with the capacity and facility to instigate a change in the world. Consequently, an Olympic stadium is arguably the most effective form of architectural expression due to the fact that a large majority of humanity is united together to watch and participate in the spectacle. In addition to instigating change, a great venue is capable of enhancing the spirit, consciousness, and atmosphere of a great event. As stated in the introduction, with the *International Olympic Committee [IOC]* insisting that the design of all sporting facilities demonstrate care and respect for the environment,⁹² I suggest that the design of an Olympic stadium best exemplifies the principle aim and aspiration of this thesis.



Figure 3.13: Proposed Stadium, sectional plan [model].

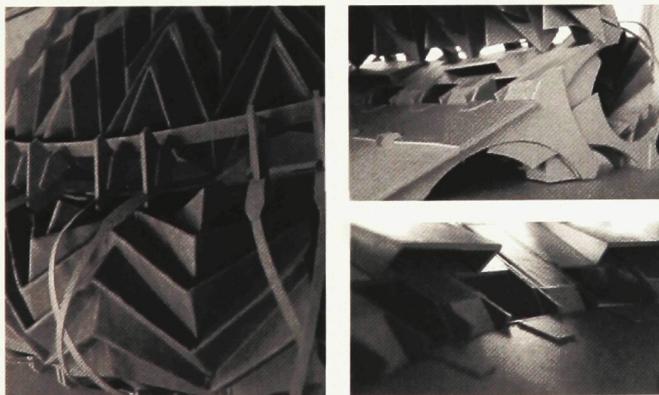


Figure 3.14: Proposed Stadium, details [model].

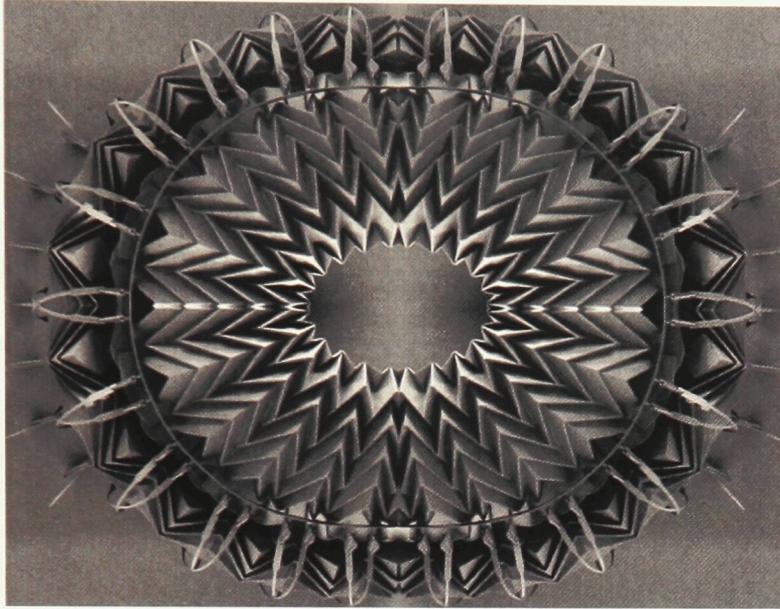


Figure 3.15: Stadium, roof plan [model].

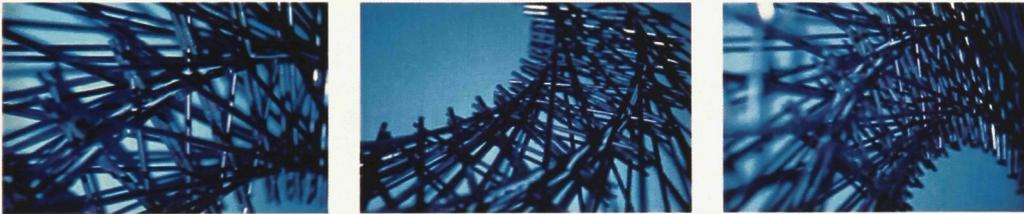


Figure 3.16: Foldable Structure, details [metal].

3.3 *Proposed Site.*

I decided to utilize the initial Olympic site for the 2008 bid that centered on resuscitating and reviving the abandoned industrial waterfront area in Toronto, Ontario. With the majority of the site being abandoned and awaiting demolition, there is a negligible sum of existing built context that could be utilized in aiding and directing the design process. Vitruvius suggested that a site must exemplify "health" – and although the majority of the waterfront site is presently abandoned, I argue that the site supplies a 'healthy' link between the built and the natural. Set against the backdrop of Lake Ontario, the site is impregnated with the capacity to generate a unified correlation linking the spectator, anticipated architecture, and natural environment within a single frame of experience. Although the site is presently abandoned and awaiting demolition, I suggest that the 'beauty' of the stadium, upon realization, will generate renewed desire and rehabilitated hope. Once inserted into the natural landscape, I anticipate that the architecture will enhance the uniqueness of the landscape without subjugating its natural character. On the general urban design, I intend to salvage and utilize the existing urban strategy established for the bid [appendix 2]. In believing that an individual architect/designer must not have absolute jurisdiction of an entire urban project, I designated not to suggest a general strategy for the whole of the Complex. Stated in the beginning of the paragraph, a site must exemplify 'health' and is without doubt a large and crucial factor in designing a rewarding venue. And hence, the following quote by **Baron Pierre De Coubertin**, the architect of the modern Olympics, is a suiting conclusion to this chapter of the thesis,

"The first thing to be taken into consideration when staging a sports festival is the scenery ... the scenery strikes the eyes of the spectator. When the contestants appear, the spectator immediately is confronted with their mode of fitting in with the environment, landscape and setting and the harmony of their performances with these."⁹³

[additional documentation in appendix 3]

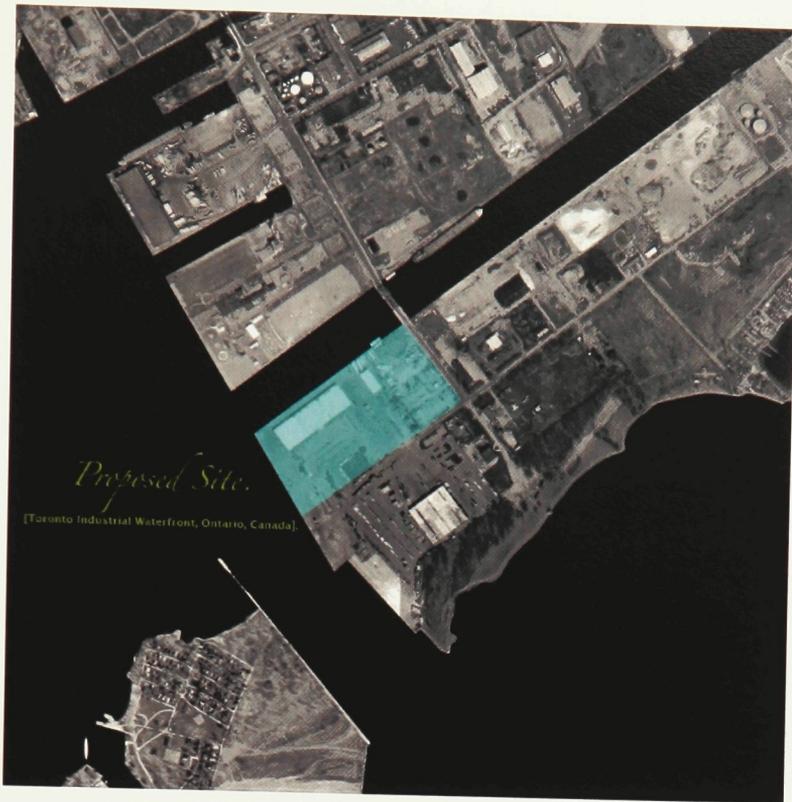


Figure 3.17: Satellite Photograph of the Industrial Waterfront Site [Toronto, Ontario].



