



Degree Program in Global Management and Politics

Course of **Global Organisation Design and HRM**

Understanding the Biomimetic Organization Through Life's Principles

Prof. Luca Giustiniano

SUPERVISOR

Prof. Silvia Dello Russo

CO-SUPERVISOR

ID 73111

CANDIDATE

Academic Year **2021/2022**

CONTENTS

1. Introduction	3
<i>1.1 Sustainability, frameworks and incentives</i>	4
<i>1.2 Nature’s definition</i>	5
2. Patterns of Nature	6
<i>2.1 Evolve to survive</i>	7
<i>2.2 Adapt to changing conditions</i>	9
<i>2.3 Be locally attuned and responsive</i>	11
<i>2.4 Integrate development with growth</i>	13
<i>2.5 Be resource efficient</i>	15
<i>2.6 Use life-friendly chemistry</i>	17
3. Methodology	20
<i>3.1 Interviews & Indicators</i>	20
<i>3.2 The Value Creation Tool</i>	21
4. Building the tool	22
<i>4.1 Extracting the indicators</i>	22
<i>4.2 The graphical representations</i>	35
5. Implications for managers	35
6. Limitations	36
7. Conclusion	37
8. Bibliography	39
Appendix 1	41
Appendix 2	49
Appendix 3	54
Summary	55

1. Introduction

Organisms and ecosystems have been perfected throughout millennia of evolution and have remained robust to perturbations by continuing to evolve according to the requests of the environment. Natural structures have, for these reasons, acted as an inspiration for human engineering, architecture and design for millennia. In fact, the original definition of *biomimetics* was coined by Otto Schmitt as the '[examination] of biological phenomenology in the hopes of gaining insight and inspiration for developing physical or composite bio-physical systems in the image of life.' However, this efficacy has not solely been limited to replicating nature in the physical and structural dimensions. Researchers since the early 2000s have begun exploring biomimetics in the organizational and relational dimensions as inspirations for human action in the fields of organization theory and management.

Biomimetics applied to the organizational sphere may offer insights into long-term sustainability, help organize and delegate work, increase adaptability in uncertainty, aid in becoming more in harmony with the local 'ecosystem', and even reimagine the organizational model as a whole. These objectives are crucial in a time in which firms must transition from using nature as a resource, to recognizing it as a whole which they are part of¹. There is a strong necessity for a sustainable accountability framework of the firm - which goes further than contemporary approaches like the Triple Bottom Line, ESGs or the Circular Economy- and biomimicry may be effective and radical enough to be this very framework.

The issue remains in the applicability of such a framework. A modern definition presented by Bogatyreva in *Biomimetic Management* sheds light on this question: 'biomimetics is not simply copying nature – it involves extracting laws and patterns from nature under conditions specific to the system and then, by analogy, applying these regularities to construct a new system'². In this paradigm, who practices biomimetics takes on an interpretative role rather than a imitative one. Laws, patterns and principles, instead of structures, become the objects

¹ Elkington, John. "Accounting for the Triple Bottom Line." *Measuring Business Excellence* 2, no. 3 (1998): 18–22. <https://doi.org/10.1108/eb025539>.

² Bogatyreva, O.A. and Shillerov, A.E. (2015) "Self-organization and self-management," in *Biomimetic Management: Building a bridge between people and nature*. North Charleston: Createspace Independent Publishing Platform.

Understanding the Biomimetic Organization Through Life's Principles

of observation to be decontextualized, interpreted and finally applied. The Life's Principles, a set of broad natural principles developed by the Biomimicry Institute, will act as the baseline for this interpretation. The second chapter of this paper will depart from these very principles, which each hold necessary strategies and applications in nature. On the basis of these strategies and applications, leading figures from two companies, selected on the basis of their innovative approaches and diverging fields, will be interviewed. Combined with the research conducted in chapter two, the interviews will serve to inform the development of a set of qualitative organizational indicators for the application of the Life's Principles. The indicators will be the building blocks of an evaluative tool which assigns these qualitative answers specific numerical values which can be elaborated thus providing a pragmatic understanding of biomimetic application at the organizational level.

The objective of this paper is therefore to provide a framework for researchers to qualitatively understand biomimetics applied to organizations in a realistic way. Hopefully this paper will serve as a broad and yet realistic step in the application of biomimetic frameworks at the organizational level.

1.1 Sustainability, frameworks and incentives

The current global context is marked by increasing concerns about the negative impact of human activity on the environment and society. Climate change, dwindling natural resources, social inequality, and energy insufficiency are just a few of the challenges which are faced today. In response to these challenges, organizations around the world are being called upon to adopt more sustainable practices and measures.

The European Union (EU) is at the forefront of these efforts. One of the ways in which the EU is working to promote these sustainable measures is through the use of sustainability reporting frameworks such as the Global Reporting Initiative (GRI), the Sustainability Accounting Standards Board (SASB). These frameworks aid organizations in identifying and reporting on key issues such as environmental stewardship, social engagement and governance.

In addition to promoting frameworks, the EU has also implemented a number of policies and regulations aimed at promoting sustainable practices and measures for organizations. For

Understanding the Biomimetic Organization Through Life's Principles

example, the EU has introduced legislation on the circular economy, which aims to reduce waste and promote the reuse and recycling of materials. Also, the EU has begun implementation of a carbon tax and carbon credits, both with the aim of making carbon emissions an expensive externality for organizations.

The EU also encourages sustainable practices through funding, subsidies and different incentives like the European Green Deal which aims to achieve climate-neutrality by 2050, investing in clean energy, and promoting circular economy, biodiversity, and sustainable food systems.

In Italy, the adoption of sustainable practices and frameworks is still in its infancy, and there is much work still to be done. Despite this, there are opportunities for organizations to adopt more sustainable practices, and there is much to be gained from doing so through financial incentives like the ones provided by the PNRR³. This plan has allotted over 69 billion euros to green energy and ecological transition in Italy.

This context describes a moment of incredible impetus for sustainability policies and frameworks and there is financial backing. It is therefore essential for organizations to capitalize on this transformative moment and develop or adopt their own sustainable framework to transition.

1.2 Nature's definition

When speaking of nature, there are often a variety of philosophical and semiotic difficulties which are encountered. One of such difficulties is the scope and definition of the word *nature*. What precisely is nature and where does it extend to? Are humans nature? Is there something which is *not nature*?

For the purposes of this paper, nature will be that which is observed on earth which is not man-made: organisms of all types, from unicellular bacterium, to fungi, to plants, to animals. As well as natural processes such as the carbon cycle, cloud formations, geological

³ Piano Nazionale di Ripresa e Resilienza (National Plan for Recovery and Resilience), plan approved in 2021 by Ital. Gov. to restore Italy's economy to pre-COVID-19 levels as well as encourage energy independence through green transition

transformations, dynamics and interactions between organisms or between organisms and the inanimate.

Human beings are part of nature. However, there is also something which differentiates humanity from the rest of the natural world. This is a widely debated and extremely complicated philosophical question. For the purposes of this paper, the researcher chose to view the differentiating factor between humanity and the rest of nature as the speed at which humanity evolves. This speed is aided and promoted by the use of technology which often advances much faster than our biological structures. Technology causes astronomical transformations in very short time periods, think of the transformations society has undergone in the last 100 years. These changes occur and their effects are not tested over prolonged timespans, where true resilience and sustainability is established. In fact, the average lifespan of a company has been in decline since the 1960s⁴. Therefore, there may be real use in looking towards nature's slow and gentle processes to understand what can be learned. This may also give us a *moral* orientation of where to go as a species. Rather than simply aiming to create value for stakeholders in the short-medium term, looking towards nature could be a way of integrating abundance, resilience and sustainable development over centuries.

