Arboreal Synergy: A Philosophical Exploration of Biomimetic Architecture

by

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A thesis submitted to the Faculty of Graduate and Postdoctoral Affairs in partial
fulfillment of the requirements for the degree of

Master of Architecture

Carleton University

Ottawa, Ontario

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Abstract

Biomimetic architecture as an emergent discipline possesses tremendous potential for techno-ecological synergy, yet it currently lacks the strong philosophical foundation it requires to truly inform the relationship between the built and the natural environments. Synergy in nature is attributed by environmental philosopher Freya Mathews to two fundamental principles of life: conativity and least resistance. In the pursuit of techno-ecological synergy, biomimetic designers need to embrace these concepts and address them through their work as a way of engaging the public. This can only be accomplished through the rejection of the anthropocentric and technological dogmas of modernity in favor of bioinclusivity. While architects and researchers have begun to address this difficult task, an examination of architectural precedents reveals the investigative directions needed in order to advance the field. The philosophical exploration undertaken in this thesis informs a biomimetic design strategy for the actualization of William Commanda's vision for Victoria Island along the Ottawa River. The design of the Asinabka Indigenous Cultural Centre takes inspiration from the site's rich cultural history and reinforces the synergistic potential of biomimicry through the integration of the Indigenous spiritual worldview and its relationship to the land. These concepts culminate in an impressive arboreal structure that embodies interconnectedness and in a lush roof garden that promotes a renewed encounter with nature.

Acknowledgements

I would like to express my sincere gratitude to my supervisor, Prof. Manuel Baez, for his continuous support, his valuable insight and his enthusiasm for this project.

I would also like to extend my thanks to the late William Commanda, whose work and vision have been an immense source of inspiration.

Finally, thank you to my family and friends for their constant encouragements and, in particular, to Steven Schuhmann for all his love, support and patience during this process.

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INTRODUCTION

Since the Industrial Revolution, the ecology of our planet is believed to have deteriorated at an unprecedented rate. The technologies introduced in the last two centuries to facilitate human existence have simultaneously depleted the natural environment and threatened its sustainability. Today, we have reached a critical point: we must reflect on the way we act onto our environment and reinsert ourselves into the interconnected web of living systems that form the biosphere. Designers must not only be concerned with the needs and desires of humankind, but with that of all of nature. Confronted with this problem, many thinkers, such as biologist Janine Benyus, have advanced biomimicry as an alternative approach to design. The discipline is defined as “a new science that studies nature’s models and then imitates or takes inspiration from these designs and processes to solve human problems” (Benyus 2002). Examples of biomimetic design include a metal surface that dynamically responds to its environment in the image of skin (Sung 2012), and a closed loop system of waste management inspired by metabolic processes (McDonough & Braungart 2002).

Biomimicry represents the bioinclusive aspirations of our contemporary society, that is our desire to no longer let the industrial framework enslave nature and to live in a techno-ecological synergy (Benyus 2002) (Mathews 2011). In the context of this thesis, the concept of synergy describes the essence of all enduring relationships occurring within the world: it represents a dynamic state of harmony, a constantly evolving network of entangled relationships that positively contribute to a greater whole (Ingold 2006) (Mathews 2011). Techno-ecological synergy is the state at which the relationship between the technological

agency and the natural living world becomes mutually profitable rather than confrontational.

It is the contention of this thesis that biomimicry, in its current theory and practice, has yet to emancipate itself from the industrial mentality of modernity in order to produce a true techno-ecological synergy. Indeed, the current definition of biomimicry ambiguously retains the postulates of modern industry by carelessly utilizing scientific knowledge without addressing the more profound philosophical implications of its agency. Biomimicry must be reconceptualized in order to grasp the complexity of a symbiotic rapport with the Earth. The information offered by modern science is valuable, however it remains fragmentary and compartmentalized. Indeed, the requirement for objectivity constrains the observer “above and beyond the world [they] claim to understand” (Ingold 2006). Without the possibility of engaging in the world, science remains unable to reveal to the observer the holistic essence of their relationship with the environment. Philosophy, on the other hand, has the ability to provide self-reference by placing the observer within the worldly relational framework. Thus, this thesis attempts to provide a philosophically richer paradigm for biomimicry by exploring the profound ramifications of the emulation of nature.

As an approach to architectural design, biomimicry requires further development because the production of the built environment indirectly shapes the very natural environment that acts as a primary design inspiration. In fact, at this point in time, virtually no place on Earth remains untouched by the human hand. In this context, establishing the essence of nature may be a precarious endeavour:

There is an ontological crisis involved in our ignorance of what the Earth was before we humans altered it. It's hard for us to

establish a comfortable sense of our place in the world when the world itself is so outworn and bedraggled by so many previous human efforts. [...] That's what it's like for a civilization existing in a natural milieu that has been irretrievably damaged. And yes, that is our future. (Sterling 2011)

This existential uneasiness occurs because we cling to an outdated notion of nature as a primordial entity that remains unspoiled and untouched (Mensvoort 2011). Yet, it is quite clear that nature is not a static object: life on Earth has been evolving for 3.8 billion years (Benyus 2002). Right now, nature continues to change along with us humans, just like we also change along with it (Mensvoort 2011). In this sense, humans and nature are essentially comparable and belong to the same dynamic system of interdependent relationships. The philosophy of biomimetic architecture, then, may not only be concerned with descriptive objectives such as resource efficiency and solar power use (Mathews 2011). Rather, it must define the common essence of living beings and provide a sense of our place within this active nature. Only when these concepts have been defined will it become possible to break away from the current pattern of environmental exploitation and harmoniously reinsert ourselves within the symbiotic systems of nature. This thesis will provide concepts that fundamentally describe the biological systems emulated by biomimicry and investigate their implications for architectural design.

CHAPTER 1: BIOMIMICRY AND THE CONTEMPORARY QUEST FOR TECHNO-ECOLOGICAL SYNERGY

1.1. Synergy and the principles of life

The ultimate form of biomimicry is arguably the attainment of technoeological synergy, a state of mutual cooperation between technologically-enabled humans and the rest of nature. Synergistic bonds appear to form instinctively between non-human organisms, yet human societies, especially since the rise of modernity, have been disconnected from this collaborative structure, negligently damaging it. There is hope, however, that if we can understand the modalities of nature, we may be able to integrate the synergistic network of our world. Environmental philosopher Freya Mathews attributes synergy in nature to two fundamental principles of life: conativity and least resistance (Mathews 2011). Both these principles play an important role in maintaining natural synergy.

First, the principle of conativity is described as such: “all living beings and living systems act in accordance with a will or impulse to maintain and increase their own existence” (Mathews 2011). In other words, conativity is the inherent or intentional inclination of a living organism or system towards self-actualization. The behavioral manifestation of this principle is a constant and self-directed effort to persevere within the conditions of a particular environment. A conative failure results in death and extinction, whereas growth and adaptation ensure a successful effort. In this sense, conativity is not a mere property of living systems, but truly their essence: to live is to ceaselessly produce oneself in a changing world (Ingold 2006).

The second principle of nature identified by Mathews is least resistance: “an organism will pursue its [conative] ends in ways that least provoke resistance to its activities” (Mathews 2011). Benyus also hints at this principle when she claims that “Nature uses only the energy it needs” (Benyus 2002). Simply put, living organisms will avoid superfluously wasting their energy. When an effort is necessary in order to preserve their existence, the solution requiring the least amount of work will always be favored. As a result, organisms will minimally disturb the environment and their ecosystem while pursuing their conative ends: “Ways that least provoke resistance are logically likely to be ways that least thwart the conativity of others” (Mathews 2011). Thus, least resistance is a logical principle of life that evolved from necessity.

In light of the “twin principles” of conativity and least resistance, it is possible to understand how synergy is reached in nature. In a synergistic system, organisms collectively follow the path of least resistance in such a way that their conativities are codetermined: entities mutually benefit each other in their striving to maintain their existence and, more importantly, they let the conativities of others shape their own. Such a system is dynamic, always developing in the face of fluctuating environmental conditions:

Synergy is a *recursive* function: Each element of a synergistic system does indeed harness forces or patterns or energy already at play in its environment in order to achieve its conative ends, but its ends are in turn shaped by those forces or patterns. (Mathews 2011)

In other words, synergy is attained in nature through a looping mechanism of conative adaptation. The existence of each organism is shaped by the fluctuations of a larger life system within a particular environment. If biomimetic design is to re-establish humans within the synergistic system of Earth, we must learn to apply the recursive modality of nature to the human agency. Therefore, the true

challenge of biomimicry lies in our capacity to open to the world and willingly “allow the wider life systems to *dictate our desires*” (Mathews 2011). Architecturally speaking, this implies that spaces and systems must be organized to benefit the local ecosystem as much as ourselves.

As living beings, humans are conative in essence: like the rest of nature, we strive to “maintain and increase” our existence; however, unlike the rest of nature, we do not always follow the path of least resistance by instinctively adjusting our conativities to that of our environment. This divergence is due to reflexive awareness, the capacity of the human mind to consciously reflect on the worldly experience (Mathews 2011). Through this contemplative process, our sense of existence reaches new conceptual dimensions:

The reflexive being “lifts,” so to speak, its representation of the world out of the world, in order to examine it. Its reflexivity is like a transparent layer of mind that can be peeled back and in this sense separated from the original unity of mind and world. Once thus peeled back, the ideal representation of world can be mentally manipulated – negated, rearranged, embellished. (Mathews 2011)

The reflexive mind iteratively constructs meanings for human existence. Consequently, we develop and reinterpret our representations of the world. What emerges from the “reflective being” defines the manner through which it actualizes its self-determined conativities. Thus, it sometimes chooses to break away from the synergistic balance of nature in the pursuit of iterated existential goals (Mathews 2011). Architecture, just like every other aspect of our existence, is determined by this thought process. Thus, its production may disregard the fundamental principles of life. For example, the erection of monumental cathedrals, a considerably straining task contradicting with the principle of least resistance, has been justified by religious beliefs. Similarly, we have built for

ourselves an environment that ignores the conativity of non-human life in an effort to elevate ourselves above nature.