Figure 3.18: Site Documentation.

Emergent Architecture: A Resurgence of Natural 'Beauty'.

A Closing Word from the Author.

*Architecture is designed for humanity, infused with the facility to increase the human consciousness of its existence in time. With the severe 'intoxication' resulting from the haste of modern life, the rate of consumption and destruction is generating a **collective fear** of impending global destruction. Yet, until the natural environment is transformed into a commodity for financial gain, the importance of sustaining the equilibrium linking the built and the natural will continue to reside ancillary to the infatuation with material and economic profit. In addition to immediate utilitarian obligation, architecture is the signification, materialization, and realization of the principles that pervade life, expressing the quest for '**beauty**', unity, and perfection. Architecture is an expression and reflection of the energy, inspiration, invention, and imagination that enliven the 'everydayness' of human existence. Originating from the Greek '**archi**', meaning 'first' [original] and '**tect**', the generation of form through assemblage,⁹⁴ architecture is infused with the facility and responsibility to influence change in the world – guiding humanity in the direction of restoring a lasting equilibrium within the natural and the built through the assemblage of a **progressive, adaptive, dynamic, and unified [sustainable]** future.*

Appendix 1: Evolutionary vs. Conventional.

Evolutionary.

Conventional.

Human beings are caretakers of one another and of all living things.

Concerned with self-acquisition motivated by greed and preoccupied with conventional image-making.

**Feels accountable to conserving energy and materials.
Seeks to do more with less.**

Convenience is paramount. Spawns the "out-of sight, out-of mind" mentality. Not concerned with consequences, only seeking immediate gain.

Perceives present and future as a continual, evolving process and seeks to implement nature-based technologies for human benefit. Encourages architectural innovation as a necessary process toward achieving ultimate efficiency of structure and habitat.

Seeks exploitation of materials and methods with the greatest immediate gain. Views architecture and the natural environment as a collection of historical idioms, styles and familiar images to be reiterated in accordance with personal taste.

Nature and technology are one to the mutual benefit of both and natural processes are integral with public consciousness.

Technology is meant to make nature "subservient" to be exploited to create an unnecessary consumer need.

**Committed to educating everyone about design and the workings of nature. Everyone can be an "expert".
Genius is common, not uncommon.**

Assumes every human endeavor requires specialized knowledge and expertise, creating an exclusive vocabulary that alienates and codifies communication.

All living things are interconnected and sustained by their relatedness with one another.

*Things exist independently of one another.
Actions in one area have no consequences in another area.*

Uses the intelligence of nature as a design directive and integrates natural phenomena and processes as an essential aspect of the resultant design.

*Architecture is a "machine for living".
Nature is ancillary.
The environment must be controlled and made comfortable through familiarity and convenience.*

Works by interdisciplinary means to achieve a comprehensive understanding of a given challenge.

Seeks the answers to a problem that may not be found within the immediate field of observation.

*Circumscribed by familiar materials and means.
Seeks answers by specialization.
Moves in the realm of the known.
Dares not to go too "far ahead".*

Adapts to local conditions and resources and implements available and labour, using natural diversity as a means to conserve energy and create the most efficient structure and environmental relationship.

Uses easily obtainable standardized equipment materials to create self-imposed environments, disregarding high-energy consumption and inefficient output.

Considers indigenous historical practices, lifestyles, values and technologies as a basis for current problem-solving and design development.

*The making of places as predetermined images based on present-day standards, fashions and trends.
Asserts intellectual design rationale.*

**Nature is a resource of universal principles devoid of nationalistic, religious, political and symbolic associations.
The resultant architecture is countenanced by timelessness and originality.**

Building as symbol, as political statement, as religious icon, contributing to the psychological division of humanity.

Considers the total energy input and output of materials and labour and attempts to create economical solutions of energy conservation.

*Materials and labour are chosen through standard means.
How a material is produced and the amount of energy expenditure per product is irrelevant.
Unit cost and per-diem labour wages are the primary concern.*

**Maximizes structural and ecological efficiency.
Seeks the root causes of problems and attempts to implement long-term solutions.**

*Responds symptomatically to a given problem.
Rampant [extensive] use of toxic substances to "combat" short-term problems.
Pesticides, nuclear waste and untreated sewage are typical by-products.*

**Finds ways to let nature contribute in solving small- and large-scale problems.
Restorative process proceeds from nature-based technologies.**

*Human intellect is primary method of problem-solving.
Nature not considered as a design partner.
Achieving immediate results a design goal - people and nature a secondary concern. Image is primary motivation.*

**Renewable and regenerative biological processes considered as basis for materials and energy sources.
Waste products used as food sources.**

Materials acquired from standard industry methods.
Excessive waste of materials an assumed consequence.
Degenerative materials is thrown away – used as landfill.
Fossil fuels unable to be reabsorbed in a food chain.

Design “mistakes” used as possible catalyst in developing new concepts.

Design imagination infused with biological processes. Human intent and purpose in communication with nature's organic directives – a complementary association. Human intention develops from insights into the workings of natural phenomena. Humanity works with nature.

Design process predetermined and rigid. Man is meant to render nature subservient to human “ingenuity”. Nature's bounty at the whim of human needs and desires. Humanity and nature at odds. The “we don't need nature” attitude in design takes root.

Interdisciplinary experience crucial to insightful understanding of the healthy use of technology and development of human values. Skill in different fields a prerequisite for design ability. The well-rounded human being evolves.

Design is seen as a singular pursuit.
Skill and experience in other fields are irrelevant.
The specialist mentality abounds.
The specialist human being evolves.

See design as a moral imperative; use knowledge from visible and invisible forces at work in nature. People relationships and education an underlying commitment.

See design as “consumer service business” with a “bottom-line” mentality [attitude].
Architecture as commodity and utilitarian shelter expressed by tradition-acceptable image.

Uses plants and organic matter as environment cleansing devices. Sees living organisms as technologically useful tools. Lets nature be a tool for restoring damaged environments.

Assumes machine technology the only practical means of creating and restoring living habitats.

Innate curiosity to question and analyze; seek solutions at multiple levels – social, environmental, emotional and psychological – a mutual deepening of human understanding.

Self-expression and financial gain; distinctively fitting in to accepted social and aesthetic paradigms.
Comfort and convenience.

Independence, energy conservation, risk-taking imagination, exploration of the unknown, strengthening of human dignity, insight and understanding.

Conforming through acceptance. Economic gain as basis of success, living things as commodities to be bought and sold for personal profit.

Long-term education and relationship development; biosocial Evolution and increased comprehension of natural phenomena And their application to everyday life. Life as adventure. Acknowledgment of human ingenuity and spiritual fortitude.

Short-term cost and material benefit.

Life is a series of checks and balances to be maintained and endured; safety, economic and psychological security an unspoken need.

Capacity to buy a requisite to the "good life".

Comprehensive research of site, eco-biological systems, technologies and educating people about design possibilities; safety, structure and energy efficiency significant issues.

Design circumscribed by rectilinear assumptions. Little or no research in alternative materials and methods of construction. Exploration of structural form rarely considered.

Design process is multidisciplinary and comprehensive. Continuous questioning and willingness to find a better way characterizes the process of design and construction through to completion.