2. Patterns of Nature

The patterns nature offers are potentially infinite. Each organism has its own specific actions and behaviors which follow internal logics and objectives.⁵ This is what differentiates the animate from the inanimate. Many biomimetic researchers and engineers have in fact focused on one species of organism to learn from or imitate and have reaped great successes.⁶ The aim of this paper however, is to go further than the individual species and organisms to rather look at nature as a whole. Though specific applications may be extracted from a single species, observing nature as a unitary phenomenon allows for a comprehensive framework to aspire towards. As mentioned earlier, however, this paper is not an attempt to carve out the

⁴ Statista, "Average Company Lifespan of S&P 500 Companies 1965-2030."

⁵ Bogatyreva, O. and Shillerov, A. (2015) "Top-down, bottom-up or up-side down," in *Biomimetic Management: Building a bridge between people and nature*. North Charleston: Createspace Independent Publishing Platform.

⁶ Vincent, J.F.V. *et al.* (2006) "Biomimetics: Its practice and theory," *Journal of The Royal Society Interface*, 3(9), pp. 471–482. Available at: <https://doi.org/10.1098/rsif.2006.0127>.

Understanding the Biomimetic Organization Through Life's Principles

perfect biomimetic firm, but rather a general framework which can aid in understanding biomimetic organization.

Though a scientific consensus on the overarching patterns of nature has not been reached, nature's *Life Principles* are an inspiring step in that direction. The *Life Principles* is a framework proposed by the Biomimicry Institute⁷ in 2010, composed of six essential principles (macro-patterns) observed across a very wide variety of organisms and natural processes. Each principle holds a set of strategies which are fundamental in understanding the framework as a whole. These strategies will provide an understanding of the possible organizational applications of Life's Principles. Therefore each principle will be both presented with its natural strategies and examples, as well as its possible applications in organizational theory. These organizational examples aim to clarify some of the possible applications of these strategies.

Nature's Six Life Principles are⁸:

1. Evolve to survive
2. Adapt to changing conditions
3. Be locally attuned and responsive
4. Integrate Development with Growth
5. Be Resource Efficient
6. Use Life Friendly Chemistry

2.1 Evolve to survive

One could describe *evolution for survival* as the quintessential pattern in nature. The Biomimicry Institute describes it as a “continuous incorporation and embodiment of information to ensure enduring performance”. This process of evolution can be broken down

⁷ The Biomimicry Institute is a research hub for education, culture and industry application of biomimicry. It is one of the foremost exponents of biomimetics at the global level.

⁸ Biomimicry Institute, 2010

into a variety of sub-strategies: *replication of successful strategies, integration of the novelty and reshuffling of information.*

First and foremost, evolution is a replication of successful strategies. Repetition and conservation of successful functions and structures is selected for through ‘the survival of the fittest’. This can be observed in the long-term with the conservation of working structural elements compared to less useful ones. For example, humanity has been cooking its meat for millennia now and contemporaneously we are losing our third set of molar teeth, the ones used in intensive chewing, necessary to break down the tough fibres of raw meat⁹.

Coupled with the conservation of successful strategies, is also a constant integration of novelty. When new dynamics emerge, an organism will transform accordingly. Darwin’s observations of finches in the Galapagos demonstrates how little environmental differences, like the abundance of a particular fruit or seed on one island, can lead to important structural differences in the same species¹⁰. The prime example of this process of integration is genetic mutation, a directed trial and error which selects for successful innovations. In this sense, mistakes are always an opportunity to grow in nature. For mistakes to be valuable, organisms have a mechanism of continuously reshuffling and exchanging information to create new options. This reshuffling can occur only because information is fast and free-flowing and organisms are often profoundly interconnected and dependent on each other and with the surrounding environment. One example is ant colonies’ communication systems, which can transmit highly sophisticated messages across a whole colony in a matter of seconds¹¹, or the signals which trees can send miles apart¹². Free-flowing information systems allow organisms to be extremely sensitive to changes in the environment while also remaining agile in transforming and altering that very information for their own benefit.

⁹ Hawks, “Why Are Humans Evolving to Lack Their Wisdom Teeth?”

¹⁰ In Darwin’s observations, in a couple of generations the finches beaks transformed to adapt to shapes of fruits or seeds they needed to obtain. Abzhanov, Protas, Grant, Tabin, Abzhanov, A. *et al.* (2004) “*bmp4* and morphological variation of beaks in Darwin's finches,” *Science*, 305(5689), pp. 1462–1465. Available at: <https://doi.org/10.1126/science.1098095>.

¹¹ Jackson, D.E. and Ratnieks, F.L.W. (2006) “Communication in ants,” *Current Biology*, 16(15). Available at: <https://doi.org/10.1016/j.cub.2006.07.015>.

¹² Simard, S.W. (2018) “Mycorrhizal networks facilitate tree communication, learning, and memory,” *Memory and Learning in Plants*, pp. 191–213. Available at: https://doi.org/10.1007/978-3-319-75596-0_10.

Evolve to survive has several possible implications for organizational theory. First and foremost, it emphasises the *replication of successful strategies*. If an organization identifies a strategy or function as successful, it should try to understand why such a strategy works, conserve it and try to replicate it. Conversely, an organization's unsuccessful innovations should not necessarily be seen as failures, rather they should be regarded an integral part of the evolving process. It is particularly important to *learn from an organizational mistake*: what went wrong, is there any redemption for this idea, what can be tweaked or improved, etc. These processes can be much more easily accommodated if information is free-flowing in and outside the company. Communication systems, internet and interconnectedness allow for information to travel at higher speeds and magnitude. These communication systems can accommodate information exchange both within and outside the organization. Having a greater number of minds and perspectives work on a problem will likely lead to a greater amount of mistakes and errors, but will also make for faster innovation and evolution¹³. This concept mirrors the *open innovation* framework proposed by Henry Chesbrough¹⁴, which is demonstrating high resilience and success in its early applications.

2.2 Adapt to changing conditions

To adapt to changing conditions, nature remains in touch, sensitive and responsive to the dynamic processes which surround it. For example, when there are changes in weather, like a sudden rainstorm in a forest, the whole ecosystem will respond to it, from one day to another, plants will change positions, animals and insects might seek cover, fungi will grow. This adaptive quality is necessary to keep integrity through constantly transforming conditions. For this adaptation to keep working, an organism must constantly add energy and resources to alter its repetitive strategies to adapt to ongoing changes. One example of this process being foraging ants voluntarily altering searching and foraging behaviours¹⁵. Energy is very valuable in nature, but a part of it must be dedicated to a constant adaptation and exploration.

¹³ Amabile and Khaire, *Creativity and the Role of the Leader*

¹⁴ Chesbrough, H. (2019) "From open science to open innovation," *Open Innovation Results*, pp. 51–66. Available at: <https://doi.org/10.1093/oso/9780198841906.003.0004>.

¹⁵ Gordon, D.M. (1995) "The expandable network of Ant Exploration," *Animal Behaviour*, 50(4), pp. 995–1007. Available at: [https://doi.org/10.1016/0003-3472\(95\)80100-6](https://doi.org/10.1016/0003-3472(95)80100-6).

The energy release expended in adaptation can however be mitigated through prediction mechanisms. Prediction mechanisms test out the environment by adopting a variety of different processes, forms and behaviors. This variety and diversification allows for an organism or population to be prepared in the case of changing conditions. Organisms also actively predict for what might occur in the short and medium term. One well-known phenomenon is farm animals predicting large earthquakes by showing erratic behavior even 24 hours before the fact¹⁶. Another example, observed across a variety of species, is hoarding and preparatory behaviors before winter¹⁷. These predictive mechanisms are essential for preparation and programming, which in nature may be the very essence between life and death.

These strategies hold a variety of possible applications and implications for organizations. Firstly, organisms can maintain integrity through self-renewal by constantly adding energy and resources to the system. This can be applied to organizations by regularly evaluating and updating policies, processes, and systems to improve performance and stay competitive. An example of this would be a company that regularly conducts a SWOT analysis to identify and address its strengths, weaknesses, opportunities, and threats.