While reflexivity confers humans some latitude regarding the principles of life, it does not truly set us apart from nature. Indeed, Freya Mathews advance that living beings, whether they are reflexive or not, are in essence both mental and physical entities (Mathews 2011). It is not the mind, then, that is exclusive to humankind, but rather a property of the mind. Reflexivity constitutes a difference in degree but not in essence. It allows us to mentally reproduce the universe “at different levels of abstraction” (Mathews 2011), but human existence ultimately takes root at the same fundamental level as the rest of life. Thus, reflexive awareness does not prevent us from following the two life principles. However, rather than relying on organic processes, a reflexive being must make the conscious decision to act towards creating a synergistic equilibrium with the rest of the world.

1.2. The technological problem of modern anthropocentrism

Modernity has been dominated by an erroneous, yet powerful anthropocentric worldview, which developed from a heightened appreciation for the human ability of reflexive awareness (Mathews 2011). This paradigm seemingly originates in medieval Christianity, particularly in the works of theologians such as Saint Augustine and Saint Thomas Aquinas (White 1967) (Steiner 2011). Indeed, these writers present the notion of a “rational soul” akin to the idea of a reflexive mind. However, Christian tradition interprets this concept as the ontological separation between humankind and nature: on the one hand, humans approach the spiritual essence of God through reason; on the other hand,

the non-rational entities of nature need guidance because they may never access the divine truth themselves (Steiner 2011). The relationship between these two levels of being is particularly evident in the Creation narrative:

“[...] God said, ‘Let Us make man in Our image, according to Our likeness; and let them rule over the fish of the sea and over the birds of the sky and over the cattle and over all the earth, and over every creeping thing that creeps on the earth’ ” (The Bible, Genesis. 1:26).

This passage orders humankind and nature into a hierarchical system of dominance and subordination. Humans are invested with the divine right to shape the world according to their desires. In contrast, nature is presented as existing only for the service of humankind. The two entities belong to mutually exclusive, unequal classes (Steiner 2011) (White 1967). As the “superior beings” invested with reflexive abilities, humans are not bound by the same principle as nature. Today, this dualistic and anthropocentric world view persists, although it has mostly shed its religious connotations.

From the Industrial Revolution on, humankind has asserted its self-appointed power over nature through a ruthless technological hegemony. For modernist architects, the city as a machine became the ultimate expression of human progress, while “nature became irrelevant and passé” (Stokoe 2013) (Sterling 2011). Indeed, technology has been the weapon of choice for the anthropocentric subjugation of nature, and the advances of modernity have made its agency incredibly prevalent in our society. While questioning the essence of modern technology, Heidegger noted its unprecedented character: it is an all-encompassing and violent mode of revealing (Heidegger 2008). This ordering, referred to as an “enframing,” challenges worldly entities against their natural tendencies of emergence and reveals them as “standing-reserve” (Heidegger 2008) (Foltz 1995). In other words, the value of a thing within the technological paradigm

does not lie in the character of that thing but in its relevance as stockpile in the industrial system of total production. Thus, the agency of modern technology enabled by anthropocentrism does not recognize the intrinsic conativity within nature and recklessly thwarts it. In the same vein, it trumps the principle of least resistance by fueling human activities with energy extracted from the environment (Mathews 2011). The insatiable endeavour of modern technology can be observed in the production of a modernist architecture that consumes and subdues the natural environment during the 20th century.

Furthermore, the ordering of modern technology has coerced our civilization in the same way it did the natural environment. A subjected condition was gradually induced in modern culture as technology penetrated all spheres of human existence. Indeed, while technology was initially developed in order to assist human conativity, the latter has grown to be recursively entangled to the former (Heidegger 2008), and it is now assumed that humankind must ensure technological progress at all costs. Foltz has pointed out how modern society within the enframing is essentially revealed as an inventory of human resources. We are taught to become efficient and productive members of society, not so much for our own individual well-being, but rather so that we can actively engage in the technological framework that organizes our existence (Foltz 1995). It is possibly for this reason that the global population is becoming increasingly urbanized (Stokoe 2013). By adhering to the technological doctrine, however, we simultaneously dissociate ourselves from the fundamental level of reality to which nature belongs, resulting in a lingering feeling of alienation (Foltz 1995). The rigid and linear organization of the modernist city reveals how technology has dissociated our existence from natural processes. In this sense, modern technology is problematic not so much because it facilitates the actualization of

anthropocentric ambitions, but rather because its agency profoundly hinders our ability to break away from the existing patterns of natural and human exploitation.

Biomimicry has just begun to address the paradigm shift necessary to the techno-ecological synergy envisioned by its advocates. While the emerging research presents a ground-breaking potential for sustainability, the biomimetic approach so far has been principally descriptive, neglecting to address the deeper philosophical implications of its agency (Mathews 2011). Accordingly, its logic remains unintentionally embedded in the anthropocentric dogma of modernity, and its rhetoric and practice are incoherent (Mathews 2011) (Goldstein & Johnson 2014). For example, in a passage of *Biomimicry*, Benyus assumes a basic anthropocentric viewpoint by preserving the modern ontological divide between nature and society (Goldstein & Johnson 2014):

With all due respect to plants, sugar and starch are not what we humans had in mind (plants already do a fine job of making those for us). What does interest us is the possibility of producing hydrogen gas from sunlight and water. (Benyus 2002)

In this discourse, no effort is made to connect human and non-human conativities, simply because they are perceived as separate and irreconcilable pursuits. Benyus, while attempting to promote a bioinclusive revolution, falls into an ideological trap. Because the structure of our society has been profoundly determined by anthropocentrism, biomimicry as a developing field of study has yet to escape from this model. Nevertheless, according to Armstrong (2011a), this shift is crucial if architectural design and other endeavours are to truly challenge the destructive structure of modern industry.

1.3. The post-modern search for bioinclusivity

In the face of climate change and the depletion of our planet's ecological system, the delusions of modern anthropocentrism are being slowly dismantled. A post-modern desire for bioinclusivity is gaining strength, yet it remains uncertain as to how our society will ideologically and technologically adapt to this transition. Currently, in design practices, including architecture, large efforts are dedicated to resource efficiency and moderated consumption as means to limit the deteriorating effects of human activity on the natural environment. Terms such as “reduce”, “avoid”, “minimize”, “sustain”, “limit” and “halt” are hugely popular in environmental discourses as they promote a less ecologically aggressive industry while preserving established economic institutions. However, such vocabulary ultimately continues to enable environmental destruction, be it at a slower rate (McDonough & Braungart 2002). Techno-ecological synergy cannot be achieved through such half-measures, constrained by the parameters of the existing industrial framework (Armstrong 2011a), that fail to address the deeper “underlying causes of a non-sustainable or even degenerative design” (Stokoe 2013). A less destructive attitude towards nature is not the same as a constructive approach: humans must learn to re-establish themselves within the framework of mutually beneficial exchanges that sustain an ecosystem. The modernist notion of architecture as a machine must be abandoned and replaced by a new ideal of architecture as an organism.

In the pursuit of bioinclusivity, the boundaries of our moral reasoning must expand to include the wellbeing of non-human life (Mathews 2011). To do so, we must be able to understand nature at its most fundamental level: we must relate to its conativities and exist in continuity with the flow of least resistance.

Architecture, rather than setting itself against nature, must harmonize with natural forces in a non-invasive manner. While Western civilization seems to have lost this ability, other societies, considered primitive by modern standards, have been able to accomplish this successfully. Their ideological traditions, then, may become the model for our bioinclusive future. In particular, animistic thought presents an interesting antecedent, where life is understood as a cyclic process of emergence rather than the property of a thing (Ingold 2006). Humans, just like animals, plants, and even non-biological entities arise from this state of constant change and their substance is animated by the same all-encompassing force. From this perspective originates “a heightened sensitivity and responsiveness, in perception and action, to an environment that is always in flux” (Ingold 2006). Animists are “truly open to the world” and “perpetually astonished” by it (Ingold 2006). This might be observed in the rawness of buildings that are directly informed by local conditions. For example, First Nations architecture in Canada uses simple technologies and materials because they take advantage of what is directly offered by nature (Nabokov & Easton 1989). In this sense, the animistic viewpoint stimulates a profound respect for nature and an intrinsic experience of interconnectedness that are foreign to modern Western thought. It does not conceive an ontological separation between nature and humankind but rather sees them as essentially similar beings of equal moral stature. Thus, from an animistic perspective, the post-modern society must reject dualism and develop an inclusive understanding of nature that will transpire in the expression of biomimetic architecture.

In a bioinclusive society, the enframing of modern technology no longer violently challenges things as standing-reserve because the intrinsic value of nature is recognized and respected. Rather, bringing things forth into

appearance requires skills and an artistic sensibility. Heidegger refers to this mode of creation as *techné*. This type of making, unlike modern technology, does not try to overpower the natural order but rather belongs to it (Heidegger 2008) (Foltz 1995). For instance, the craftsman using wood to make a bed must relate to the processes of self-emergence of the tree in an attuned and responsive manner. He must expertly and fundamentally know the substance of his work and mediate the method that will extract the shapes awaiting within (Foltz 1995). From a Canadian perspective, there may be no better example of *techné* than the birch bark canoes fabricated by the First Nations. Indeed, the canoe maker has to understand the ways in which the materials can be collected and manipulated to form a simple but durable vessel. More importantly, he must also know how the canoe will navigate the flow of the river, and how the body of the passenger will inhabit it (Southwell & Mears 2005). Only when all these things are recognized and sensibly connected does the canoe emerge from the bark, the roots and the wood that have been gathered from the forest. *Techné*, then, bring things forth in continuity with their natural progression rather than forcefully extracting them from their concealment. This is what biomimetic architecture should set to accomplish.