Linear, check-off list approach; predetermined stylistic formula applied to building program. Little or no research or inquisitiveness [criticality].

Design through to completed building a premeditated [deliberate] procedure.

Greater understanding of natural relationships and the possibilities of structural form, construction materials and means; increased sense of ecological responsibility and interdependence; strengthened commitment to beneficial social and educational change.

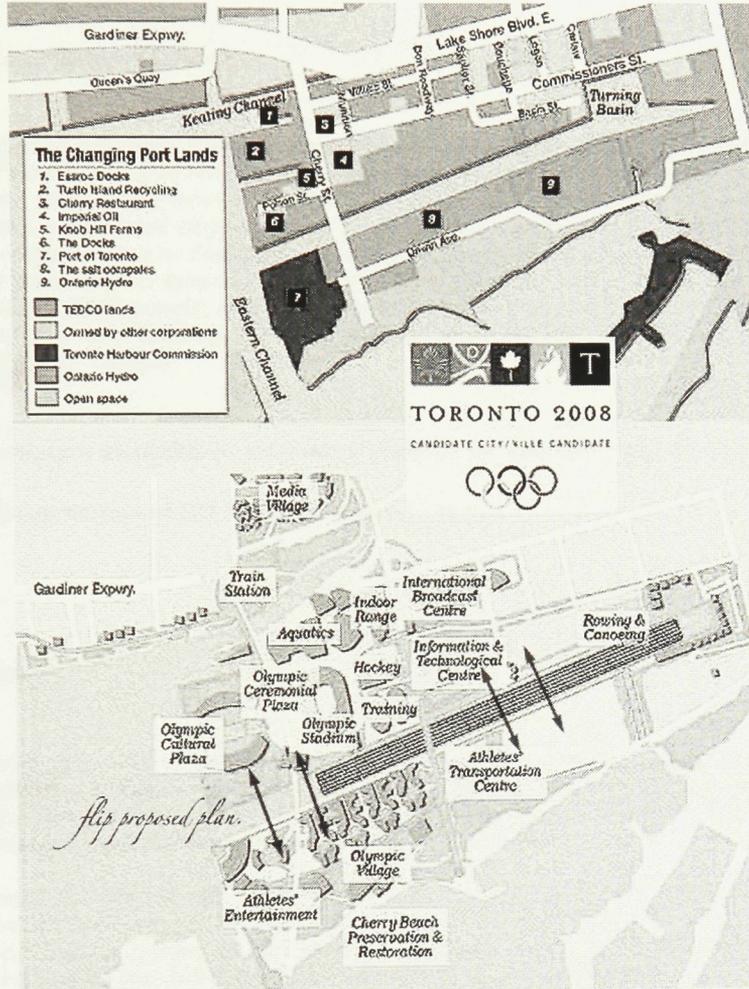
Continuation of traditional means and methods of construction; eclectic appearances and forms dictated by historically accepted styles; architecture as assertion of "man over nature" apparent. Architecture first - humanity second.

Understanding of design as genuine expression of nature-based principles related directly to raising the human condition through reconstructed education and a new attitude of design practice. Long-term, generational goals of strengthening human and interdependency.

Continued fragmentation of individual/societal relationships; consumerism an overriding force; dangerous levels of natural resources rampantly consumed; architecture for profit vastly outweighs architecture as expression of nature and humanity.

[excerpt from - Evolutionary Architecture: Nature as a Basis for Design, Eugene Tsui]

Appendix 2: Olympic Complex 2008.



Suggested Olympic Complex 2008 [Toronto].

[image from - fyitoronto.com/generic6.shtml]

Appendix 3: Sustainable technology.

ETFE [ethylene tetrafluoroethylene]

Ethylene Tetra Fluoro Ethylene [ETFE] material known as 'Texlon' certainly has the potential to revolutionise the way large-span roofs are put together. The sizes of the structural members at **Eden**, for example, would have been prohibitively large to support a traditional glazing solution and transparent plastics would have degraded and could not have supported the geometries involved. Traditional rigid-edge roofing or cladding has its weak points at the edges, whereas in the Texlon panel system the movement is taken up within the **ETFE** material itself. This article looks at the physical properties of **ETFE** panels; strength, weight and toughness, light transmission qualities, resistance to wind and snow loading, U-values and sound insulation. The article also gives technical details about **ETFE** and 'Texlon'.

[additional information available in architects' journal. 14 February (pg. 36-39)]

[www.greenconstruction.co.uk/Archive/RoundUp37.htm]

ETFE Foil Cushions

ETFE foil cushions consist of a cushion of air held between layers of the material **ETFE [ethylene tetrafluoroethylene]**, a polymeric material related to **Teflon**. It has been used in a growing number of buildings in the last ten years, from tennis centres to hospitals as well as in a large number of recently completed lottery-funded projects.

In order to develop an understanding of the potential benefits and disadvantages of the use of **ETFE foil cushions**, basic properties of the material have been analysed, data has been gathered about the production process, and a comparison has been made with its main rival: glass. Work shows that **ETFE** can be a very useful material for use in the right circumstances, especially overhead sky-light/atria situations, where its low weight, good thermal properties and high solar radiation transmission including light transparency, are of most value.

A swimming pool roof is an ideal application, but glass may offer better characteristics where clear vision is required, or damage is likely from people.

[architects' journal - www.ajplus.co.uk/buro_happold/patterns4/]

ETFE is strong, as well as light - the foil is one per cent of the weight of glass, but can take 400 times its own weight. This gave scope for considerably larger areas clad with **ETFE** than glazing would have allowed, with the largest hexagons measuring 11 m from point to point [**project Eden**]. At the same time, the foil lets in a plantfriendly 97 per cent of UV light. **ETFE** has impeccable green credentials: it is recyclable and because it is so slippery it is, in effect, self-cleansing.

[architects' journal - www.ajplus.co.uk/eden/building/]

ETFE Detailed Properties
[Ethylene Tetrafluoroethylene]

The table below lists a generally accepted summary of properties that we [texloc] believe to be reliable – please note that many of these resins are produced in several varieties and property characteristics may vary. Therefore, determination of resin is dependent on the application and this table is only meant to serve as a general guideline.

Properties	ASTM or Unit	ETFE
MECHANICAL PROPERTIES		
Specific Gravity	D792	1.74
Elongation %	D638	420~460
Tensile Strength (psi)	D638	6,100~6,800
Flexural Strength (psi)	D790	5,500
Compressive Strength	D695	2,500
Tensile Elastic Modulus (Young's Modulus) (psi)	D638	85,000~95,000
	D790	128,000~171,000
Flexural Modulus 103MPa (103kgf/cm²)	D790	0.9~1.4 (9.0~14.0)
Flex Life (MIT cycles)	D2176	10,000~27,000
Hardness Durometer Shore D	D636	D75
Coefficient of Friction	on steel	0.06
Abrasion Resistance 1000 revs.	taber	n.a
Impact Strength IZOD 73°F/23°C, notched ft/lbs/in	D256	no break
THERMAL PROPERTIES		
Melting Point	°C	267
	(°F)	(512)
Upper Service Temperature (20,000h)	°C	150
	(°F)	(302)
Flame Rating**	UL 94	V-0
Thermal Conductivity	BTU/hr/ft ² /deg F in cal/sec/cm ² ,°C/cm	1.65 5.7 x 10 ⁻⁴
Linear Coefficient of Thermal Expansion 10-5 °C	D696	13
Heat of Fusion	BTU/LB	20
Heat of Combustion	BTU/LB	8100
Low Temperature Embrittlement	°C	-100
	(°F)	(-148)
ELECTRICAL PROPERTIES		
Dielectric Constant	D150/103Hz	2.6
	D150/106Hz	2.6
Dielectric Strength 10 mil film	D149	1600

Volume Resistivity ohm-cm	D257	>10 ¹⁶
Surface Resistivity ohm/sq.	D257	>10 ¹⁵

GENERAL PROPERTIES

Chemical/Solvent Resistance	D543	Excellent
Water Absorption, 24h	%	<0.03
Deformation Under Load	*D621/100°C	5.4
	**D621/25°C	2.3
Refractive Index		1.40
Limiting Oxygen Index Properties	>95 ASTM or Unit	31 ETFE

[www.texloc.com/closet/cl_etfe_properties.htm]

As well as being strong, lightweight, anti static, and highly transparent to UV light it is not degraded by sunlight, has better insulation properties than glass, and is **recyclable**.