Another strategy applied in nature is to increase resilience through predictive mechanisms of variation, redundancy, and decentralization. Organizations could potentially achieve this strategy by promoting a culture of experimentation, diversifying teams, and having multiple systems in place to mitigate risks and minimize the impact of unexpected events. An example could be a company that has multiple suppliers of raw materials to ensure continuity of operations in case of disruptions, as well as a culture of experimentation with different products, services and methods to ensure they are always ahead of the competition.

Finally, incorporating diversity is also crucial in organizations. A diverse workforce brings different perspectives and ideas to the table, leading to better decision-making and problem-solving. An example of this would be a company that actively seeks to recruit individuals

¹⁶ Wikelski, M. *et al.* (2020) "Potential short-term earthquake forecasting by Farm Animal Monitoring," *Ethology*, 126(9), pp. 931–941. Available at: <https://doi.org/10.1111/eth.13078>.

¹⁷ White, J.A. and Geluso, K. (2012) "Seasonal link between food hoarding and burrow use in a nonhibernating rodent," *Journal of Mammalogy*, 93(1), pp. 149–160. Available at: <https://doi.org/10.1644/11-mamm-a-031.1>.

from underrepresented groups or with divergent thinking to bring new ideas and perspectives to the organization.

2.3 Be locally attuned and responsive

To *be locally attuned and responsive* addresses the necessary links and interrelations organisms have with and within their surrounding environment. A species in nature can never exist alone, it always exists within an ecosystem, surrounded by a variety of other organisms on which it is dependent, be it for food, mutualistic relationships, exploitative relationships, competition or even for predatory pressure. A great example of this interdependency is the predator-prey model. If the number of prey increases as they reproduce then predators have more access to food and thus increase in number as well. Prey, at this point, will decrease due to being overexploited, and by consequence the number of predators with access to food decreases as well, lowering their number, and the cycle continues on and on. Nature constantly reaches new equilibriums, which equalize disproportionate imbalances in resources or distribution.

Why does this mechanism function? This is due to organisms capacity to fit perfectly and integrate within their surrounding environment. In nature, what is used is readily available materials, energy and relationships. Usually what is most used is the resource which is most abundant within the local area. Desert foxes hunt for scorpions and locusts and eat leaves to stay hydrated, foxes in a forest will usually eat small mammals and drink from streams. Arctic foxes will eat any anything from stool to berries to any animal dead or alive and eat snow. The major differentiating factor between these cousin species is the environment they live in and their attunement to it.

Another important strategy found throughout nature is the willingness to form cooperative relationships. Mutualistic relationships can be found everywhere throughout nature, between bees and flowers, trees and fungi, humans and bacteria, coral and algae, etc. These relationships serve both to facilitate integration with the environment as well as improve survival chances for both species. These relationships often develop because it begins as a marginal benefit for both species, and through repetition and specialization it becomes more and more integral of the species' behavior to the point where some become interdependent on the relationship.

Understanding the Biomimetic Organization Through Life's Principles

Cyclic processes and feedback loops are key in enabling attunement and responsiveness to the surrounding environment. An example of a cyclic process found in nature is the water cycle, in which water evaporates from the Earth's surface, forms clouds, and then falls back to the surface as precipitation forming lakes, rivers, puddles, which in turn evaporate and so on. This cycle helps to regulate the Earth's temperature and distribute water to different parts of the globe, ensuring the local availability of this essential resource. Another example of a cyclic process is the carbon cycle, in which carbon is exchanged between the atmosphere, land, and oceans through processes such as photosynthesis and respiration. This cycle plays a crucial role in regulating the Earth's climate by sequestering excess carbon dioxide from the atmosphere. Similarly, feedback loops, such as the one found in the Earth's climate system, also help to maintain ecosystems regulated to their surroundings. For example, the greenhouse effect, in which certain gases in the Earth's atmosphere trap heat and warm the planet, is regulated through feedback loops that adjust the amount of these gases in the atmosphere in response to changes in temperature. By utilizing cyclic processes and feedback loops, natural systems are able to maintain balance and adapt to their surroundings.

Utilizing readily available materials and energy is a crucial strategy for a sustainable local environment. In an organizational context however it seems the inverse is true. Very often firms and companies source materials and energy from abroad, for lower cost margins. This leads to a variety of externalities such as emissions due to transport, dependency on energy from external sources, exploitation of third world countries and employees. On the other hand, by using sustainable resources and implementing energy-efficient practices locally an organization will become more resilient, independent and financially stable in the long-run. Finally, cultivating cooperative relationships is a key strategy found in nature. In organizations, this can be achieved by fostering a culture of collaboration and teamwork internally and externally. For example, a company may create a network of organizations and universities to encourage cross-pollination and collaboration on innovation projects.

For cyclic processes, organizations could leverage the cyclical patterns in the market, by aligning their operations and strategies accordingly. For example, a retail company may plan their inventory and promotional strategies based on the cyclical patterns of consumer demand throughout the year. Whereas feedback loops could be applied in an organizational context by creating systems for continuous feedback and improvement. For example, a company may

implement a customer feedback system for CRM (customer relationship management) that allows for real-time feedback on products and services, which can then be used to make necessary improvements.

2.4 Integrate development with growth

Natural Strategies

“Integrate development with growth suggests approaches for maintaining stability and prevailing under complex circumstances. With self-organization an element of this principle, we observe birds, ants, fish, and many other species employ graceful and uncomplicated survival techniques. For example, ‘flocks of birds dance across the sky, as if flowing choreography. Without a director, these birds self-organize with simple rules that effectively result in emergent, aligned community’¹⁸

Nature has developed a variety of strategies for integrating development with growth in a way that is efficient and sustainable. One such strategy is the use of *modular and nested components*, which allows for the fitting of multiple units within each other progressively from simple to complex. This strategy is seen in the hierarchical structure of many natural systems, such as the organization of cells into tissues, tissues into organs, and organs into systems within living organisms. For example, the human respiratory system is composed of nested components such as the bronchi, alveoli, and capillaries, which work together to provide oxygen to the body's tissues.

Nature therefore prefers building from the bottom up approach, by assembling components one unit at a time. This strategy is seen in the construction of natural structures such as shells, skeletons, and nests, which are built from small, individual units that come together to form a larger whole¹⁹. An example of building from the bottom up is a beaver's dam. It is constructed from branches and mud that are placed one by one to create the structure. This bottom-up approach allows for flexibility and adaptability in the face of changing environmental conditions.

¹⁸ Biomimicry for Social Innovation, 2018

¹⁹ Bateson, G. (2002) *Mind and nature: A necessary unity*. Cresskill, NJ: Hampton Press.

Understanding the Biomimetic Organization Through Life's Principles

Nature also employs the strategy of self-organization, which involves creating conditions to allow components to interact in concert to move towards an enriched system²⁰. An example of self-organization is the formation of a school of fish, in which individual fish align their behavior and movements with those of their neighbors to create a cohesive unit²¹. By self-organizing, natural systems are able to adapt and evolve in response to changing conditions.

In organization theory, modularity can be applied at many different levels through the use of modular design, which involves creating components that can be easily combined and rearranged to form a larger whole. Modularity can serve both in product development as well as in organization structure. This approach allows organizations to adapt swiftly in response to changing market conditions and customer needs. For example, the automotive industry has successfully implemented modular design in the production of cars, allowing for the customization of individual components such as engines and transmissions to meet specific customer requirements.

Building from the bottom-up can be applied through incremental development, in which an organization breaks down a large project into smaller, achievable goals that can be completed one at a time²². This approach is also extremely successfully adopted in the Kaizen philosophy of development used in many Japanese firms. This philosophy aims at a small incremental development coming from the lower levels of the firm. This type of development doesn't radically change the firm causing necessary readaptation at every step, but rather incrementally and constantly improves it.