In this vein, *techné* offers a valuable point of departure for bioinclusive biomimetic design. Indeed, the term, as described by Heidegger, does not only encompass the notion of making, but also the idea of opening to the world and knowing about its truth (Foltz 1995). In the quest for bioinclusivity, this attitude is essential: with *techné* as a model, biomimetic designers could sensitively engage with the processes of nature and relate to them on a sensorial, and possibly emotional, level. Through the biomimetic project, society would be able to elude the modern feeling of alienation brought about by the technological enframing

and reach the state of astonished openness of the animists. Thanks to this sense of interconnectedness newly re-introduced by the act of making mindfully, humans may finally embrace “the collective pursuit of conative ends in accordance with the principle of least resistance” that exists in the natural world (Mathews 2011). The scientific teachings of biology should complement this deep knowledge of nature, but not supersede it. In this sense, techné would enrich the discipline of biomimetic architecture by providing a new philosophical and technological framework in the pursuit of collective conativities.

CHAPTER 2: EXISTING WORKS AND CURRENT RESEARCH IN BIOMIMETIC ARCHITECTURE

2.1. An emergent discipline

From its most primitive origins, architecture is believed to have been inspired by nature. Vitruvius imagined that it is by observing swallows building their nests that humans learned to build their own shelters from available resources (Vitruvius n.d.). Examples of vernacular architecture modeled after nature abound around the globe, yet biomimetic architecture as an interdisciplinary collaboration between designers and scientists is still in its infancy. Nevertheless, the compelling prospect it presents as an ecologically integrated alternative to the environmentally devastating industries of today generates an infectious optimism, as expressed by Michael Pawlyn in the introduction of *Biomimicry in Architecture*:

We are entering the Ecological Age, and it is the contention of this book that many of the lessons that we will need for this new era are to be found in nature itself. [...] For virtually every problem that we currently face – whether it is producing energy, finding fresh water or manufacturing benign materials – there will be numerous examples from nature that we could benefit from studying (Pawlyn 2011).

In this spirit, large efforts are being initiated to promote biomimetic architecture and noteworthy buildings and research projects exploring this approach are emerging. This chapter will investigate the successes and shortcomings of such ventures from a philosophical point of view based on the themes discussed in the previous chapter.

2.2. The Eastgate Centre by Mick Pearce and Arup

Illustration 1: Two early models for mound ventilation (Source: Turner & Soar 2008b)

To begin with, few biomimetic buildings have been celebrated as much as the Eastgate Centre, built in Harare, Zimbabwe in 1996. Designed by architect Mick Pearce in collaboration with a team of engineers at Arup, the office and shopping complex draws inspiration from termite mounds for passive heating and cooling. Interestingly enough, Turner and Soar (2008a) have demonstrated since the construction of the building that the biological concepts used by the designers of Eastgate are partly erroneous and incomplete. For example, an inaccurate assumption that drove Pearce's design is that ventilation in termite mounds allows the internal temperature to remain stable yearlong. In reality, while day to day fluctuations are kept to a minimum thanks to thermal mass, it appears that mound temperatures vary throughout the year to match soil temperatures (Turner & Soar 2008a). Additionally, it is correct that chimney-like tunnels ventilate the nest, either through heat-driven convection for capped chimney mounds or wind-induced convection for open chimney mounds (illus. 1). However, these mechanisms are infrequent and unreliable in such a small

structure. Thus the respiratory functions of the termite mound also involve diffusion as well as mixed diffusion-convection flows (Turner & Soar 2008a).

The design of the Eastgate Centre largely draws from the model of thermally regulated open chimney mounds ventilated through induced flow (Turner & Soar 2008a). This influence is easily observable in the 48 masonry chimneys that crown the edifice (illus. 2). Thanks to the stack effect caused by the wind velocity differential between the ground and the top of the edifice, these chimneys act as a warm air exhaust. On stagnant days, low-speed fans provide supplementary ventilation as necessary. However, these vents alone are not sufficient in maintaining comfortable conditions in the interior spaces. At night, cool air is drawn into the lower levels of the buildings and stored within large labyrinthine voids in the concrete floor. Then, during the day, this air is slowly released inside the building like a refreshing breeze. In addition, deep

Illustration 2: The pink-hued Eastgate Centre, with its distinctive chimneys (Source: Brazier 2008)

overhangs shading the façade prevent excess heat gain from the sun. Thanks to these innovations, the Eastgate Centre does not rely on a conventional heating and cooling system and utilizes only 10% of the energy required by mechanical equipment in comparable conventional constructions (Pawlyn 2011).

The termite-inspired architecture in Harare actualizes the desire to depart from conventional building technologies by attempting to “reveal and parallel natural processes” (Klein 2009). The Eastgate Centre thus embrace passive design concepts by using heavy masonry and concrete to moderate temperature fluctuations and by modelling its overall form as a response to natural forces such as the sun and the wind. These efforts are in-line with the modality of least resistance, yet the presence of powered fans reveals how the project mitigates modern design gestures rather than proposing a true alternative abreast of natural conativities. This example simply shows how difficult it can be to address these complex issues within the institutionalized framework of contemporary architecture and illustrates the necessity to pursue interdisciplinary work to shift our thinking. Thus, the collaboration between biologist Turner and engineer Soar has produced novel ideas for future termite-inspired buildings:

Imagine, for example, porous walls that are permeated with a complex reticulum that, like in the termite mound, acts a low-pass filter for turbulent winds. In this instance, an interior space of a building could be wind-ventilated without having to resort to tall chimneys, and without subjecting the inhabitants to the inconvenient gustiness that attends to the usual means of local wind capture, namely opening a window. Now, it is the windows that are the barriers and the walls that connect the inhabitants to the world outside (Turner & Soar 2008a).

The Eastgate Centre, then, only represents a rough prototype demonstrating how the study of termite mounds can transform the way we build and interact with our environment. Yet, it marks the necessary first step on the biomimetic path towards techno-ecological synergy.

2.3. The Eden Project biomes by Grimshaw & Partners

Another notable work of biomimetic architecture consists in the Rainforest and Mediterranean Biomes of the Eden project. These large greenhouses, designed by Grimshaw & Partners, occupy a reclaimed clay pit in Cornwall, England since 2000. The architecture was conceived as a series of bubbles scaled and arranged to follow the irregular topography of this unusual site (Pawlyn 2011). In addition, the “the poor load-bearing capacity of the soil” called for a lightweight structure (Grimshaw & Partners 2001). Exploration of natural examples ranged from carbon molecules to pollen grains and revealed that hexagonal and pentagonal geodesic organizations of spherical structures were particularly efficient. The geodesic dome popularized by Buckminster-Fuller in the mid-twentieth century is indeed a model of structural integrity and brought sustainability at the forefront of the architectural discipline (Langdon 2014). The Grimshaw design team adapted this technology to its multiple dome scheme by supporting the intersection between two spheres with triangular steel trusses (Grimshaw & Partners 2001). Moreover, the design was optimized for light penetration with the selection of ethylene tetrafluoroethylene (ETFE) as the cladding material. ETFE is a durable and recyclable plastic that can be manufactured in a much larger size than safety glass, thus allowing each cell of the hexagonal grid to be significantly larger, yet less structural steel is required due to the lightness of the material. Indeed, an ETFE pillow consists of multiple superposed layers sealed around the edges and inflated with air and thus presents a negligible weight. As a result, the superstructure of the Eden Project Biomes (illus. 3) is quite efficient in terms of form and material consumption in comparison with a more conventional design (Pawlyn 2011).

Michael Pawlyn was part of the design team for the Eden Project Biomes. In *Biomimicry in Architecture* (Pawlyn 2011), he mentions the effortlessness with which the geodesic domes follow the contours of the landscape rather than cutting through them. When compared with the nineteenth century Palm House at Kew Gardens, which is “a highly symmetrical building on a flattened site”, Pawlyn suggests that the Biomes exemplify respect for the natural landscape. In this regard, the architecture of the Biomes may indeed lean towards the path of least resistance by “flow[ing] around obstacles rather than trying to surmount them” (Mathews 2011). However, from a programmatic point of view, it is unclear how the Rainforest and the Mediterranean Biomes contribute to the conative pursuit of the life systems of Southern England. Indeed, such installations present the risk of introducing invasive species of exotic plants in the local ecosystem, consequently hindering the existence of current life forms (Hulme 2015). At best, the greenhouses won’t have any effect, constructive or destructive, on the natural

Illustration 3: Eden Project Biomes (Source: Burt 2001)

environment of the reclaimed quarries. Thus, in this project, human conativity has not been allowed to reshape and fit within that of nature. This is not quite yet an appropriate context for successful synergistic interactions between architecture and the environment.

2.4. Form finding processes by Frei Otto

German architect and engineer Frei Otto was a pioneer of biomimetic architecture decades before the discipline was popularized by Janine Benyus. His work focused primarily on form finding processes in both inanimate and animate nature for architectural application. Indeed, striking similarities of form between inorganic and organic entities reveal how the same processes of self-formation and self-ordering appear time and again in the natural world (Schanz 1995). Otto believed that understanding the principles behind these phenomena was essential for the architect to comprehend and control his own design. Thus, building is an act of creative investigation: a shape is not made but rather discovered through the study of emergence (Otto & Songel 2010). Otto's experimental methodology made extensive use of physical models (illus. 4) as a way to envision construction and encouraged a reflexive exploration of form, as recalled by a former member of his atelier:

We built soap film models, tensile fabric models made of stretch fabrics, and some without stretch which we patterned. We made inflatable forms, cable nets, and deployable models all as an iterative design tool and not as a visualization of a finished design. Models started out as very crude elements and through a series of iterations became sophisticated analytical tools. (Goldsmith 2016)

Under the hand of Frei Otto, biological and technological processes once considered irreconcilable were coming together into elegant and poetic architectural solutions. Thus, the study of spider webs inspired the dramatic

cable mesh structure of the West German Pavilion at Expo 67 (illus. 5) (Pawlyn 2011), while force distribution patterns in trees were the primary model for the branching structures of the unbuilt Saudi Arabia Council of Ministers (illus. 6) (Goldsmith 2016). This legacy is an invaluable lesson of methods, knowledge and expertise for biomimetic designers today.