- *ETFE weighs less than 1 % of the equivalent sized pane of glass, needs less steel to hold it up and lets more light through*
- *ETFE is recyclable and long lasting with a life span of over 25 years*
- *ETFE is tough. A single inflated pillow can take the weight of a rugby team*
- *ETFE is non-stick and therefore self cleaning*

[www.edenproject.com/3440_3472.htm]

ETFE membrane

High grade films for air-supported roof or facade modules, double or multi-layer system for insulation, self-cleaning, lowest fire load, self-extinguishing, hail-resistant, clear or white, limited colour possibilities, light transmission up to 90 %, life expectancy over 20 years

[www.skyspan.com/07_material.html]

ETFE [ethylene tetrafluoroethylene] is a fluorine-based transparent plastic that works as a sort of puffer jacket for buildings, and is a lightweight alternative to glass. It allows architects to escape the weight of steel, glass, stone and concrete.

Its first major public outings are spectacular. Like Sunday supplement spreads of science's latest discoveries, the **Leicester National Space Centre** and the **Eden Project**, both scheduled to open mid-year, and the **Air Pavilion** at the **Magna Science Adventure Centre in Rotherham**, which opened this month all have the cellular structure of biological magnifications – blood cells, flies' eyes, and tortoise shells.

As a cheap alternative to glass for covered streets, office-building atriums, shopping centres and leisure parks, it could spread like an umbrella in rainy climates.

ETFE is put together in sections of transparent inflated pillows. Its weight is 1 % that of glass, it transmits 15 % more light, has the thermal properties of triple glazing and costs a quarter to half less to install than glass.

It has been available since the early 1980s, but architects have not until now had the confidence that it would prove durable. Installed in Centreparcs leisure centres in the UK, its life expectancy originally estimated at 10 years is now put at 50 years – double glazing, which is only as durable as its silicone seals, gives out in less than 20 years.

*A researcher at **DuPont** originally discovered **Teflon**, from which **ETFE** was developed, by accident in 1938. While researching refrigerants, he found that he was unable to dissolve or burn this new substance. It was immediately taken up in the war effort, coating wires and lining tanks against chemical corrosion. A 'foil' version, **ETFE**, was developed by the mid-1980s to provide the mechanical strength **Teflon** lacks.*

[www.sapoonline.co.za/news/article.aspx?idArticle=985]

Note: PV technology is an example of an environmentally sustainable construction innovation that could be utilized in present architectural design. However, with the high cost and problematic and toxic disposal and recycling dilemma, I have decided not to apply this technology to the proposed stadium. Yet, it is important to keep this system in mind as it could be added to the structure in the future. With the continuing research and development of environmental sustainable technology [example: PV], solutions to the present dilemmas are bound to emerge.

PHOTOVOLTAIC technology

***Photovoltaic technology [PV]** is today a popular part of the building vocabulary. It can be used on both existing and new buildings. Its use in the building envelope is very varied and open ways for creative designers. In particular semitransparent **photovoltaic glass** modules can be changed into a truly multifunctional building component which is able to serve in addition to an electricity production other functions of the building envelope as well. Such synergy effects of a photovoltaic module only turn out to be successful if its integration in the building fabric is carefully understood and the **photovoltaic** is fully integrated into the overall design and energy concept of a building. Presently in particular non-technical barriers still need to be solved to allow an intelligent and wide spread application of **photovoltaic** in the built environment.*

*There is an increasing awareness about the destruction of the natural environment and a growing concern about the quality of the built environment. In the center of interest of necessary changes is the building envelope – the rise of new technological developments allows for completely different visions of a conventional facade or roof. With respect to the multi-functionalism of the building envelope it is more and more necessary to make use of different **active** and **passive solar** techniques. One solar technique, which is increasingly becoming an important part of the building vocabulary, is the **photovoltaic [=PV]**.*

*A **photovoltaic** module is basically a covering material, which has the added value that given the right conditions it can produce electricity during certain periods of the day – the production of electricity may be considered thus a bonus to this unique exterior building material.*

[In addition] roofs are ideally suited for **photovoltaic integration** – there is usually less shadowing effects at roof heights than at ground level and a roof usually provides a large unused surface for integration.

[www.nesea.org/buildings/images/paper%20Hagemann%20Solar%20Conference%20USA%202001.htm]

- Initially developed for the space program over 30 years ago, **PV**, like a fuel cell, relies upon chemical reactions to generate electricity. **PV** cells are small, square shaped semiconductors manufactured in thin film layers from silicon and other conductive materials. When sunlight strikes the **PV** cell, chemical reactions release electrons, generating electric current. The small current from individual **PV** cells, which are installed in modules, can power individual homes and businesses or can be plugged into the bulk electricity grid.

PV systems operate without producing air, water or solid wastes.

When constructed as grid-connected central station systems, they require significant land, which can impact existing ecosystems. Nevertheless, most **PV** installations come in the form of distributed systems that use little or no land since the panels are installed on buildings.

Manufacturing **PV** cells involves the generation of some hazardous materials. Nonetheless, appropriate handling of these small quantities of hazardous material reduces risks of exposure to humans and to the environment.

Like **PV**, solar-thermal technologies generate zero air emissions, though some emissions are created during the manufacture of both technologies.

[www.powerscorecard.org/tech_detail.cfm?resource_id=9]

Sunlight is converted to electricity using photovoltaic or solar cells – **photovoltaic [PV]** cells are semiconductor devices, usually made of silicon, which contain no liquids, corrosive chemicals or moving parts. They produce electricity as long as light shines on them, they require little maintenance, do not pollute and they operate silently, making **photovoltaic energy** the cleanest and safest method of power generation.

Photovoltaic cells and modules

Photovoltaic cells come in many sizes, but most are 10 cm by 10 cm and generate about half a volt of electricity. **PV** cells are bundled together in modules or panels to produce higher voltages and increased power. A 12-volt module, for example, depending on its power output, could have 30 to 40 **PV** cells. A module producing 50 watts of power measures approximately 40 cm by 100 cm. **PV** panels are not highly efficient, converting only 12 to 15 per cent of the sun's light into electricity, but laboratory prototypes are reaching 30 per cent efficiency.

PV modules generate direct current [DC], the kind of electricity produced by batteries. Although incandescent lights can operate on DC, most electric devices require 120-volt alternating current [AC] as supplied by utilities. A device known as an inverter converts DC to AC current. Inverters vary in size and in the quality of electricity they supply. Less expensive inverters are suitable for simple loads, such as lights and water pumps, but models with good quality waveform output are needed to power electronic devices such as televisions, stereos, microwave ovens and computers.