On the other hand, nature's use of self-organization, in which conditions are created to allow components to self-coordinate and move towards an enriched system, can also be translated to organizational practices in order to facilitate development and growth. One way in which this strategy can be applied is through the use of self-organizing teams, in which team members are given the autonomy to organize and coordinate their work in a way that best meets the needs of the organization. This approach can lead to greater creativity, innovation,

²⁰ Prigogine, I. and Stengers, I. (1985) *Order out of chaos: Man's new dialogue with nature*. London: Fontana Paperbacks.

²¹ Couzin, I.D. *et al.* (2005) "Effective leadership and decision-making in animal groups on the move," *Nature*, 433(7025), pp. 513–516. Available at: <https://doi.org/10.1038/nature03236>.

²² Kerzner, H. (2017) "Project Management Case Studies." Available at: <https://doi.org/10.1002/9781119389040>.

and efficiency within the team. For example, the software company Valve has implemented a self-organizing structure in which employees are free to choose the projects they want to work on and form teams around those projects. This approach has resulted in a high level of employee satisfaction and a strong track record of successful projects.

Another way in which the strategy of self-organization can be applied in organizational practices is through the use of complex adaptive systems, in which an organization's various components (such as departments, teams, and individuals) are able to interact and adapt in response to changing circumstances²³. This approach allows organizations to be more flexible and responsive to their environment, and can lead to greater innovation and long-term success. For example, the organizational structure of the biotech company Genentech is based on a complex adaptive system model, in which teams are free to form and dissolve based on the changing needs of the organization. This approach has allowed Genentech to remain at the forefront of its industry and achieve consistent growth.

2.5 Be resource efficient

“As society demands more ecologically responsive leaders, the principle of *be resource efficient* serves as a standard for the competent and sensible use of limited resources and opportunities within an organization, i.e. sustainable practices, managing a team’s time and using low energy processes in long-term projects”

The strategy of using low energy processes is observed in the metabolic processes of living organisms, which are designed to operate at the lowest possible energy cost²⁴. For example, the process of photosynthesis in plants, which converts sunlight into chemical energy, is highly efficient, with less than 1% of the energy absorbed being lost as heat. By utilizing low energy processes, natural systems are able to conserve resources and maintain sustainability.

²³ Holling, C.S. (2001) “Understanding the complexity of economic, ecological, and Social Systems,” *Ecosystems*, 4(5), pp. 390–405. Available at: <https://doi.org/10.1007/s10021-001-0101-5>.

²⁴ Schneider, E.D. and Kay, J.J. (1994) “Life as a manifestation of the second law of Thermodynamics,” *Mathematical and Computer Modelling*, 19(6-8), pp. 25–48. Available at: [https://doi.org/10.1016/0895-7177\(94\)90188-0](https://doi.org/10.1016/0895-7177(94)90188-0).

Understanding the Biomimetic Organization Through Life's Principles

Nature also manages resource efficiency through the recycling of all materials, by keeping them in a closed loop. This strategy is seen in the way that natural systems such as ecosystems and watersheds recycle nutrients and other substances through processes such as decomposition and evaporation. An example of material recycling in nature is the nitrogen cycle, in which nitrogen is cycled through the atmosphere, soil, and living organisms, allowing it to be used repeatedly rather than being lost²⁵. By recycling materials, natural systems are able to conserve resources and maintain a balance within the system.

Nature has an elegance and simplicity which emerges from fitting form to function. The shape or pattern of a component is selected based on its specific needs. This strategy is seen in the way that the shape and structure of organisms are optimized for their specific functions, such as the streamlined body of a dolphin for swimming at high speeds and the aerodynamic and silent wings of an owl for nighttime flights. Another example of fitting form to function in nature is the structure of a leaf, which is optimized for photosynthesis with its large surface area and intricate vascular system. By fitting form to function, natural systems are able to minimize the use of resources and increase their efficiency with simple and elegant solutions.

This resource efficiency is crucial in organizational success. If a company has to succeed, in particular while adopting a sustainable model of development, it must find elegant and efficient solutions to minimize costs. The use of multi-functional design is a starting point. This strategy can be applied in an organizational setting through the use of multi-use products and services, which can meet a variety of customer needs. The mobile phone industry has successfully implemented multi-functional design in its products through the creation of smartphones, which serve as a phone, a computer, and a camera all in one device. Whereas internally to an organization, this multifunctional design could correspond to using a single platform to communicate, share data and process it.

Another way in which nature's resource efficiency can be translated to organizational practices is through the use of low energy processes, which equates to the minimization of energy consumption. This strategy can be applied in an organizational setting through the use of energy-efficient technologies and practices, such as LED lighting and energy-efficient

²⁵ Stein, L.Y. and Klotz, M.G. (2016) "The nitrogen cycle," *Current Biology*, 26(3). Available at: <https://doi.org/10.1016/j.cub.2015.12.021>.

Understanding the Biomimetic Organization Through Life's Principles

appliances. For example, the retail company IKEA has implemented a number of energy-efficient initiatives, including the use of LED lighting and solar panels, which have resulted in a reduction in energy consumption and an increase in sustainability. By using low energy processes, organizations can conserve resources and reduce their environmental impact.

An alternative way in which this can be achieved is through the recycling of most or all materials. This strategy can be applied in an organizational setting through the implementation of recycling programs and the use of sustainable materials.

Finally, the last strategy nature uses for resource efficiency is fitting form to function. This strategy can be applied in an organizational setting through the use of design thinking, which involves understanding the needs of the customer and designing solutions that meet those needs in an efficient and effective manner. For example, the design firm IDEO has successfully applied design thinking to a variety of industries, including healthcare, education, and retail, resulting in innovative products and services that meet the needs of customers. By fitting form to function, organizations can minimize the use of resources and increase their efficiency.

2.6 Use life-friendly chemistry

“Use of life-friendly chemistry, reminds us to streamline processes and break products down into non-threatening components, innovate, and make use of a small and selective subset of elements in projects. Figuratively speaking, this notion can inform those in charge of intricate ventures of the advantages of breaking apart processes whenever possible. Each of these principles and their descriptors presents exceptional opportunities of applications in leadership and management.”

Nature uses life-friendly chemistry to sustain and support life on Earth. One way in which this is achieved is through the use of a small subset of elements in the construction of molecules within organisms²⁶. This strategy is seen in the way that nature builds proteins, nucleic acids, and other biological molecules from a relatively small set of elements such as

²⁶ Ball, P. (1999) *Life's matrix: A biography of water*. New York: Farrar, Straus, and Giroux.

Understanding the Biomimetic Organization Through Life's Principles

carbon, hydrogen, oxygen, nitrogen, and sulfur. By building selectively with a small subset of elements, nature is able to create a diverse range of molecules with a minimal use of resources.

In nature life-friendly chemistry occurs through the breakdown of complex products and molecules into benign constituents. This strategy is seen in the way that natural systems decompose organic matter into simple, non-toxic substances such as carbon dioxide and water. This process occurs through the action of enzymes and microbes, which break down organic matter in a way that produces no harmful by-products. By breaking down products into benign constituents, nature is able to sustain itself and maintain a balance within the system.

Finally, nature also uses life-friendly chemistry by doing chemistry in water. Water is an excellent solvent, allowing for the dissolution and reaction of a wide range of chemical substances. This property of water is critical for many biological processes, such as digestion and metabolism, which depend on the ability of water to dissolve and transport molecules. By doing chemistry in water, nature is able to support a diverse range of chemical reactions in a safe and efficient manner.

In organizations, the strategy of doing chemistry in water can be applied by using environmentally friendly processes in their operations. For example, a company may use water-based solutions instead of toxic chemicals in their manufacturing processes. Another example is a hospital that may use water-based cleaning solutions instead of harmful chemicals to disinfect surfaces.