Illustration 4: Soap film model for a tent (Source: Otto n.d.)

Illustration 5: West German Pavilion at Expo 67 (Source: Otto n.d.)

Illustration 6: Model for the Council of Ministers (Source: Otto n.d.)

Furthermore, Frei Otto's form finding processes are doubtlessly akin to the type of biomimetic techné envisioned in Chapter 1. Indeed, this methodology requires the designer to engage with the materiality of the work, and thus with the world in which architecture is rooted. This open attitude allows for unexpected discoveries that can shift thinking and advance the bioinclusive goal of our contemporary society. Humankind and nature, in Otto's view, are parts of the same whole, and technology should embody this sense of coexistence rather than express antagonism (Otto 1995). Consequently, an important characteristic of Otto's designs is their economy of effort and material. By using a limited amount of resources, he attempted to respect the integrity of the environment. That is not to say, however, that Otto has resolved the challenge of techno-ecological synergy, as the applicability of any biomimetic ideas depends on the established framework of the construction industry as well as on the resources available. For example, the production of steel components, used in many of Otto's buildings, requires a significant amount of energy in opposition with the principle of least resistance. Nevertheless, Frei Otto's experimental methods present important potential for structural innovation and could contribute to the evolution of a synergistic architecture in the future.

2.5. Material-based design computation by Neri Oxman

Neri Oxman investigates the discrepancy between the processes of emergence in nature and the paradigm of computational design. Indeed, in the natural world, the form of objects derives from their structure, which itself arises from the material with which they are made. Yet, in the architectural practice, this hierarchical design sequence is inverted:

In most cases, structural strategies are addressed by way of post-rationalisation in support of the building's utility captured by

spatial properties. In this light, material selection and application are dependent on structural solutions. (Oxman 2010b)

With the advances of computational design, this approach to architectural design has become particularly prevalent as the digital environment accounts for geometrical configuration, but not for materiality. As a direct consequence, objects fabricated through additive manufacturing are usually composed of one single material with fixed properties. Compared to natural growth, this technique is wasteful and inefficient. Indeed, organic matter is heterogeneous and its properties are strategically organized in response to external requirements. For example, human skin presents different attributes according to the function of various anatomic locations. Thus, our facial skin is thin with large pores in order to act as a filter, while the skin on our palms is thick with small pores and behaves like a protective barrier (Oxman 2015).

The new design models proposed by Oxman emulate the “material-first” strategy of nature in the digital realm:

Variable property design (VPD) is a design approach, a methodology and a technical framework by which to model, simulate and fabricate material assemblies with varying properties designed to correspond to multiple and continuously varied functional constraints. [...] In this approach, material precedes shape, and it is the structuring of material properties as a function of performance that anticipates their form. (Oxman 2010b)

The project *Beast* (illus. 7) is a chaise lounge prototype developed to illustrate this novel approach to modelling, analysis and fabrication. The design utilizes five different material compositions ranging from stiff to soft. An initial surface modeled after the human form is input as digital parameters. It is then tessellated following a Voronoi pattern according to its curvature: flat areas present a sparse arrangement of large cells, while curved areas are densely organized into small cells. Each of these cells is assigned one of the five materials according to loading

Illustration 7: Chaise lounge *Beast* (Source: Reshef 2010)

requirements: vertical regions under compression are stiff, while horizontal regions under tension are soft. Finally, material thickness is determined by body pressure mapping, so that high pressure points correspond to softer and thicker areas, while low pressure points coincide with thinner, stiffer regions. Due to the current limitations of multi-material 3D-printing technology, the scaled prototype was produced in thirty-two sections, each comprising the five material combinations (Oxman 2010a). The assembled chair is an efficient material-based response to structural requirements and environmental conditions. With further advances in fabrication technologies, “gradation control of multiple materials within one print” could be applied at the architectural scale to “save weight and material quantity while reducing energy inputs” (Oxman 2010b).

Oxman’s material-based design computation shares certain similarities with Frei Otto’s form finding processes. Indeed, both approaches emancipate themselves from conventional design methods by rejecting arbitrary

determinations of architectural shape independent of material. However, while Otto worked with physical objects, Oxman operates in the digital realm. This brings an interesting question concerning the possibility of computational techné in the future. In 2004, when questioned about the necessity of physical experiments in the digital age, Otto replied: “The computer can only calculate what is already conceptually inside of it; you can only find what you look for in computers. Nevertheless, you can find what you haven’t searched for with free experimentation” (Otto & Songel 2010). This element of serendipity described by Otto is, without a doubt, tied to the astonished openness of techné. Today, a decade after Otto’s comment, has computer technology evolved sufficiently to provide the same flexibility as physical modelling? Probably not. Yet, maybe the “shift from a geometric-centric to a material-based approach in computationally enabled form-generation” envisioned by Oxman (2010b) will provide the missing pieces. In any case, the possibility of producing seamless multi-material building components is an exciting prospect. For example, a building skin that breathes while providing structural support would eliminate the need for separate structural and mechanical systems (Oxman 2009). Such innovations would save considerable sums of material and energy while ensuring continuous exchanges between the natural and the built environment, bringing us closer to fulfilling the bioinclusive ambitions of techno-ecological synergy.

2.6. Metabolic materials by Rachel Armstrong

Rachel Armstrong addresses the problem of contemporary construction practices which extract energy from the environment and transfer it to our cities in a unilateral process. She suggests to restructure this relationship so that architecture may enter in a symbiotic dialogue with the environment. Metabolic

materials are proposed as “a chemical interface or language through which artificial structures such as, architecture, can connect with natural systems” (Armstrong 2011b). While metabolic materials are not alive and do not carry DNA, they do possess the metabolic ability to chemically transform “one group of substances into another with the absorption or production of energy” (Armstrong 2011b). Such materials could allow our buildings to grow, self-repair and respond to environmental disturbances (Armstrong 2009). A specific chemical agent that can produce these reactions is the protocell, a droplet of fatty acid suspected to have played a role in the origin of life. Protocells are able to move in their environment and to follow chemical gradients. Additionally, they can be engineered in order to undergo particular chemical reactions useful to architecture:

The architectural properties of protocells include the shedding of skins, altering the chemistry of an environment through their ‘waste’ products, the precipitation of solids, population based interactions, light sensitivity and responsiveness to vibration. (Armstrong 2011b)

It is suggested that these properties could be used to replace the decaying woodpiles that support the city of Venice with a limestone-like reef (illus. 8). Indeed,

Illustration 8: Visualization of a synthetic reef supporting the city of Venice (Source: Kerrigan n.d.)

protocells can absorb the carbon dioxide dissolved in the waters of the canals and excrete a solid carbonate deposit that will reinforce the city's foundations. Moreover, they can be programmed to be repelled by light in such a way that material deposition would only occur underneath the buildings while leaving the navigation channels clear (Armstrong 2009). This new reef would provide a new habitat for the local marine life while improving the overall water quality, reconstructing the city as an active and collaborative agent of the ecosystem.

The metabolic materials envisioned by Armstrong constitute without a doubt a revolutionary idea in a field that has been entangled with the industrial framework for at least two centuries. Indeed, it proposes a shift from inert constructions to living structures that interact with the environment (Armstrong 2011b). Such systems would develop in response to their environment and appeal to the conativity of nature by creating habitats that are welcoming not only to humans, but also to other local organisms. Furthermore, because these materials harness the properties of metabolism, their assembly system would follow a cyclic process of nutrient circulation rather than a linear, unilateral chain of voracious consumption (Armstrong 2011b), thus adhering to the path of least resistance. Metabolic materials thus possess the potential to establish constructive relationships between the artificial and natural entities in the environment. Yet, because the resulting architecture emerges from pre-programmed protocells, the opening embodiment of creation through techné is somehow lost with metabolic materials. Humans cannot interact with protocells through the substantial act of making; the sensorial experience rather depends on the properties of the emerging structures.

CHAPTER 3: DESIGN PROPOSAL

3.1. Site presentation

In other times, less than two kilometers upstream from Parliament Hill in the national capital (illus. 9), the Ottawa River tumbled into the dramatic Chaudière Falls. These notable cascades have been, for thousands of years, a point of reference for Aboriginal populations on the territory. The Algonquins believe that the circle of turbulent waters, with its swirling mist, symbolizes the bowl of the Creator's pipe. To them, the powerful sound produced by the water crashing on the rocks is the call of the Earth. Asinabka, meaning "Place of Glare Rock" in the Algonquin language, is a spiritually charged location. For this reason, the falls and their adjacent islands have been used as ceremonial grounds and as a strategic meeting place by the Aboriginal people since time immemorial:

The Akikpautik [Chaudière Falls] symbolized the bowl of the sacred pipe, with its constant spray taking the prayers of the people to the cosmic creator in perpetuity. The underground rock formations, the karsts, and the underground rivers sang messages from the womb of Mother Earth at this sacred place, and the thundering water drum of the Chaudière Rapids called the people to the source. (Thumbadoo 2014a)

The falls are indeed a powerful force, and when the first non-indigenous settlers arrived in the region, they did not fail to notice their spectacular flow. Upon establishing a village on the Northern shore of the Ottawa River in 1801, Loyalist Philemon Wright intended to turn the region into a jewel of the lumber industry. He started modestly by building a timber raft, which he then floated to Quebec City. As Francophone and Anglophone colonists settled on both sides of the river, the industry grew quickly. In 1828, the first bridge between the two towns was completed, and in 1829, Wright's son, Ruggles, built the first timber slide.

Meanwhile, the First Nations presence decreased around the waterfalls, although some Aboriginal Canadians who remained in the area became employed as raftsmen by local companies (Thumbadoo 2014a) (Boucher 2012).

From the 1870's on, the Ottawa River sawmills were the most productive in the country, until the 1890's when British Columbia seized industrial leadership. Simultaneously, the timber trade in the Ottawa region slowly gave way to the sawn lumber and pulp and paper industries. In 1910, a massive ring-dam was built to harness the hydroelectric power of the Chaudière Falls. After the 1930's, a boom and bust cycle induced by increased competition has characterized the local industry and the region was never able to truly regain its former industrial prominence. The last Chaudière Island mills were permanently closed in 2005. However, the various hydroelectric power stations remain active to this day (illus. 10).