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[www.solarenergysociety.ca/2003/photovoltaic.asp]

Benefits/Costs

PV roofing products provide environmental benefits because they do not produce pollution or carbon dioxide emissions like fossil fuel-based utility power – they are also more attractive than many other solar systems, which increases consumer acceptance.

Expected cost of electricity produced from a PV system is equal to about 25 to 50 cents per kilowatt-hour [kWh] when considering initial cost spread over the lifetime of the system, plus maintenance costs. This compares with an average rate of about 8 cents per kWh for utility supplied power [utility rates can range from anywhere between 6–17 cents and peak rates can be over 20 cents per kWh in the United States].

Homes not in proximity of electric power lines, PV systems may be less costly than extending power lines to the home. Unlike generators, they operate silently and require little maintenance.

[www.toolbase.org/tertiaryT.asp?TrackID=1472&DocumentID=2143]

History of PV development

Until some twenty-five years ago, PV was mainly known as an energy source for satellites. After the first oil price shock, in the early 1970s, interest grew in the use of PV for terrestrial applications, and national and international investments in research and development, demonstration and dissemination have led to important technical improvements and a drop in the price of PV modules by a factor of more than 20.

PV power generation is now economically competitive for loads of up to a few kW in many remote sites away from the mains electricity grid, and interest is growing world-wide in the development of grid connected PV power generation. Of particular interest is the integration of PV modules into buildings, where they can act not only as power generators, but also as architectural building cladding elements. In this way, PV module costs can be offset against the costs of the cladding which they replace, resulting in a reduction in the costs of PV electricity.

The PV cell and module manufacturing industry is currently dominated by major international companies, including utilities and oil companies, and programmes to develop and promote PV technology are supported by both national and international funding agencies – the long term prospects for PV power generation are widely considered to be encouraging.

[europa.eu.int/comm./energy_transport/atlas/htmlu/pvint.html]

PV Panel Disposal and Recycling

Due to the fact that some toxic chemicals are used in making PV panels, disposal at the end of their useful life is another potential environmental issue – presently only a small volume of PV panels are disposed of each year, so this is currently a minor issue. But the industry is already looking ahead toward recycling methods for future PV panels.

Of course, no form of energy production is completely free of effects on the environment. As with any consumer product, the raw materials for PV systems must be shipped to factories, and completed products must be shipped from factories to consumers. In many cases, components may also be shipped from one factory to another for assembly – transporting PV materials, components, and final products uses some energy and produces some air pollution and greenhouse gases, in addition to contributing slightly to traffic and noise problems.

Some energy is also used in manufacturing PV systems. However, efforts to minimize manufacturing costs and increase output are also reducing the amount of energy used to manufacture each PV system.

[www.nrel.gov/ncpv/pvmenu.cgi?site=ncpv&idx=3&body=infores.html]

Note: With water becoming decreasingly abundant and the largest source of waste, I have decided to utilize a rainwater harvesting system within the proposed stadium. Since stadia are generally completely covered by a large roof structure, harvesting rainwater is an optimal energy-free and sustainable system of minimizing the waste of ground and purified water. In addition, I plan to apply water conservation methods [illustrated below] to help minimize the unnecessary waste.

What is graywater?

Any water that has been used in the home, except water from toilets, is called graywater – dish, shower, sink and laundry water comprise 50–80 % of residential "waste" water. This may be reused for other purposes, especially landscape irrigation.

Why use graywater?

Unlike a lot of ecological stopgap measures, graywater use is a part of the fundamental solution to many ecological problems and will probably remain essentially unchanged in the distant future. The benefits of graywater recycling include:

- *Lower fresh water use*
- *Less strain on septic tank or treatment plant*
- *Highly effective purification*
- *Less energy and chemical use*
- *Groundwater recharge*
- *Plant growth*
- *Reclamation of otherwise wasted nutrients*

[previous page – www.greywater.net/]

Recycling [Grey]Water

Water purity is also important. Chemical and microbial contaminants make it unappetizing or unhealthy, and it can clog complicated fluid systems. The **Aerobic Rotational Membrane System [ARMS]** research project at **NASA's Kennedy Space Center [KSC]**, Florida, may help. "We're trying to move toward a biological treatment method using bacteria to help cleanse the water," said Tony Rector, Dynamac Corporation bioprocess engineer at KSC. The KSC prototype shop fabricated a model of the system. It is being tested inside KSC's Space Life Sciences Laboratory, and Rector and colleagues designed it.

At **NASA's Ames Research Center [ARC]**, Moffett Field, California, a water recycler enabling reuse for three years without resupply is being developed on a timeline to fit into exploration plans, according to ARC scientist Michael Flynn. A preliminary engineering development unit can hourly recycle 13.2 pounds, about one gallon, of waste into drinkable water.

Many of these recycling technologies may have earth-based uses. NASA is working with the Expeditionary Unit Water Purification Program of the U.S. Office of Naval Research and Bureau of Reclamation to explore ways to use recycling in remote locations.

[www.sciencedaily.com/releases/2004/11/041114233648.htm]

What is the Future of Water Recycling?

While recycling is a term generally applied to aluminum cans, glass bottles, and newspapers, water can be recycled as well. Water recycling is reusing treated wastewater for beneficial purposes such as agricultural and landscape irrigation, industrial processes, toilet flushing, and replenishing a ground water basin – referred to as ground water recharge. Water is sometimes recycled and reused onsite; for example, when an industrial facility recycles water used for cooling processes. A common type of recycled water is water that has been reclaimed from municipal wastewater, or sewage. The term water recycling is generally used synonymously with water reclamation and water reuse.

Water recycling has proven to be effective and successful in creating a new and reliable water supply, while not compromising public health. Nonpotable reuse is a widely accepted practice that will continue to grow. However, in many parts of the United States, the uses of recycled water are expanding in order to accommodate the needs of the environment and growing water supply demands. Advances in wastewater treatment technology and health studies of indirect potable reuse have led many to predict that planned indirect potable reuse will soon become more common.

While water recycling is a sustainable approach and can be cost-effective in the long term, the treatment of wastewater for reuse and the installation of distribution systems can be initially expensive compared to such water supply alternatives as imported water or ground water. Institutional barriers, as well as varying agency priorities, can make it difficult to implement water-recycling projects. Finally, early in the planning process, agencies must implement public outreach to address any concerns and to keep the public involved in the planning process.

As water demands and environmental needs grow, water recycling will play a greater role in our overall water supply. By working together to overcome obstacles, water recycling, along with water conservation, can help us to conserve and sustainably manage our vital water resources.

[www.epa.gov/region9/water/recycling/]

Water conservation methods:

- **Toilets**

- _ Low flush toilets
- _ Dual flush toilets [3/6 litres]
- _ Vacuum or compressed air toilets
- _ Cistern displacement devices
- _ Waterless toilets
- _ Composting toilets [heated or unheated]
- _ Incinerating toilets

- **Urinals**

- _ Urinal controls [infrared, radar, autoflush]
- _ Waterless urinals

- **Wash Hand Basins**

- _ Push taps
- _ Flow control, self closing
- _ Tap flow regulators

- **Showers**

- _ Shower mixers
- _ Water saving showerheads
- _ Self closing shower system

- **Water Supply**

- _ Auto shut off and pressure regulators

- **Rain Water and Grey Water**

- _ Rain water recycling systems
- _ Grey water recycling systems

[www.arch.hku.hk/research/BEER/sustain.htm#3.3]

Rainwater harvesting systems can be as simple as directing gutters to a lidded garbage can or as complex as a concrete cistern, roof washer and filtration system. But whatever your application, rest assured that you'll be getting some of the purest – and cheapest – water around.