Building selectively with a small subset of elements could mean for organizations to use only a limited number of steps in their supply chain. By limiting the length and the complexity of the supply chain and focusing on what is more readily available and sustainable, an organization can reduce its dependency on scarce or unsustainable resources, improving its long-term viability. Furthermore, it can increase its control and reduce negative externalities produced through long distance transport as well as logistical complications.

Breaking down products into benign constituents means that organisms break down harmful products into safe components that can be reused or safely eliminated. In organizations, this strategy can be applied by implementing environmentally friendly waste management

Understanding the Biomimetic Organization Through Life's Principles

practices. For example, a company may recycle its waste instead of simply disposing of it. Another example is a hospital that may implement a composting program for its organic waste.

By implementing these strategies of life-friendly chemistry, organizations can reduce their impact on the environment and improve their chances of survival and success in a sustainable world.

<u>Life Principles</u>	Strategy
Evolve to survive	Replicate strategies that work
	Integrate the unexpected: incorporate mistakes in ways that can lead to new forms and functions
	Reshuffle information: exchange and alter information to create new options
Adapt to changing conditions	Maintain integrity through self-renewal
	Embody resilience through variation, redundancy and decentralization
	Incorporate diversity: include multiple forms, processes, or systems to meet a functional need
Be locally attuned and responsive	Leverage cyclic processes: take advantage of phenomena that repeat themselves
	Use feedback loops: engage in cyclic information flows to modify a reaction appropriately
	Use readily available materials and energy: build with abundant accessible materials while harnessing freely available energy
	Cultivate cooperative relationships: find value through win-win interactions
Integrate development with growth	Invest optimally in strategies that promote both development and growth
	Combine modular and nested components
	Build from the bottom up : assemble components one unit at a time
	Self-organize
Be resource efficient	Skillfully and conservatively take advantage of local resources and opportunities
	Use multifunctional design: meet multiple needs with one elegant solution
	Use low energy processes: minimize energy consumption by reducing requisite temperatures, pressures and/or time for reactions
	Recycle all materials: keep all materials in a closed loop
	Fit form to function: select for shape or pattern based on need
Use life friendly chemistry	Do chemistry in water: use water as solvent
	Build selectively with a small subset of elements: assemble relatively few elements in elegant ways
	Break down products into benign constituents

3. Methodology

3.1 Interviews & Indicators

Having defined the Life's Principles and their strategies in nature, as well as some of their possible organizational implications, the next step is to develop the qualitative indicators of the framework. These indicators will be extrapolated both through the research on the Life's Principles and its possible logical applications, as well as through a series of interviews conducted with figures from two innovative yet differentiated organizations. These will serve to extrapolate a series of organizational indicators for each strategy of the Life's Principles through association. The interviews, conducted with innovative managers coming from different fields, would provide informed and diverse associations that the ones extrapolated through the research. However these interviews could also tether this research to reality and to actual applicability. The aim of the interviews would thus be to investigate on their interpretations of natural strategies applied to *their own* organizations.

Concerning the contents of the interview, each Life Principle will be broken down in its respective strategies, for example:

Adapt to changing conditions:

- *Maintain integrity through self-renewal*
- *Embody resilience through variation, redundancy and decentralization*
- *Incorporate diversity*

And each strategy will require its separate question. The questions will be open-ended and will all have a brief introduction. This introduction will present the particular strategy through a vignette²⁷. These are either visual or literary images (stories) which serve to contextualize, clarify and provide a more personal understanding within qualitative research. The vignettes provided will be examples of the application of a strategy within nature.

²⁷ Barter, C. and Renold, E. (1999) "The Use of Vignettes in Qualitative Research," *Social Research Update* [Preprint], (25).

A sample question may be:

Incorporate diversity

'To become more resilient a mechanism used in nature is incorporation of functional diversity. This process can be observed in the variety of forms and processes nature adopts in its systems and in its organisms. The oldest mammalian species still present on earth today is the platypus. It is characterized by its strange variety of functions: a beak, venomous claws, fluorescent fur, egg-laying and yet living in water. How do you think this functional diversity present in many organisms in nature is incorporated in [company name]?'

The vignettes will hopefully provide a clear understanding of the question and lead the interviewee to answer while creating associations with the natural patterns and processes provided in the examples. The free associations are important in the extrapolation of indicators.

The interviewees will hopefully deliver differentiated answers and thus create a wider variety of possible interpretations for the organizational applications of the natural strategies. Having been answered, the interviewer will evaluate if the question has been explored thoroughly enough and if the theme has been understood. If not, the interviewer may ask a specific follow-up question. On the other hand, if the interviewee has been very exhaustive with their answer, he/she may have already answered another question's scope. In this case, the interviewer will skip the already-answered question.

3.2 The Value Creation Tool

These interviews will be recorded and the thematic contents will be extrapolated. On the basis of these contents and the research conducted a series of indicators will take shape and specific qualitative questions (indicators) will be compiled. This set of indicators will thus serve to create an elementary evaluation tool built on Excel, denominated Value Creation Tool.

Understanding the Biomimetic Organization Through Life's Principles

The indicators are not obligatory, some in fact may not apply to certain organizations, therefore there is an option in the column “Is it relevant?” to select “No”, and the specific indicator will not be counted in the general framework for that firm.

For the tool, the indicators will have prefixed answers which will in turn have assigned numerical values. This will allow the qualitative indicators to assume a quantitative value and thus become more easily digestible and workable. An example is as follows:

INDICATORS: Questions of biomimetic fit	IS IT RELEVANT? (only select no if strictly outside the scope of the firm)	SELECT ANSWER IF RELEVANT	VALUE x Indicator
<i>To what degree is your company open with its internal activities and processes?</i>	Yes	To a medium degree	0,67
		To a high degree	
		To a medium degree	
		To a low degree	
		Never	

These numerical representations for each qualitative indicator will assign the answer a value from 0 to 1, with 0 being the lowest and 1 the highest. The values of the indicators will be cumulated and divided by the component parts to extract values for each strategy. Then, similarly, strategies will be cumulated and divided to form values for each Principle. This will finally result in a set of macro-values evaluating the firm’s performance in each Life’s Principle out of 1 and will be graphically represented with a set of radar graphs to visualize simply the areas in which there is margin for improvement.

4. Building the Tool

4.1 Extracting the indicators

The selected organizations for the interviews are Italian and share an innovative approach within their respective sectors. The firms, however, are quite different. This is because they were selected with the purpose of broadening the scope of the framework and thus providing

differentiated answers. The level of preparation in the subject matter would also contribute to inform their associations thus the two firms were also picked on the basis of innovative frameworks within the Italian organizational sphere.

Ca' Colonna is a small agricultural firm specialized in biological and innovative farming based in Emilia-Romagna. The figures interviewed from Ca'Colonna were Gian Luca Bagnara (Project Manager) and Maria Teresa Menganelli (President). They share a vast experience of working with international organizations such as the EU and FAO. Mr. Bagnara holds a professorship. They are pioneers of biological and sustainable agriculture in Italy.²⁸

On the other hand, Tecno Group is a large, international, energy and sustainability monitoring group of companies based in Naples. The figure who was interviewed was Lorenzo Corona, environmental sustainability specialist for the firm. He works with large energy firms to monitor indicators for frameworks such as the ESGs.²⁹

The questions posed to the interviewees aimed at stimulating varied interpretations and contrasting points of exposure through spontaneous associations. These answers, integrated with the research conducted in chapter 2 resulted in a variety of indicators being extrapolated. The following is a breakdown of identified indicators for each Life Principle Strategy:

1. *Evolve to survive*

- a. *Replicate strategies that work*

In the interview, the question for this strategy was:

“In nature, once identified, successful strategies are replicated while obsolete ones decay and are discarded. Think of the teeth of humans, since meat stopped being eaten raw, third molars started to decay, nowadays there are people who never develop third molars. Do you have methods for successful strategies and have you ever had to abandon strategies?”