Because of its history and its critical location at the border of Québec and Ontario, the Chaudière Falls site offers an exceptional opportunity for cultural exchange between the Francophone, Anglophone and Aboriginal communities of Canada as well as with international visitors in the national capital region. The post-industrial site is in great need of revitalization (illus. 11) and its potential should be exploited to promote understanding and tolerance within the different cultural communities in the city as well as to foster exchange with natural entities in the urban environment. In particular, Chaudière Falls should be celebrated as a remarkable feature of the land rather than concealed by a dam (illus. 12).

Illustration 9: Urban situation
scale 1:20 000

Project Site / 0. Chaudière + Albert + Victoria Islands

Institutions & Monuments / 1. Canadian Museum of History / 2. National Gallery of Canada / 3. Rideau Canal Locks / 4. Parliament Hill / 5. National War Memorial / 6. Supreme Court of Canada / 7. Library and Archives Canada / 8. Canadian War Museum

Parks / 9. Parc des Portageurs / 10. Parc Sainte-Bernadette / 11. Parc Fontaine / 12. Parc Jacques-Cartier / 13. Ottawa River Woods / 14. Nepean Point / 15. Major's Hill Park / 16. Garden of the Provinces and Territories / 17. Nanny Goat Hill Community Garden / 18. Dundonald Park / 19. McNabb Park / 20. Laroche Park

Illustration 10: Current land use
scale 1:3500

Active Industrial Use

1. Centrale Hull 2 / 2. Generating Station No.4 / 3. Generating Station N0.2 / 4. Grinder Powerhouse

Adaptive Reuse / Non-Industrial

5. Vertical Reality (Rock climbing facility) / 6. Mill Street Brew Pub / 7. Aboriginal Experiences (Aboriginal cultural attraction) / 8. Royal Canadian Navy Monument

Unoccupied / Demolished

9. E.B. Eddy Paper Mill / 10. Ottawa Electric Railway Co. Steam Plant / 11. Booth Board Mill / 12. Groundwood Pulp Mill / 13. Ottawa Electric Railway Co. Powerhouse / 14. Bronson Co. Office / 15. Wilson Carbide Mill

Illustration 11: Decaying structure of the Booth Board Mill

Illustration 12: Industrial facilities concealing the falls

3.2. Architectural program

Illustration 13: Single totem pole marking the Indigenous significance of the site

This architectural project is inspired by and honours the vision of Algonquin Elder William Commanda and of the global eco-community of the Circle of All Nations for a National Indigenous Centre on the Chaudière island complex. The Centre and its architecture will promote healing on three levels: “Healing individual and collective relationships with Mother Earth; Healing, strengthening and unifying Indigenous Peoples; and Healing relationships with all others” (Commanda 2010). Asinabka is envisaged as a natural and spiritual sanctuary for the First Nations, Metis and Inuit peoples (illus. 13) and as a special gathering place that will strengthen their presence within the national capital region and celebrate their traditional knowledge. Moreover, the new institution will symbolically recognize the importance of the Aboriginal community within

Canada and mark reconciliation after years of injustice. Asinabka will also be a place of international dialogue, inviting people from Canada and from all over the world to share their values and ideology. Contemporary questions of global importance, such as the environmental crisis and universal peace, will be discussed in this stimulating gathering place.

The National Indigenous Centre imagined by William Commanda was an ambitious project with cultural, political, social and ecological implications. The proposed project can only address part of this vision, but it is conceived as the first step towards its full realization. The new building, located on the Western portion of Victoria Island, will be home to the Asinabka Indigenous Cultural Centre. Victoria Island was chosen for the erection of the first building at Asinabka because of its central location in relation to the rest of the site, in the hope that its activities may expand towards every area of the site. It is imagined that further construction will take place on both sides of the Portage Bridge, while Chaudière and Albert Islands will be restored as a natural sanctuary where a pine forest will lusciously grow. A network of pedestrian pathways on these islands will lead to the undammed Chaudière Falls (illus. 14).

Three main interior spaces within the Asinabka Indigenous Cultural Centre address the three levels of healing targeted by Commanda's proposal. The first space, a three-storey greenhouse on the south end of the building, will contribute towards the healing of our relationships with the natural environment by cultivating native species of plants recognized by the First Nations for their medicinal properties. The ground floor will serve as an exhibition space where visitors will learn about traditional healing practices. If desired, they will be able to purchase selected species of plants and care for them at home. On the second

floor of the greenhouse, educational workshops will be offered for people desiring to learn more about the medicinal properties of the local flora and the proper way to care for it. A resource centre will also provide additional documentation for researchers and more curious visitors. The third level of the greenhouse is conceived as a healing lounge where visitors may rest and meditate within the vegetation. The second major space, a circular meeting hall overlooked by a mezzanine, and the third one, a 1015-seat auditorium, contributes to the healing of relationships within First Nations communities and beyond. The meeting hall will host the local and international community for discussions, lectures and receptions. Meanwhile, the auditorium will reinforce the cultural identity of the First Nations and promote intercultural exchanges by accommodating a large variety of stage productions. This facility is completed with changing rooms for the artists as well as storage rooms and technical areas. The three spaces are connected on the ground floor level by a foyer bathed in natural light where visitors will be able to share their experiences.

Smaller spaces on the ground and second storey complete the architectural program and further advance the three levels of healing. On the ground level (illus. 15), arts and crafts studios as well as dance and music studios encourage artistic endeavours promoting Aboriginal culture. A communal kitchen is proposed to connect with the Aboriginal culture and with the local environment on a different sensorial level. The spaces on the second floor (illus. 16) include a café-lounge, an aboriginal language resource centre, a multimedia room, several multipurpose rooms and administrative offices. As much as possible, visual connections with the exterior stimulate a certain openness to the surrounding environment. Finally, the green roof at the third level and the vegetated canopy over it will be discussed further later in this chapter (illus. 17 & 18).

Illustration 14: Site plan
scale 1:3000

- 1. Greenhouse exhibition
- 2. Foyer
- 3. Bar
- 4. Coatcheck
- 5. Changing room
- 6. Storage
- 7. Washroom
- 8. Auditorium
- 9. Meeting hall
- 10. Communal kitchen
- 11. Arts & crafts studio
- 12. Music and dance studio
- 13. Office

Illustration 15: Ground floor plan
scale 1:400

1. Greenhouse workshop
2. Greenhouse resource centre
3. Café-lounge
4. Meeting hall mezzanine
5. Auditorium
6. Language resource centre
7. Multipurpose room
8. Office
9. Washroom
10. Storage
11. Kitchenette

Illustration 16: Second floor plan
scale 1:400

- 1. Greenhouse healing space
- 2. Lounge
- 3. Performance space

Illustration 17: Green roof plan
scale 1:400

Illustration 18 : Canopy top view
scale 1:400

3.3. Major design concepts

Environmental stewardship, a particular subject of great importance to Commanda, is brought forth to restore the severed relationship between the community and the land, and to stimulate techno-ecological synergy. Techné as a design method informing biomimetic architecture facilitates this reconciliation by creating opportunities for “communicative exchanges” between humans and natural entities on site (Mathews 2011). Through these multiple encounters, humans can learn about the conativities of other organisms and their contribution to the synergy of the ecosystem. Engagement with the life of the place “induce[s] it to disclose to us its own sense of itself” and provides the self-reference necessary for adapted human conativities and least resistance (Mathews 2011). In particular, exchanges with three living entities related to the site are favored: the life-giving Ottawa River, the cheerful birds and the decimated but very desirable pine forest.

First, the Ottawa River surrounds the site with its vigorous waters sustaining all life in the area. As such, it exemplifies the sense of active interrelatedness sought after in this project. The First Nations recognize the criticality of our relationship with water:

When I was struggling hard to understand megadumps, [Algonquin elder] William Commanda instead insisted on going out to buy me a kayak – he sent me to the water, to understand what it was really all about – and as I paddle, I find the journey on the waters offers me endless lessons. William knew what a teacher water is. His people knew intimately how water worked, how it moved, how it shifted with the seasons, how it sustained life. (Thumbadoo 2014b)

By being with water, humans may be able to better understand the flow of nature and form a holistic bond with the network of life. In particular, the undamming of the falls will allow the passage of migrating fish species to resume (Thumbadoo 2014b) and instill a new tangible energy to the site. Views and pathways accessing

the water help in establishing a connection with this vital force. This experience will transform our way of being within the world, developing our conativities in order to better contribute to these complex linkages.

Second, birds inhabit both the urban and the natural landscape of the Ottawa region. The way they navigate air movements during flight demonstrates their instinctive knowledge of the world's forces. The soaring eagle is so notable that many aboriginal tribes of Canada consider this bird to be the wise messenger of the Creator (Aitken 2012). As such, an eagle feather is a symbol of wisdom and courage and is carried with pride and honor. Moreover, many species of birds are vocal creatures, suggesting the possibility of a “musical encounter” that may transform our conativity:

In such an encounter the other party – the bird [...] – may begin to express its sense of itself, and as the encounter proceeds to the level of synergy, cross-species patterns of sound may be created that express but enlarge the musical signatures of both parties. In this sense, each party will be molded via the encounter. Our own human conativity [...] will have been bent toward the conativity of our musical confreres. (Mathews 2011)

Thus, some exterior performance spaces are conceived to attract local populations of birds so that our voices can intertwine in a new form of cooperative encounters.

Third, the white and red pine forest of the Ottawa River Valley has been greatly affected by the industrial exploitation of the last two centuries. The project suggests a reforestation of the islands as a way to reclaim the lost biodiversity, rejecting the violent practices of the industrial age. This renewing process acts as a “symbolic statement of reconciliation and unification” (Commanda 2010) within ourselves and with nature. Special spaces are dedicated to the growing of native plants that will later be planted on site or elsewhere in the city. The urban

Illustration 19: Medicine Wheel

community will be able to enjoy this green sanctuary, thus facilitating encounters with nature and stimulating our conative transformation.