Why Rainwater?

Rainwater can be used for potable water (drinking, cooking, bathing) or nonpotable uses such as landscape irrigation, livestock watering and washing. Collecting and using rainwater has numerous benefits, ranging from improved water quality to reduced stress on underground aquifers.

Rainwater percolates through the earth and rocks, where it picks up minerals and salts. Captured before it hits the ground, rainwater is free of many pollutants that plague surface and underground water supplies and, according to the Texas Water Development Board, "almost always exceeds [the quality] of ground or surface water." Rainwater typically has very low hardness levels, which reduces the use of soaps and detergents, and eliminates the need for a water softener. Fewer minerals also saves wear and tear on your plumbing fixtures.

Stored rainwater also is a good standby in times of emergencies such as power outages or during periods of extreme drought when wells dry up. In some areas where water supplies may not be available or dependable (or may be prohibitively expensive), collected rainwater is sometimes the least expensive option and can easily be less expensive than bottled water. Rainwater harvesting reduces the impact on aquifers, lessening the demand on ecologically sensitive or threatened aquifers. Collecting some of the rainwater falling on impervious surfaces also minimizes erosion and flooding: On some lots, as much as 50 percent of the land area is covered by roof surface.

Because it doesn't have to be treated, pumped or distributed through a complex network, harvested rainwater saves energy and the use of chemicals. Some municipal water users sometimes switch to harvested rainwater as a way to avoid chlorination and fluoridation treatments.

Between rainstorms, various pollutants can settle out of the air and onto your roof. Many rainwater harvesting systems incorporate a roof washer to keep these contaminants from entering the cistern – capturing and discarding the first several gallons of rainwater during a storm before conveying the rest to the cistern.

[www.motherearthnews.com/index/php?page=rec&id=2050]

What is Rainwater Harvesting and Why is it Important?

Water is our most precious natural resource and something that most of us take for granted. We are now increasingly becoming aware of the importance of water to our survival and its limited supply, especially in such a dry continent as Australia.

The harvesting of rainwater simply involves the collection of water from surfaces on which rain falls, and subsequently storing this water for later use. Normally water is collected from the roofs of buildings and stored in rainwater tanks. This is very common in rural Australia. Water can also be collected in dams from rain falling on the ground and producing runoff. Either way, the water collected can be considered to be precious.

The collection of rainwater from the roofs of buildings can easily take place within our cities and towns, not just in rural Australia. All that is necessary to capture this water is to direct the flow of rainwater from roof gutters to a rainwater storage tank. By doing this, water can be collected and used for various uses. If you are reliant on collected rainwater and are not connected to a town's water supply, then the water collected will be especially important to you. If you are from the city, then it is possible to replace all or at least a substantial portion of your fresh water requirements by the capture and storage of rainwater from your roof. Being largely self sufficient in water supply is possible for a vast majority of Australian households and buildings.

What are the Benefits in Rainwater Harvesting?

By capturing water directly, we can significantly reduce our reliance on water storage dams. This places less stress on these water storages and can potentially reduce the need to expand these dams or build new ones.

Collecting and using your own water can also significantly reduce your water bills.

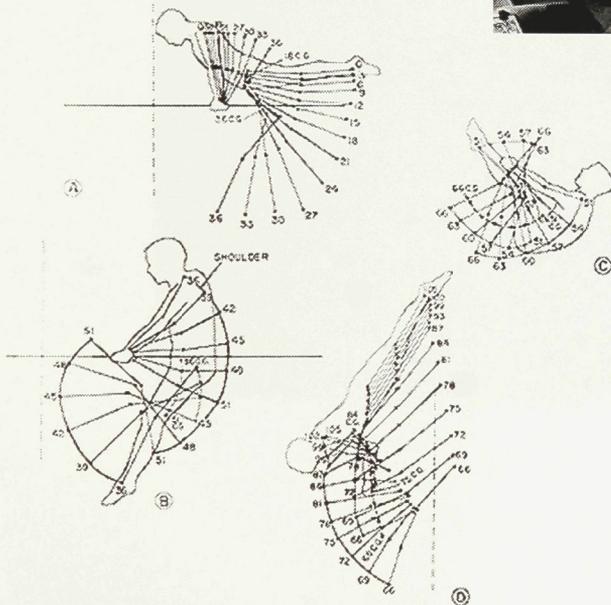
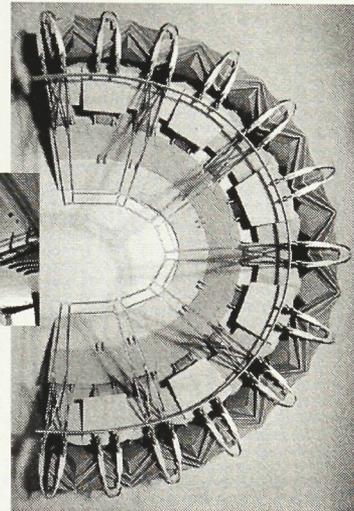
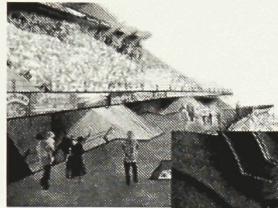
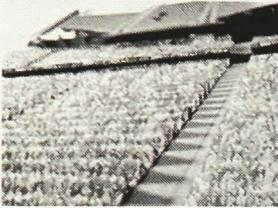
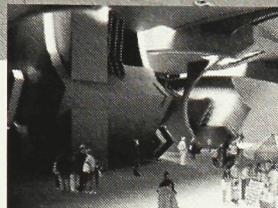
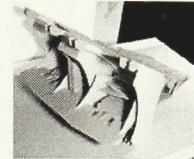
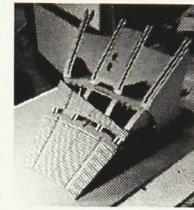
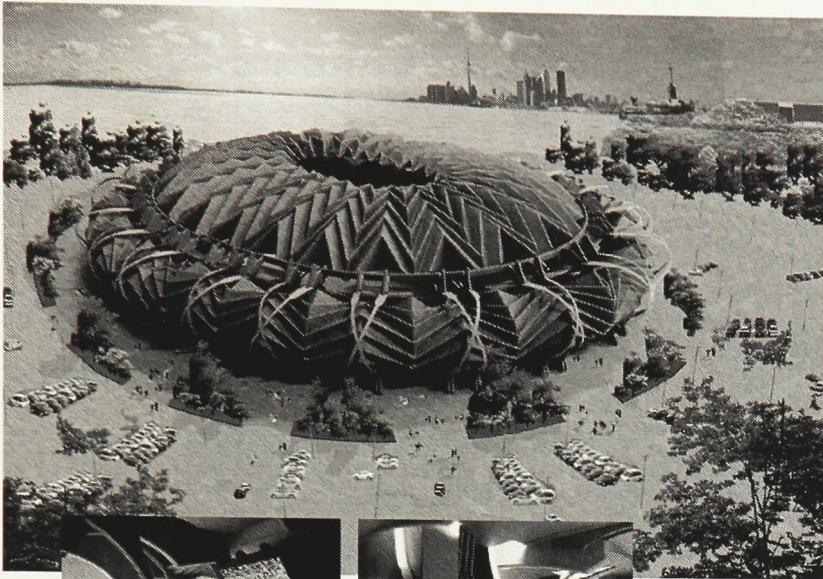
By capturing water, the flow of stormwater is also reduced and this minimizes the likelihood of overloading the stormwater systems in our neighbourhoods.