²⁸ See Appendix 1

²⁹ See Appendix 2

Understanding the Biomimetic Organization Through Life's Principles

In the Ca' Colonna interview the answer mentioned the idea of organizational 'mistakes' in various lights: "Mistakes are made because they have to be made and even when you see the workers on the field making a mistake you let them make it because they have to hit rock bottom by themselves." In this light, mistakes are seen as opportunities for evolution in an organizational context, obviously as long as they are "small". This leads to the formulation of an indicator question on the treatment of small mistakes in the organizational context.

Another emergent theme was 'priority-setting' as opposed to abandoning a strategy. This emerged in the Ca' Colonna interview: "I'd say that more than things you leave behind, it's the priorities you give yourself. The reverse reasoning." In this sense what can be extrapolated is a certain priority or shared line then leads to the replication of successful strategies and processes within the organization. The idea of a shared values or codes is what best exemplifies a shared priority within an organizational context. Therefore another indicator was dedicated to the use of a written code of conduct within the organization.

Another two indicators referring to the replication of successful and abandonment of obsolete strategies were formulated. One evaluating the multifunctionality and transversality of successful strategies and practices and the other evaluating the speed at which the company is willing to abandon surpassed strategies.

Therefore the extracted indicators for this strategy are:

STRATEGY	INDICATORS: Questions of biomimetic fit
Replicate strategies that work	<i>Does the company have a written code of conduct?</i>
	<i>How often are successful strategies/practices applied or replicated in other areas/sectors/levels of the firm?</i>
	<i>How are small mistakes treated in the organizational context?</i>
	<i>How quickly are obsolete practices and strategies abandoned?</i>

b. Integrate the unexpected

In the interviews, the question posed regarding this strategy mentioned the processes of genetic variation. Genetic variation was presented as a *process of directed trial and error*. In answering this question several themes emerged. First and foremost, there was an idea of repeated ‘small errors’ which was also present in the *replication of successful strategies*. But in this case it was mentioned as a way to direct exploration at low costs: “every mistake carries with it a cost, which can be economic, financial, etc. – the smaller the error, the less impactful it is, the better you can adjust the course”. An indicator must be dedicated to the introduction of novel organizational practices but also another to understand how organizational objectives are impacted as it adjusts its course, this could happen with a simple SWOT analysis. Therefore, the questions may be: *how often are new organizational practices tested?; how often does your company conduct SWOT or other types of strategic analyses for development?*.

An identified theme from the research was that organisms have built in mechanisms to integrate unexpected events. For this reason a general question on the organizational climate during unexpected events was included. This would reveal the perceived positioning of the firm in terms of the unpredictable or chaotic events.

Therefore, for this strategy the proposed organizational indicators are:

STRATEGY	INDICATORS: Questions of biomimetic fit
Integrate the unexpected	<i>How often are new strategies or organizational practices introduced?</i>
	<i>How often does your company conduct SWOT or other types of strategic analyses for development?</i>
	<i>How does your company view unexpected events?</i>

c. Reshuffle information

Understanding the Biomimetic Organization Through Life's Principles

The strategy of reshuffling information implies taking the available information and constantly remixing it to obtain new combinations, like what occurs with DNA in genetic mutation. This strategy concerns the way information is handled and the way it impacts the company. Therefore, reshuffling information is highly connected to the information openness of a firm (open innovation). This is because frameworks like open innovation prioritize the interconnection and free-flowing of information both within and outside the company. The indicators therefore investigate openness of information: one evaluating how much information the company shared with the outside; another measuring how much information it lets from the outside in; and finally a third evaluating how much internal openness and reshuffling of information there is.

The extracted indicators are as follows:

STRATEGY	INDICATORS: Questions of biomimetic fit
Reshuffle information	<i>To what degree is your company open with its internal activities and processes?</i>
	<i>To what degree does your company delegate research and development to outside sources?</i>
	<i>To what degree does your company interchange and mix teams and sectors which usually wouldn't collaborate?</i>

2. Adapt to changing conditions

a. Maintain integrity through self-renewal

For this strategy, the question posed to the interviewees mentioned the speed of self-renewal to adapt to outside dynamic conditions and how it is facilitated by efficient communication and interconnected networks. In the Tecno Group interview the answer mentioned the speed of information traveling within the company, as well as external communications. This was interpreted similarly in the Ca' Colonna interview: "there are two levels (of communication). One is the level of internal communication within the company, the other is the level of external communication with stakeholders." This leads to the extraction of two indicators,

Understanding the Biomimetic Organization Through Life's Principles

one measuring the speed and efficacy of communication on the inside and the other on the outside.

STRATEGY	INDICATORS: Questions of biomimetic fit
Maintain integrity through self-renewal	<i>How fast and efficiently does information travel within your company?</i>
	<i>How fast and efficiently does information travel from your company to the outside?</i>

b. Embody resilience through variation, redundancy and decentralization

This strategy is best summarized as a incorporated variance to alter the organizations behaviors thus improving resilience. The vignette in the interview presented how certain animals demonstrate predictive and highly preparatory behaviors in light of incumbent trials. The answers focused on various forms of programming and preventive mechanisms adapted in the respective companies. For Gian Luca Bagnara (Ca' Colonna) this was also a diversification of the suppliers and of clients. This is also what was essentially understood from the research.

STRATEGY	INDICATORS: Questions of biomimetic fit
Embody resilience through variation, redundancy and decentralization	<i>To what degree has your company developed preventive measures for crises/unexpected events?</i>
	<i>How diversified is your supply chain?</i>
	<i>How diversified are your clients?</i>

c. Incorporate diversity

For this strategy, the vignette presented the example of functional diversity in certain species of animals, like the platypus. The answers were quite unified, they were interpreted as questions on either a diversified workforce (both companies) or diversified products and services (Ca' Colonna). Therefore the questions went to investigate these two aspects.

STRATEGY	INDICATORS: Questions of biomimetic fit
Incorporate diversity	<i>How diversified are your products/services?</i>
	<i>How diverse is your workforce in terms of ideas, culture, nationality?</i>

3. *Be locally attuned and responsive*

a. *Leverage cyclic processes*

This strategy refers to recursive processes such as the water cycle, which are self-sustaining and continuous. A cyclic process which every organization has to contend with is the market. Similarly, as mentioned in the Ca' Colonna interview, in agriculture there are cyclic processes of culture. These represent the heightened or lowered moments of production due to seasonality of agricultural products. These processes can be prepared for with a strict programming of culture cycles, and by preparing and expanding storages for moments of low production. The indicators thus go on to investigate preparedness in moments of both heightened and lowered moments of demand/production.

STRATEGY	INDICATORS: Questions of biomimetic fit
Leverage cyclic processes	<i>How are moments of high demand handled by the company?</i>
	<i>How are moments of low demand handled by the company?</i>
	<i>Are there any mechanisms or processes in place to prepare for production highs and lows?</i>

b. *Use feedback loops*

When it comes to feedback loops, the general theme which emerged from the research is a relationship and feedback from customers and clients as well as an internal mechanism of feedbacks which can internally improve the company.

Understanding the Biomimetic Organization Through Life's Principles

This results in two fundamental indicators, one investigating if the company uses Customer Relationship Management for constant digestible feedback, another investigating if there are feedback loops within the company itself.

STRATEGY	INDICATORS: Questions of biomimetic fit
Use feedback loops	<i>Does your company conduct CRM?</i>
	<i>How much is feedback catered to within your company?</i>

c. Use readily available materials and energy

For this strategy the question posed in the interviews stressed the specialization of an organism to its local ecosystem. This led to answers concerning the activities of the firm conducted locally as well as production of local or traditional products (Ca' Colonna). In this case the indicators extracted should vert first and foremost on the sourcing of products and energy. The amount of workforce being local was included as an indicator.