In addition to the three specific entities, orientation and location are given particular attention. These factors play a considerable role in the passive heating and cooling of a building and as such they should always be addressed with care by the designer. However, traditional Indigenous knowledge teaches us that the significance of the four cardinal directions goes beyond energy efficiency. Indeed, they inform the manner in which the land relates to different aspects of holistic health. The traditional Medicine Wheel of the First Nations¹ (illus. 19) illustrates this concept by associating each direction with a different aspect of healthy living: just like the four directions are interrelated, all four aspects

1. The Medicine Wheel design and symbolism vary from one tribe to another. The color scheme introduced in Illustration 19 is used by the Circle of All Nations, the “global eco-community” founded by Commanda. Symbolic interpretations are drawn from a text by Nicole Bell of the Kitigan Zibi First Nation.

of life are interwoven and must be cultivated in balance (Wilson 2003). Thus, east is identified with spiritual life, south with physical life, west with emotional life and north with mental life (Bell 2014). Additional fourfold allegories confer additional layers to the Medicine Wheel, including the four seasons, the four elements and the four stages of life (Bell 2014). The First Nations, in a typical animist worldview, believe that the land is alive with spirits, and that it is by being open to all its facets that holistic health may be achieved (Wilson 2003). Following a conscious aspiration to dwell in the world, Indigenous tribes in North America have embedded this view of the cosmos in their traditional architecture. For instance, the four principal posts of the Navajo house are aligned with the four cardinal directions (Nabokov & Easton 1989). In the same vein, the architectural project presented here is oriented with this directionality. Thus, the main façade of the green house faces south so that the sunlight may nurture both plants and visitors. The focal point of the auditorium is aligned with the north because this direction is associated with the enactment of knowledge (Bell 2014), in this case in the form of artistic and cultural productions. Finally, the circular form of the meeting hall illustrates the cyclic character of life as embodied by the Medicine Wheel.

3.4. Arboreal structure

The beliefs of the First Nations integrate the relational ontology of animistic thought by describing the land as the womb from which all life continually emerges (Scott 1989) (Wilson 2003). Meanwhile, contemporary Western society remains embedded in a technological paradigm shaped by anthropocentrism. The Asinabka Indigenous Cultural Centre, as a self-governed Aboriginal institution existing within the larger context of a Western capital,

presents an unprecedented opportunity to promote the transition from a collective industrial mindset to a bioinclusive one. Architecturally, the Centre must express this ideological transformation with creative gestures that will not only speak to the First Nations but also to the larger community of Ottawa and Canada. While the visceral bond that unites humankind to the land is deeper than symbolism, architectural allegories may constitute a first step towards re-establishing a holistic appreciation of ourselves and nature. In this spirit, an arboreal system of columns and canopy (illus. 20) is envisioned as a defining architectural design element that integrates techno-ecological functions responding to the three site entities. The design is informed by Mathews' two fundamental principles of life as well as by specific biological models, in an effort to incorporate the reciprocally transformative effects of philosophy and science in biomimicry.

Illustration 20: Arboreal columns-and-canopy structure

Traditional Indigenous architecture is known to make ingenious use of readily available materials, which may be as varied as saplings, wattle-and-daub and snow (Nabokov & Easton 1989). For this project, it is important to pay homage to this ancestral resourcefulness, which was born as a response to local conditions and thus promotes a sense of rootedness within the natural world. One locally-sourced material in particular possess the potential to convey the authentically raw quality of tribal dwellings while promoting ecological sustainability. Glue-laminated timber has already been used in contemporary works of Indigenous architecture, for instance the Aanischaaukamikw Cree Cultural Institute by Douglas Cardinal. Moreover, a shift in policies in the wood-manufacturing sector towards “Cradle-to-Cradle” design could completely eliminate waste from the timber products lifecycle (Brauer et al. 2010). Such an innovation would contribute to the ideological and technological transition towards techno-ecological synergy.

Based on the concepts proposed by Oxman (2010a) (2010b), since wood is a fibrous material, any inspirational source informing the structural form of the glue-laminated canopy should be of a similar fibrous composition. The most critical inspiration for this came from one of the three site entities: the birds. More precisely, it came from an avian adaptation that combines strength and lightness: the feather. This structure is organized at the microscale into a bundle of beta-keratin fibres surrounded by a protein matrix (Lingham-Soliar 2014). The feather rachis, or shaft, presents two possible fibre arrangements dependant on location (illus. 21). The first arrangement is found on the ventral and dorsal walls of the rachis. It consists in parallel fibres oriented axially, and is flexible in torsion but longitudinally rigid. On the other hand, fibres on the lateral walls are oriented tangentially along the rachis axis and meet perpendicularly with

Illustration 21: Fibrous structure of the feather rachis

each other. In that case, they are stiff in torsion but flexible along their length (Lingham-Soliar 2014).

The two fibre arrangements of the feather rachis were explored with physical models. Thin slices of wood were used to represent glue-laminated timber at a small scale, and particular care was taken in manipulating the material with the responsive awareness of *techné*. The helical arrangement of fibres led to more interesting observations. In particular, it was found that it is possible to achieve this geometry by weaving the intersecting fibres together. This technique is akin to basketry, an ancestral craft found in many cultures around the world. This universality suggests that similar techniques have been developed in multiple occasions by attentive craftsmen following the path of least resistance and exploiting the natural qualities of fibrous materials. In this sense, weaving, as the poetic revealing of an entity (the basket) concealed within a material (grasses, roots, etc.), is a form of *techné*. The column prototype thus conceived (illus. 22) represents an attempt to address the holistic sensibility and the material intuition involved in Heideggerian *techné*.

Illustration 22: Conceptual model of woven column

While translating the model to full architectural scale, it was obvious that thick glue-laminated timber does not act in the same manner as the thin strips of fibrous materials previously used. Additionally, stresses that may be acceptable at the scale of a basket may not translate to the building scale. Indeed, literal weaving would entail important technical difficulties, in particular during the fabrication and the assembly process. Blindly committing to a form or a technique may critically challenge the material, and thus it was decided to explore how this issue has been addressed in other built projects. Two buildings by architect Shigeru Ban propose alternate solutions for glue-laminated timber structures inspired by the art of weaving. First, in the Nine Bridges Country Club, the architect uses half-lap joints at each intersection so that two members may cross each other without bending (Scheurer 2010). Second, in the Pompidou-Metz Centre, he assigns different layers to members oriented in different directions so that they overlap instead of interlacing (Scheurer 2010). The Pompidou-Metz solution was preferred for

this project because it preserves the integrity of each individual member, thus remaining closer to the model created through techné. Glue-laminated timber members are arranged into two double layers and parallel members are connected by an additional laminated timber piece. Points of intersection are stabilized with two threaded bolt with tension springs, while the footing is supported by slotted-steel fixings underneath the floor plate (illus. 23).

Illustration 23: Glue-laminated timber column details
scale 1:20

Illustration 24: Three-way junction in honeycomb hexagonal cells

To complete the arboreal metaphor of the structural form, each woven column must branch out so that its ramifications may mingle with others into a continuous canopy. The wooden columns are distributed uniformly in the building along a hexagonal pattern rather than along the conventional rectangular grid. Indeed, as the designers of the Eden Project discovered, pentagonal and hexagonal structures abound in nature because this arrangement is particularly effective in distributing loads evenly (Pawlyn 2011). Most notably, the three-way 120 degree junction between the hexagonal cells of a honeycomb (illus. 24) is a very efficient and economical joint (Biomimicry Institute n.d.). It was thus decided to utilize this form for the columns-and-canopy structure. In the same spirit, the concrete floor slabs are also organized into hexagonal bays and reinforced with ribs running parallel to the perimeter (illus. 25). In addition to contributing to structural efficiency, the hexagonal grid breaks away from the more traditional spatial framework of Western architecture and confers a more organic quality to the architecture.

Illustration 25: Concrete floor structure with glue-laminated timber column
scale 1:250

Building on the information gathered from the initial physical model, the columns merging into the canopy were modeled digitally. More precisely, a computational method approaching Frei Otto's form finding processes with tensile membranes was employed. This allowed for the creation of a funicular shell that serves as the virtual formwork guiding the woven columns-and-canopy structure. The first step in reaching this form was to model simple geometries, such as cylinders and two-dimensional surfaces, which approximate the envisioned structure in shape and location (illus. 26). Secondly, this configuration was relaxed and manipulated using distributed loads until pre-established spatial requirements are met (illus. 27). Thirdly, a series of curves representing woven threads were drawn along the surface. Finally, a cross-section was applied to each of these curves, thus producing the final form of each wooden member (illus. 28).

In a sense, the digital modeling approach may appear quite restricting as it does not possess the haptic character of physical modeling and requires imputing parametric constraints. The creation of a physical model during primary explorations was thus crucial in providing information for the computational phase. The digital approach then allowed the quick testing of multiple iterations of an idea and facilitated the visualization of different architectural solutions. Additionally, a highly detailed prototype of the column-and-canopy assembly (illus. 29 & 30) was produced using additive manufacturing technology in order to provide a better understanding of the formal aspect of the structure. However, the haptic information provided by *techné* is lost with this fabrication method. As a way to address this further, additional experimentation involving physical models would be necessary in order to test the developed structure and discover new possibilities. Optimal results would be obtained by alternating between digital and physical modeling at different stages of the design process.