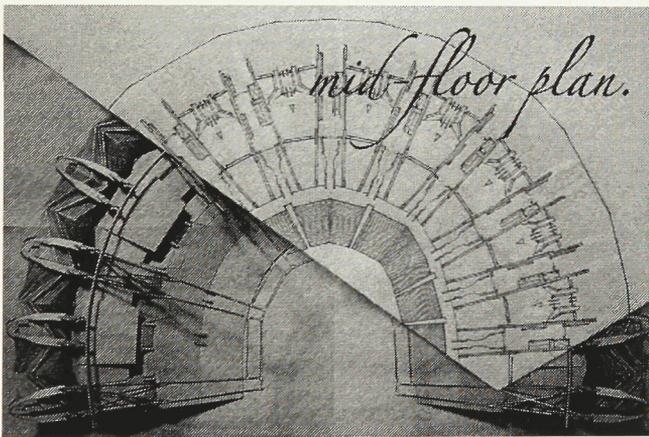
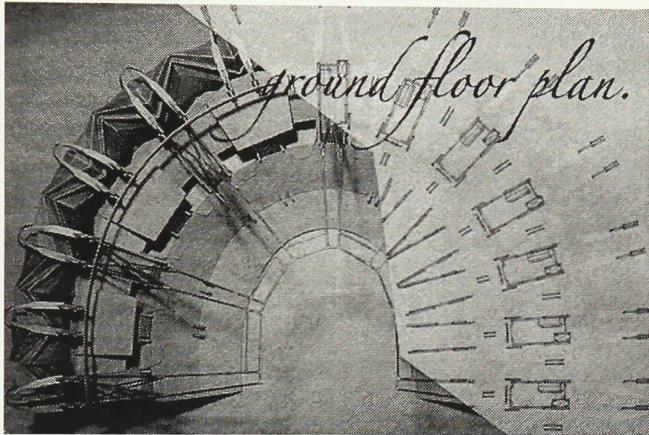
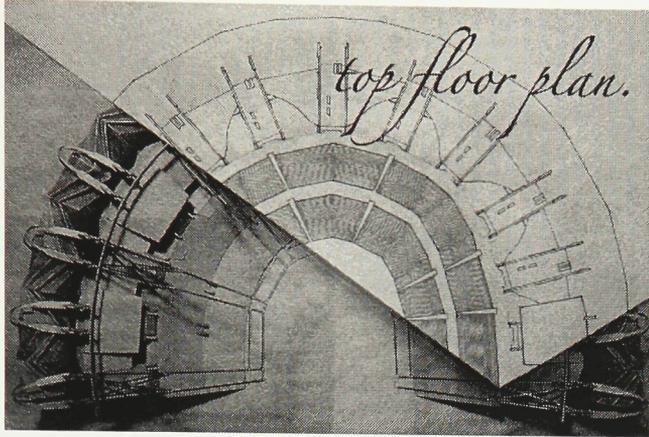
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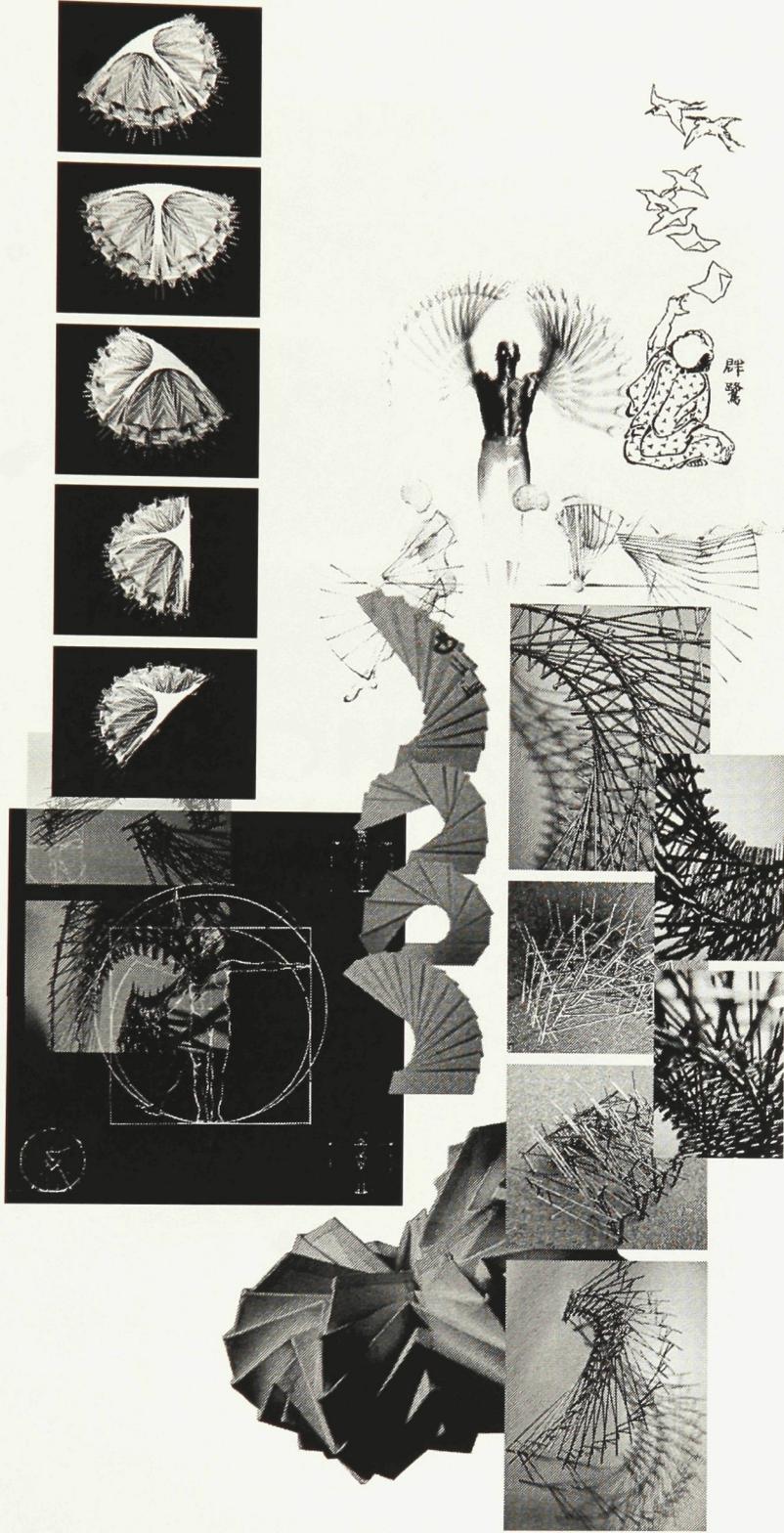
Appendix 4: Additional documentation.