STRATEGY	INDICATORS: Questions of biomimetic fit
Use readily available materials and energy	<i>Does your company source its products/services locally?</i>
	<i>How much of your energy consumed is self-produced or is sourced from a nearby source? (within 100km)</i>
	<i>How much of your workforce is local (coming from the same city or region)?</i>

d. Cultivate cooperative relationships

In the interviews, the vignette was on the importance of mutualistic relationships in nature, such as bees and flowers. This concept of mutualistic relationships was interpreted as cooperation and collaboration with organizations both within and outside the sector, as well as an involvement in community activities. Inside the sector this arose in associations, partnerships or 'hubs' like the one mentioned by Lorenzo Corona: "The sustainability hub

Understanding the Biomimetic Organization Through Life's Principles

sees within it Tecno, Tecno Energy, two companies called Wufinance and Aires ... and other spinoff partners such as research centres and universities with which Tecno collaborates on certain projects". On the other hand, on the outside we observe partnerships with universities, communities, local government as mentioned in the Ca' Colonna interview: "We have a project of social farming aiming to create relationships with social cooperatives such as Caritas, precisely to build mutualistic relationships on the territory and a hire personnel from these cooperatives". This therefore results in three indicators being developed: one strictly on the research front concerning ties with universities and research centres; another concerning the community and local area; and a third concerning industry associations and sector ties.

STRATEGY	INDICATORS: Questions of biomimetic fit
Cultivate cooperative relationships	<i>Does your company have any ties with universities/research centres?</i>
	<i>Does your company organize or participate in local community activities/events?</i>
	<i>Is your organization part of an association with other firms in its sector?</i>

4. Integrate development with growth

a. Combine modular and nested components

For the strategy on combining modular and nested components imposes a standardization of products or services to fit into others and be used effectively and compatibly with others not necessarily emanating from their own company. This strategy therefore was separated into three separate indicators. First and foremost, is there a standardization of the products and services? To what degree are these products and services compatible with your own internal products and services? To what degree are these products and services compatible with other companies' products and services?

STRATEGY	INDICATORS: Questions of biomimetic fit
	<i>Are your products/services standardized?</i>

Combine modular and nested components	<i>To what degree are your products/services compatible with your companies other products/services?</i>
	<i>To what degree are your products/services compatible with other companies' products/services?</i>

b. Build from the bottom up

Concerning the building from the bottom up the vignette in the interview mentioned how there were processes within the development of organisms, such as the human being, that began with simple and elemental building blocks which then incrementally went to become more complex and articulated. This concept was interpreted two fold: on the one hand in the Tecno interview it was read as an incremental development and expansion of the organization, on the other it was seen as an initiative within the firm departing from lower levels to build complicated projects. Thus the two indicators extrapolated for the strategy of building from the bottom up are:

STRATEGY	INDICATORS: Questions of biomimetic fit
Build from the bottom up	<i>How often do initiatives/projects originate from lower employees?</i>
	<i>To what degree do you use incremental development?</i>

c. Self-organize

Self-organization is an organizational phenomenon which is already observed and adopted in certain contexts. For this strategy three indicators inquiring on the freedom of initiative and of self-organization are proposed:

STRATEGY	INDICATORS: Questions of biomimetic fit
----------	---

Self-organize	<i>How free are employees to work on their own projects in work time?</i>
	<i>Do work groups self-assign roles in group projects?</i>
	<i>Would you describe your organizational structure as more horizontal or vertical?</i>

5. *Be resource efficient*

a. *Fit form to function*

Fitting form to function is the natural strategy by which organisms improve and adapt their shapes and structures to the necessary roles and functions they play within their environment. The example presented in the interview was the structural specialization of form animals adopt in their respective environments and how through the form these animals acquire particular advantages within those environments, which wouldn't otherwise work. In the research this emerged as a process which is already adopted in certain organizations which is called design thinking. A creative process which is based on user contribution and prototyping to essentially come to a concrete and functionally fitted form. *"To what degree does your company use design thinking?"* In essence this indicator asks, to what degree is the form of the product/service you provide shaped by customer needs?

STRATEGY	INDICATORS: Questions of biomimetic fit
Fit form to function	<i>To what degree does your company use design thinking?</i>

b. *Use multifunctional design*

This strategy represents the multidimensionality and complexity of nature in its fullest. There is no *one*-function in nature but rather every one organ, tissue, and even cell plays a variety of roles which are fundamental to the functioning of the whole. This multifunctional design spurred was interpreted as both a multifunctionality of products and services, as well as the multifunctionality of the component parts of the company, the employees. This concept also arose in the Ca' Colonna interview in which the response was to segment the market for

Understanding the Biomimetic Organization Through Life's Principles

particular multifunctional use of varied qualities of agricultural product. In the specific example they explained that Ca' Colonna would sent the first selection to Almaverde (high quality biological brand) and then the second selection to Babaco and third to HoReCa.

STRATEGY	INDICATORS: Questions of biomimetic fit
Use multifunctional design	<i>To what degree are your products/services multifunctional?</i>
	<i>To what degree are employees eclectic in their roles?</i>

c. Use low-energy processes

Using low energy processes is fundamental in nature, since nothing comes for free and survival depends on the minimization of energy consumption. This strategy in turn can be extremely useful for firms as well to cut energy costs and become environmentally friendly. This emerged in the Tecno interview: “though we have no energy intensive processes, we do care about the environmental impact. We try to minimize our carbon footprint as much as possible.” This strategy can be adopted by firms by consciously adopting practices which use low-energy processes such as light-saving lightbulbs or energy-efficient machinery, or on the other hand by producing energy independently through renewable energy sources such as solar panels or wind turbines. Therefore the indicators go to investigate these two aspects:

STRATEGY	INDICATORS: Questions of biomimetic fit
Use low energy processes	<i>Does your company use reduced energy practices? (lightsaving lightbulbs, energy efficient machinery or appliances, etc.)</i>
	<i>How much energy consumed is independently produced and renewable?</i>

d. Recycle all materials

This strategy is seen in how ecosystems such as the forest biome are so profoundly interconnected that when one component decays or falls it is absorbed and goes to feed the

Understanding the Biomimetic Organization Through Life's Principles

the other components cyclically. Therefore, by definition, nothing goes to waste. For this strategy three indicators were extrapolated, all measuring how much recycling is part of the company culture. One indicator inquiring into if the company has a recycling program, another into the quantity recycled, and finally the recyclability of the products produced, if the company is creates products.

STRATEGY	INDICATORS: Questions of biomimetic fit
Recycle all materials	<i>Does your company abide to a recycling program?</i>
	<i>How much of your waste is recycled?</i>
	<i>How much of your products is recyceable?</i>

6. Use life-friendly chemistry

a. Do chemistry in water

For this strategy, two simple indicators were extrapolated, one investigating if any hazardous materials are used in production and another investigating in the use of water as a possible dilutant for such materials.

STRATEGY	INDICATORS: Questions of biomimetic fit
Do chemistry in water	<i>Does your company use any hazardous materials?</i>
	<i>To what degree does your company use water as a dilutant?</i>

b. Build selectively with a small subset of elements

Building selectively with a small subset of elements indicates a construction from bottom to the top through a small and relatively simple construction. This can be interpreted as a short supply chain. Therefore the two indicators go to measure the intricacy and complexity of the supply chain as well as its length.