**Illustration 26: Simplified
structure geometry**

**Illustration 27: Reference
surface for structure**

Illustration 28: Typical canopy bay

Illustration 29: 3D-printed prototype top view

Illustration 30: 3D-printed prototype side view

As a way of responding to the conativity of the river, a rain harvesting system is integrated to the columns-and-canopy structure. The collected water is either stored underground or immediately recirculated into the building. It may be used for plant watering and toilet flushing, and other possible applications. Thanks to this additional water source, the building requirements for chemically treated water extracted from the river are reduced and water resources are optimized according to the needs of building users. The rain collecting system is mainly inspired by two biological models. First, the convex shape of the bromeliad leaves allow water to gather at the centre of the plant (illus. 31), where it is stored until needed (Biomimicry Institute n.d.). This formal adaptation inspired the design of a flower-like water collector that drains the water in six points on top of each column. The second biological adaptation emulated for the water collecting surface is the hydrophobic effect of the feather. Indeed, the surface of

Illustration 31: Water capture system in bromeliads

Illustration 32: Hydrophobic effect of feathers

a feather is formed by the barbs and barbules that branch out of the rachis. This structure creates a series of small grooves on the surface of the feather that trap small molecules of air (illus. 32), which repel water (Bormashenko et al. 2007). Researcher Edward Bormashenko has invented a superhydrophobic metallic polymer based on this principle (Bormashenko et al. 2008). This material is applied to the water harvesting surfaces of the rain collectors in order to maximize the amount of water collected.

Another addition to the arboreal structure responds to the conativities of both the birds and the forest. Vegetation is grown both inside and outside the building thanks to the addition of green walls between the columns wooden members (illus. 33) as well as a secondary canopy structure supporting vines (illus. 34). The plants on the green walls are cultivated in individual pots so that they may be easily removed and replanted outside when they get large enough. By engaging with plant life, human communities may reflect upon how they can embrace the conative pursuit of the local ecosystem. All the plants grown within the building, including in the greenhouse, would be selected with the assistance of Aboriginal elders and healers in order to insure respect towards Indigenous traditions. Moreover, the plants are native to the local ecosystem and support the biodiversity of the site, thus offering a healthy milieu for the pine forest to grow back. In the same vein, a secondary canopy lattice integrated to the canopy design supports a variety of native vine species (tab. 1), which themselves provide resting places and food for birds. Building occupants may observe these small animals from the green roof and thus reflect on the implications of a bioinclusive future.

The columns-and-canopy wooden structure turns the architecture of the Asinabka Indigenous Cultural Centre into an allegorical grove that echoes the restored forest of red and white pines growing outside the walls of the building (illus. 35 to 38). This blending of the interior and the exterior is expected to reveal how the land is tied to the emotional, spiritual, physical and mental aspects of our existential being. This biomimetic design acknowledges the intrinsic value of nature and attempts to act in harmony with the local environment rather than against it in order to promote a more sensitive and bioinclusive future.

Illustration 33: Section of single column
scale 1:150

Illustration 34: Top view of single canopy bay
scale 1:150

Table 1: Canopy vines

Plant species	Details
Bittersweet (<i>Celastrus scandens</i>)	Tea has medicinal values
Virginia creeper (<i>Parthenocissus vitacea</i>)	
Wild grape (<i>Vitis riparia</i>)	Roots, branches and sap have medicinal values

(Upreti et al. 2012) (Hanrahan 2005) (Ottawa 2012)

Illustration 35: Section AA
scale 1:400

Illustration 36: Section BB
scale 1:400

Illustration 37: Section CC
scale 1:400

Illustration 38: Section DD
scale 1:400

3.5. Roof garden

Reclaiming “ways of living in balance with Mother Earth” is a recurrent theme in Commanda’s proposal for Asinabka (Commanda 2010) and is consistent with the worldview expressed in this thesis. Asinabka, because of the international exposure it enjoys within the capital city, would position itself as a model of bioinclusivity. Roof gardens growing under the wooden canopy (illus. 39) can play an important role in achieving this exemplary status. This lush exterior space offers a place of repose to building users and provides a habitat for local wildlife, thus promoting harmonious interactions between human communities and the local ecosystem. Indeed, the success of biomimicry in achieving technological synergy strongly depends on increased opportunities to interact and

Illustration 39: Roof garden in summer

observe nature. These increased encounters are crucial in building a holistic understanding of the natural world and in defining our place within it.

The roof gardens are spatially defined by the wooden canopy above them. As such, they would further advance the conative pursuit encountered through the vine-covered portion of the design. Namely, they should provide a safe environment for birds to enter into a communicative sound exchange with humans. Thus, the roof gardens are envisioned as a haven and as a performance space for both the animal “vocalists” and the human “musicians” that will openly interact within. While an urban garden does not substitute the natural habitat of birds, “they can provide needed food and resting spots for many migratory species and offer safe nest sites for others” (Hanrahan 2005). Accordingly, a variety of native plants of different height have been selected (tab. 2) in order to provide sanctuary for multiple bird species. First, a number of groundcovers are used in order to create vegetated layers. They also define the transition between the circulatory spaces and the more densely vegetated areas. Second, wildflowers provide seeds and nectar, which attract valuable pollinating insects. In addition, their beautiful colours would contribute to the creation of environmental moods that support the encounters in the gardens. Third, small shrubs of different species are planted into thickets in order to provide shelter for small animals. In addition to attracting birds, certain selected plants possess medicinal properties well known to the First Nations (Upreti et al. 2012). In this regard, the roof gardens highlight the multiple facets of a holistic relationship with the land; walking in this space would stimulate an emotional, spiritual, physical and mental connection within it.

Table 2: Roof garden plants

Plant species	Growth habit	Details
Canada goldenrod (<i>Solidago canadensis</i>)	Wildflower	- Provides seeds for birds - Leaves, stems and roots have medicinal values
Canada mayflower (<i>Maianthemum canadense</i>)	Groundcover	- Tea has medicinal values
Canada yew (<i>Taxus canadensis</i>)	Shrub	- Leaves and twigs have medicinal values
Common evening-primrose (<i>Oenothera biennis</i>)	Wildflower	- Provides seeds for birds - Bark has medicinal values
Common elder (<i>Sambucus canadensis</i>)	Shrub	- Provides fruit for birds - Bark, roots and flowers have medicinal values
Fireweed (<i>Chamerion angustifolium</i>)	Wildflower	- Leaves and roots have medicinal values
Flowering raspberry (<i>Rubus odoratus</i>)	Shrub	- Provides fruit for birds
Foamflower (<i>Tiarella cordifolia</i>)	Groundcover	- Roots have medicinal values
Gray-headed coneflower (<i>Ratibida pinnata</i>)	Wildflower	- Provides seeds for birds
New England aster (<i>Symphyotrichum novae-angliae</i>)	Wildflower	- Provides seeds for birds
Partridgeberry (<i>Mitchella repens</i>)	Groundcover	- Fruits have medicinal values
Red-berried elder (<i>Sambucus pubens</i>)	Shrub	- Provides fruit for birds
Red osier dogwood (<i>Cornus sericea</i>)	Shrub	- Provides fruit for birds - Bark, stems, roots, fruits, pits, twigs and leaves have medicinal values
Wild bergamot (<i>Monarda fistulosa</i>)	Wildflower	- Provides nectar for birds - Roots, flowers and leaves have medicinal values
Wild ginger (<i>Asarum canadense</i>)	Groundcover	- Roots and rhizomes have medicinal values
Wild strawberry (<i>Fragaria virginiana</i>)	Groundcover	- Leaves and fruits have medicinal values

(Uprety et al. 2012) (Hanrahan 2005) (Ottawa 2012)

To a lesser extent than the birds, the roof gardens contribute to the conative pursuit with the other site entities. First, the green roof, combined with the climbing plants that cover the stone facades (illus. 41 to 43) and the vegetation on the ground, prevents the erosion of the riverbanks by slowing, sinking and storing rainwater (Biomimicry Group & HOK Group 2014). It also prevents overflow of the sewage system into the river by absorbing and filtering storm waters that would otherwise run off. Second, the conativity of the pine forest is advanced by the restoration of on site plant life. This measure facilitates ecological processes that have been compromised by industry and other human activities.

Illustration 40: Roof garden in winter

While the gardens reach their peak condition in the summer, they will be maintained all year long and host a series of activities promoting Aboriginal culture and contact with local nature. In particular, an interesting Native custom, traditionally reserved for the coldest months of the year, will be observed in winter (illus. 40). Indeed, storytelling occurs when nature lies dormant:

This was a practical choice given the fact that during the other seasons people were busy growing, gathering and hunting food. It was in the winter, with the long dark evenings, the snow and wind blowing outside, that telling stories was a way to entertain and teach the children. Another reason is that many traditional stories contain animal characters. To be respectful, people waited until the winter when animals hibernate or become less active so they cannot hear themselves being talked about. (Indian Land Tenure Foundation 2016)

Traditional storytelling plays an important role in the transmission of knowledge in Aboriginal cultures and can significantly promote intercultural understanding as well as interconnectedness with the land. It therefore is crucial to provide spaces that can animate these stories. The roof gardens offer an intimate environment ideal for listening and learning about the Aboriginal worldview. Simple shelters may be created by laying traditional wall coverings on certain areas of the canopy, so that the assembly may be protected from the elements while maintaining a sense of being within nature.

Illustration 41: South elevation
scale 1:400

Illustration 42: North-west elevation
scale 1:400

Illustration 43: North-east elevation
scale 1:400

CONCLUSION

A built environment inspired by the biological and natural world is an inspiring concept. It suggests an architecture that embraces nature, interacting constructively with the environment rather than in opposition to it. I believe biomimicry has the potential to realize this compelling vision of techno-ecological synergy. In this thesis, I have argued that a proper philosophical framework is required in order to go further than the mitigation of the effects of modern technology and allow biomimicry to flourish into a truly revolutionary approach to design. More precisely, biomimicry must clearly reject the industry-driven paradigm of modern society, which does not acknowledge the moral value of nature. Its agency must be committed to emulate the essence of nature (Mathews 2011). Thus, design must be informed by a profound understanding of the dynamic and collaborative relational network of the biosphere.