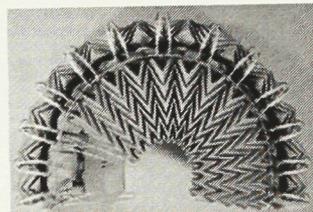
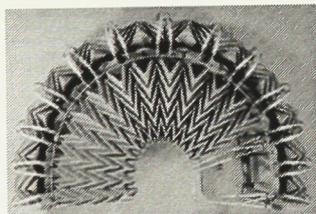
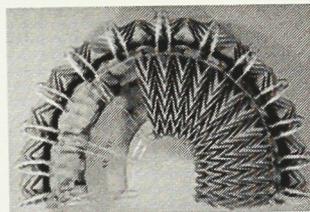
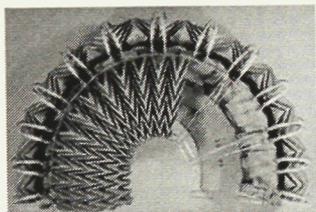
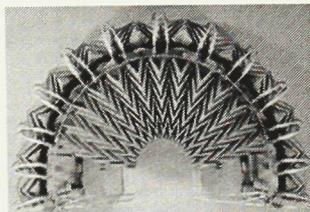
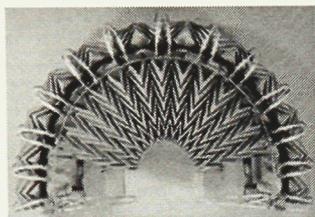
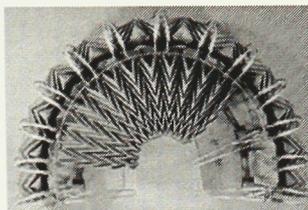
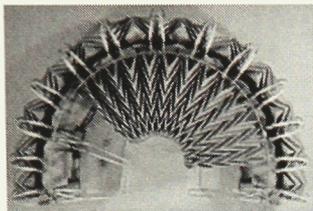
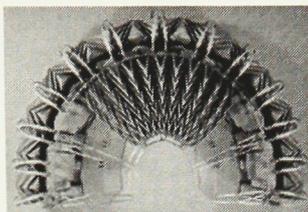
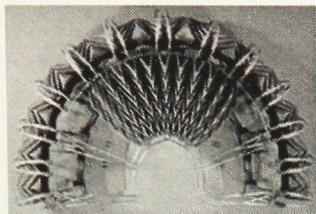
*Additional documentation illustrating the stages
of the design process.*



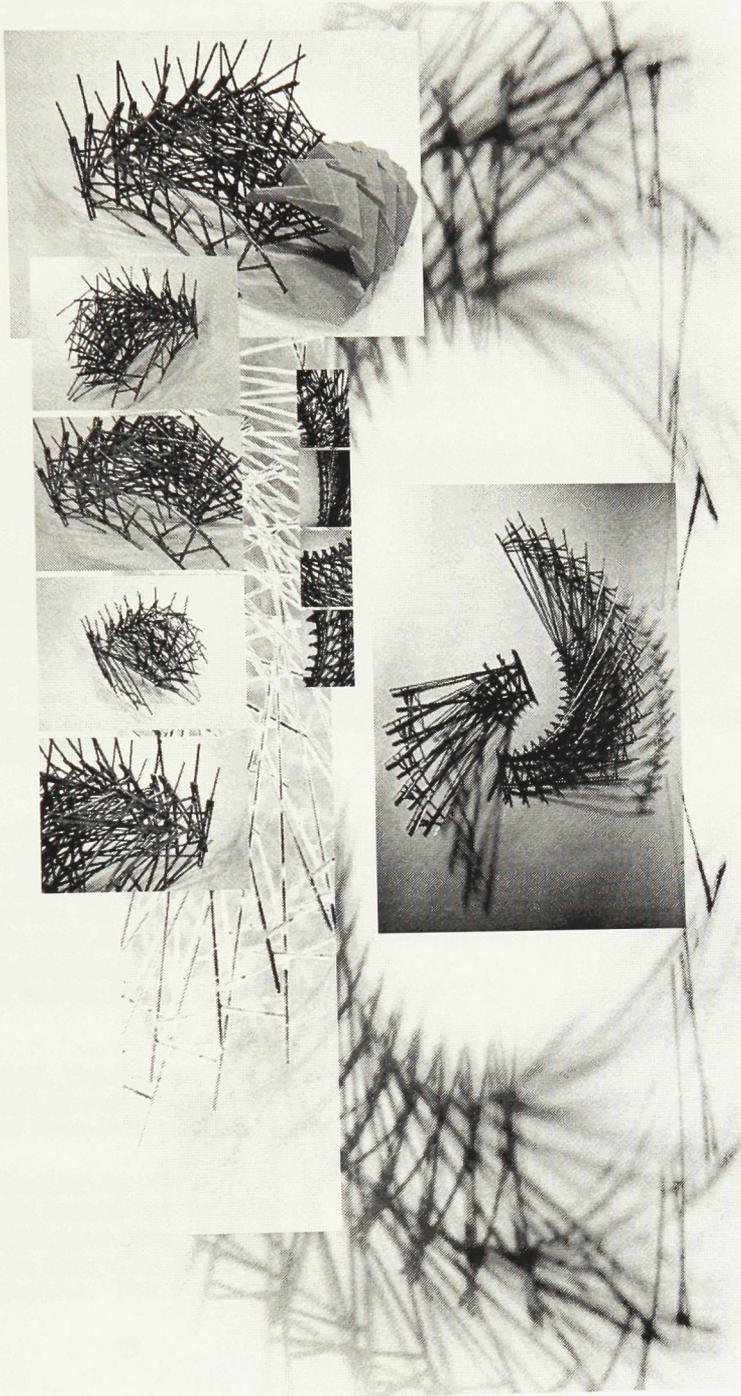












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- ⁶⁸ Okakura Kakuzo, The Book of Tea, pg. 72-80.
- ⁶⁹ Peter Engel, Origami: from Angelfish to Zen, pg. 34.
- ⁷⁰ D'arcy Wentworth Thompson, On Growth and Form: Volume II.
- ⁷¹ Peter Engel, Origami: from Angelfish to Zen, pg. 56.
- ⁷² Alexander Tzonis, Santiago Calatrava: The Poetics of Movement, pg. 12.

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- ⁷⁴ Hegel, G.W.F., On Art, pg. 126.
- ⁷⁵ Jean Baudrillard trans. Brian Singer, Seduction, pg. 57.
- ⁷⁶ Neil Leach, The Anaesthetics of Architecture, pg. 3.
- ⁷⁷ *Ibid*, pg. 75.
- ⁷⁸ Norman Crowe, Nature and the Idea of a Man-Made World: An Investigation into the Evolutionary Roots of Form and Order in the Built Environment, pg. 143.
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- ⁸⁰ *Ibid*, pg. 22.
- ⁸¹ Albert Hofstadter and Richard Kuhns, Philosophies of Art & Beauty: Selected Readings in Aesthetics from Plato to Heidegger, pg. 96.
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- ⁸⁵ *Ibid*, pg. 140.
- ⁸⁶ Norman Crowe, Nature and the Idea of a Man-Made World: An Investigation into the Evolutionary Roots of Form and Order in the Built Environment, pg. 235.

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- ⁸⁷ Frank Lloyd Wright, In the Cause of Architecture.
- ⁸⁸ Norman Crowe, Nature and the Idea of a Man-Made World: An Investigation into the Evolutionary Roots of Form and Order in the Built Environment, pg. 51.
- ⁸⁹ *Ibid*, pg. 98.
- ⁹⁰ Speech given at the University of McGill by Arthur Erickson, October 21st 2000. <www.arthurerickson.com/sp_mcgill.html>
- ⁹¹ Rod Sheard, Sports Architecture, pg. 1.
- ⁹² *Ibid*, pg. 60.
- ⁹³ *Ibid*, pg. 63.

A Closing Word from the Author.

- ⁹³ Eugene Tsui, Evolutionary Architecture: Nature as a Basis for Design, pg. 9.

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