The integrated and reciprocal relationship interlacing the built and the natural environment makes a philosophy of biomimicry particularly relevant to architectural design. Indeed, the landscape continually informs architectural interventions, which in turn transform the landscape in which they are set. This signifies that nature and the relationships within it are constantly evolving in reaction to changing environmental forces, including human activities. If the goal of biological emulation in technology is to ultimately enter into a synergistic relationship with the life systems of our planet, then it is crucial to go beyond the compartmentalized knowledge of biology. We must uncover the essence of nature as well as the principles underlying its dynamic transformations (Mathews 2011). We must also discover how humankind relates to these processes for

architecture to evolve beyond its static presence (Armstrong 2011a) and become actively engaged in a mutually constructive network of ecological interactions.

This thesis has addressed a philosophical foundation for biomimicry by exploring the role of the twin principles of nature, as defined by environmental philosopher Freya Mathews (Mathews 2011), in establishing synergy in non-human living systems: the first, conativity, is described as the striving to continue and expand one's own existence within a particular environmental context; the second, least resistance, is the instinct to conserve one's energy by avoiding confrontation and straining work, resulting in a minimal disruption of the environment (Mathews 2011). In nature, organisms let the environment guide their conative pursuits, harnessing its fluctuating forces in accordance with the principle of least resistance rather than setting against them. By doing so, they minimally disturb and even assist the conativity of the other organisms evolving in the same environment (Mathews 2011). To reach techno-ecological synergy, humans must adapt their designs to the environment in the same manner, letting it determine our desires rather than imposing ours on them (Mathews 2011). However, because our mind possesses a unique capacity for reflexive awareness, we tend to define our existential aspirations differently than the rest of nature. Indeed, our mind attributes conceptual values to our existence beyond survival, transforming our conativities and sometimes steering us away from the path of least resistance. Yet, reinstating ourselves within the synergistic network of nature remains within our reach as our physical and mental foundations are essentially linked to our environment (Mathews 2011).

The modern alienation of nature takes roots in the medieval Christian concept of the "rational soul" (Steiner 2011), an erroneous interpretation of

reflexive awareness as proof of the ontological superiority of humankind over the rest of nature. This view has encouraged the systematic exploitation of nature up to modern times (White 1967) and persists despite an increasing secularization of society. Modern technology, enabled by this paradigm, ignores the intrinsic quality of nature and rather challenges it into appearing as a “standing-reserve” for industrial production (Heidegger 2008). This agency is pervasive enough to exploit and alienate humankind in a similar manner in the interest of efficiency (Foltz 1995) (Heidegger 2008). Biomimicry emerges as a reaction to this paradigm but often remains inadvertently embedded in it (Goldstein & Johnson 2014), which is why a clear philosophical reflection is required in order to establish the scope of its agency.

The philosophical framework for biomimicry proposed in this thesis is centered on the notion of bioinclusivity, an ethic that does not favor humankind but attributes an equal value to all species populating the Earth (Mathews 2011). An interesting ideological precedent may be found in animistic cultures, who believe humankind emerges from the same cyclic processes of life as the rest of nature, making them ontologically similar (Ingold 2006). This cosmological understanding creates a sense of astonished openness, as opposed to the modern sense of alienation, and ensures that humankind feels rooted in its environment (Ingold 2006). This, in turn, allows us to create holistic designs through *techné*, a mode of creation which is attuned and responsive to the world (Heidegger 2008) (Foltz 1995). The biomimetic design method, in order to promote technoeological synergy, should stem from *techné* as much as from biological science. By doing so, biomimicry may allow the architectural designer as well as the inhabitants of architecture to engage and integrate with the natural landscape on multiple levels.

An exploration of existing biomimetic initiatives has shown how the current practice lacks a clear philosophical direction. Thus, the Eastgate Centre is ultimately an iteration of modern technology mitigated by a biomimetic form rather than a true alternative (Turner & Soar 2008), which is insufficient in establishing a synergistic relationship between architecture and the environment. Similarly, while the design of the Eden Project Biomes attempts to respect the conativities of the local environment (Pawlyn 2011), the plants cultivated within the greenhouses are potentially invasive exotic plants that may threaten native species (Hulme 2015), demonstrating an inclination in favor of human desires over ecological preservation.

In comparison with built projects, academic research in biomimetic architecture is philosophically much more precise and alludes to the principles of life described by Mathews. Frei Otto explored form-finding processes before the concept of biomimicry was defined, yet his work with physical models displays a deeply attuned responsiveness to materials (Goldsmith 2016) akin to *techné*. Although his work does not quite qualify as synergistic, Otto was concerned with respecting the conativity of the environment as well as following the path of least resistance through an economy of materials and energy (Goldsmith 2016). Neri Oxman's material-based computational design method is concerned with similar questions (Oxman 2010b) (Oxman 2010a), suggesting that explorations in the digital realm may approach *techné* in the future, thus becoming a valid mode of creation for techno-ecological synergy. In another vein, the self-generating metabolic materials envisioned by Rachel Armstrong distinguish themselves from *techné* as they grow autonomously following an initial human input in the form of protocells (Armstrong 2011b). Architectural creation with metabolic

materials is thus not as haptic as with other methods, however the resulting organic structures may still create an interesting sensorial experience.

The philosophy of biomimicry proposed in this thesis has been put to practice in the design proposal for the Asinabka Indigenous Cultural Centre. The program celebrates the inherently bioinclusive culture of the Aboriginal Peoples of Canada, in particular their relationship with the land, which “shapes all aspects of their lives” (Wilson 2003). The design has been informed by the animistic beliefs of the First Nations, notably the teachings of the Medicine Wheel concerning the vital role of an all-encompassing relationship with Mother Earth in the maintenance of holistic health. In this spirit, the project has focused on establishing a conative dialogue with three natural entities of the site, namely the river, the birds and the pine forest. This strategy was designed to promote techno-ecological synergy in the Western world by presenting an alternative to the technological enframing of modern industry.

The defining architectural component of the Cultural Centre is a biomimetic glue-laminated structure, designed to symbolically express the reclamation of the former industrial site by nature and the bioinclusive society. In compliance with the philosophical framework established in this thesis, the design lies at the intersection of techné and biological emulation. Indeed, a weaving of fibrous materials, informed by multiple traditional crafts as well as by the organization of beta-keratin fibers in the feather rachis (Lingham-Soliar 2014) inspires the helical arrangement of the columns. In the same vein, the efficient hexagonal organization of the honeycomb (Biomimicry Institute n.d.) has been emulated to generate the overall arrangement of the structure. The combination of these ideas culminated in a physical model, which was further

iterated digitally. Because computational techniques do not currently engage the same sensitivities as *techné*, it was crucial to utilize them in conjunction with the information gathered through physical modeling. The alternation between physical and digital modeling thus enhanced the design process and could be repeated indefinitely in order to optimize the form and structure of the arboreal canopy.

The arboreal structure, as a “forest”, accomplishes several functions defined in continuity with the conativities of the site entities. Thus, the rain collecting system harvests precipitation and recirculates water in the building for various uses, diminishing the need for treated water from the river. Additionally, the vegetated portions of the columns and canopy encourage the diversity of both plant and animal life on the site surrounding the building. People of all cultures involved in the cultivation of these plants are expected to reflect on the effects of their desires on the environment and adapt their conativities accordingly. In this manner, they might come to share the Aboriginal understanding of a healthy environment as crucial to our physical, mental, emotional and spiritual well-being.

The roof gardens were envisioned as the culmination of the renewed feeling of being part of nature. In this area, architecture and nature intermingle more strongly than anywhere else in the building, thanks to the overwhelming presence of vegetation under the cover of the arboreal canopy. Urban wildlife, in particular birds, are expected to feed and nest in this area in the summer months, establishing a new sensorial exchange with human communities. In winter, the cold temperatures and the snow that form an integral part of the Canadian identity will reveal another aspect of our relationship with the land: in response

to this dormant nature, the Indigenous tradition of storytelling will be promoted to animate the roof gardens.

The work undertaken in this thesis has revealed the philosophical complexity of biomimetic architecture. At least since the Industrial Revolution, architecture and technology as products of culture have been conventionally understood as the opposite of nature (Sterling 2011). In a bioinclusive paradigm, the notions of nature and culture will take on new meanings and, with time, they would most likely blend into one another. Understanding and embodying a bioinclusive ethic will require an ongoing social and ideological commitment. In this sense, reestablishing Western society within the natural world through architecture and other design endeavors might be the work of a generation of designers.

The design proposal presented in this thesis offers the beginning of possible solutions, particularly by emphasizing a constructive conative relationship between the human and natural communities at a given site. However, the second principle of life, namely least resistance, has remained largely unaddressed by the design proposal. The project has evolved under the assumption that design through techné would necessarily achieve an economy of effort, yet the arboreal structure arguably uses a superfluous amount of material. While the symbolism embedded in the structure was intended to embody interconnectedness with nature, this strategy now appears to contradict itself by going against one of the fundamental principles of life and compromising techno-ecological synergy. Least resistance would thus need to be integrated more consciously into the design method from the very beginning. A better understanding of all the environmental forces affecting the site is necessary in order to conceive appropriate strategies.

Traditional Aboriginal architecture may constitute a satisfying example of architecture accomplished through *techné* with respect for conativity and least resistance. In this sense, the relationship with the landscape goes beyond protection against the elements. This architecture is shaped by the environment, from its materials to its form and functions. Moreover, it embodies social practices and cultural norms that have developed over centuries (Nabokov & Easton 1989). Each typology, whether it is the teepee, the wigwam or the igloo, is holistically responsive to both the environment and the people for which it is designed. This architecture, rather than depending on blueprints and on building codes, is rather reliant on customs “transmitted through oral tradition and learned through repetition” (Nabokov & Easton 1989). Could it be that architectural drawings, as they are currently used, are themselves a product of modern technology embedded in the problematic industrial paradigm of modernity (Armstrong 2011a)? In this context, what would be an appropriate role for the resolutely modern, yet greatly seductive and powerful, computational tools in the biomimetic design method? Additionally, can traditional Aboriginal design techniques produce a holistic design at the scale of a multi-purpose complex such as the one proposed in this thesis? In any case, it appears that biomimetic architecture will require its own language in order to finally embrace the holistic character of nature and reach techno-ecological synergy. Finding the right approach is the challenge of this and future generations.

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