STRATEGY	INDICATORS: Questions of biomimetic fit
Build selectively with a small subset of elements	<i>How intricate and complicated is your supply chain?</i>
	<i>How long is your supply chain?</i>

c. Break down products into benign constituents

The natural strategy of breaking down products into benign constituents is observed in the handling of wastes in nature. Everything is digestible, everything feeds something else when it decays. This process is therefore essentially based on creation of and sustainable disposal of wastes. This leads to the creation of two indicators for the tool:

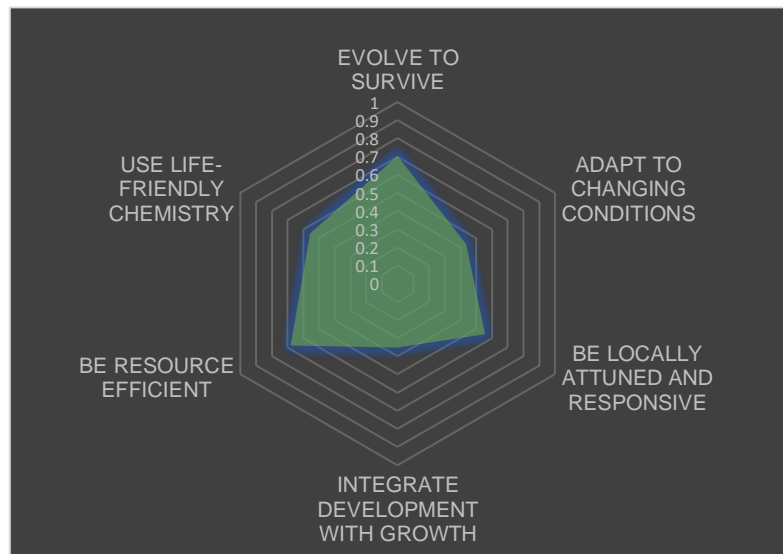
STRATEGY	INDICATORS: Questions of biomimetic fit
Break down products into benign constituents	<i>To what degree does your company produce toxic waste?</i>
	<i>To what degree does the waste produced by your company disposed sustainably?</i>

4.2 The graphical representation

The tool was also imagined as a simplification of the qualitative indicators into more easily comprehensible graphical visual representations like the one seen in the figure below. This radar graph depicts the conditions of an imaginary organization in terms of its biomimetic fit. As is evident from the graph the Principle of *integrate development with growth* is underdeveloped in this hypothetical firm. Therefore there may be the case to understand which strategies underperformed in this specific case³⁰.

³⁰ See Appendix 3 for full representation of this example and of the tool.

Therefore, though this tool is based on qualitative indicators it does emerge with a visual charted analysis. This is to sensitize and visually introduce researchers or managers interested in novel frameworks to a practical and applicative understanding of organizational biomimetics.



5. Implications for managers

The implications for the managerial class of a biomimetic framework such as the one proposed are several:

Organizational structure: Just like in nature, managers can adopt decentralized and networked structures that are more adaptable and resilient to change. This can help organizations in general to respond more effectively to challenges and opportunities.

Decision-making: Managers can learn from the way that organisms in nature make decisions, such as through consensus-building and collective intelligence, to create more effective decision-making processes.

Innovation: Managers can learn from nature's process of continuous adaptation and innovation, and apply these concepts to their own product development and innovation processes.

Resource management: Managers can learn from the way that ecosystems manage resources, such as through recycling and closed-loop systems, and apply these principles to their own resource management processes.

Collaboration: Managers can learn from the way that species in nature collaborate to achieve common goals, and apply these principles to create more effective cross-functional collaboration within and outside the organization.

6. Limitations

Of course this paper has several limitations. First and foremost, though a fully functional tool was developed, it should not be considered as a valid applicative tool for firms to base themselves on for biomimetic development today. It should rather be read as an approach to the subject. This is because organizational biomimicry is still in its infancy and the methodology for this type of research have yet to be further investigated before a framework of this type can be followed and applied by firms.

One aspect which in a second iteration could be improved is the modality of indicator extrapolation. The interviewees are innovators and experts in their areas, however by giving their own interpretations of the questions in the interview, they could have warped the question to fit their own developmental point in the organization. This obviously could constrain the qualitative indicators to what is already existent or still underdeveloped in these organizational contexts. For a more future-oriented framework, a set of indicators should be extrapolated by confronting and comparing a much larger sample size of experts coming from diverse fields.

Another limitation concerns the use of qualitative data to compile the tool. A lot of questions are willingly subjective in interpretation and thus depend on the honesty as well as a subjective understanding of the possible questions and answers: what is 'Regularly' for some may be 'Sometimes' for others. This is why this paper hopes to be a stepping stone for more research in the area and a further development of quantitative indicators similar to the ones proposed in frameworks such as the ESGs.

An interesting and unexplored subject in this paper which pervades biomimetics is the interconnectedness of all processes in the ebb and flow of nature, where each of these principles blends and ties into the others. This concept would have required a research paper in and of itself just to understand, thus it was not included in this paper, however a future

framework should likely explore how synergies between principles like the ones explored in this paper may equate into more than a sum of their parts in terms of organizational applications.

7. Conclusion

This paper aimed at creating a deeper understanding of the biomimetic organization by using the Life's Principles as tools for its measurements and application. An evaluation tool, denominated Value Creation Tool, was developed to measure specific strategies, extrapolated from nature, within the organizational context. These were measured through a variety of indicators obtained through research in the subject and through associative interviews with innovative managers. The paper and the associated tool hopefully created the baseline for future research into organizational biomimicry and acted as a stepping stone for the further development of biomimetic frameworks of evaluation. Finally and most importantly, hopefully this paper has created an understanding of the value that a biomimetic framework can hold for the future of organizations within this global context.

8. Bibliography

- Abzhanov, Arhat, Meredith Protas, B. Rosemary Grant, Peter R. Grant, and Clifford J. Tabin. “*bmp4* And Morphological Variation of Beaks in Darwin's Finches.” *Science* 305, no. 5689 (2004): 1462–65. <https://doi.org/10.1126/science.1098095>.
- Amabile T.M., Khaire M. Creativity and the role of the leader. *Harv. Bus. Rev.* 2008;10:101–109
- Ball, Philip. *Life's Matrix: A Biography of Water*. Berkeley, Calif: Univ. of California Press, 2001.
- Barter, Christine, and Emma Renold. “The Use of Vignettes in Qualitative Research.” *Social Research Update*, no. 25 (1999).
- Bogatyreva, Olga, and Alexandre Shillerov. *Biomimetic Management: Building a Bridge between People and Nature*. North Charleston: Createspace Independent Publishing Platform, 2015.
- Chesbrough, Henry. “From Open Science to Open Innovation.” *Open Innovation Results*, 2019, 51–66. <https://doi.org/10.1093/oso/9780198841906.003.0004>.
- Couzin, Iain D., Jens Krause, Nigel R. Franks, and Simon A. Levin. “Effective Leadership and Decision-Making in Animal Groups on the Move.” *Nature* 433, no. 7025 (2005): 513–16. <https://doi.org/10.1038/nature03236>.
- Fairlamb, Horace L., and Gregory Bateson. “Mind and Nature: A Necessary Unity.” *MLN* 94, no. 5 (1979): 1218. <https://doi.org/10.2307/2906578>.
- Gordon, Deborah M. “The Expandable Network of Ant Exploration.” *Animal Behaviour* 50, no. 4 (1995): 995–1007. [https://doi.org/10.1016/0003-3472\(95\)80100-6](https://doi.org/10.1016/0003-3472(95)80100-6).
- Holling, C. S. “Understanding the Complexity of Economic, Ecological, and Social Systems.” *Ecosystems* 4, no. 5 (2001): 390–405. <https://doi.org/10.1007/s10021-001-0101-5>.
- Jackson, Duncan E., and Francis L.W. Ratnieks. “Communication in Ants.” *Current Biology* 16, no. 15 (2006). <https://doi.org/10.1016/j.cub.2006.07.015>.
- Kerzner, Harold. “Project Management Case Studies,” 2017. <https://doi.org/10.1002/9781119389040>.
- Prigogine, Ilya, Isabelle Stengers, and Heinz R. Pagels. “*Order out of Chaos*.” *Physics Today* 38, no. 1 (1985): 97–99. <https://doi.org/10.1063/1.2813716>.
- Schneider, E.D., and J.J. Kay. “Life as a Manifestation of the Second Law of Thermodynamics.” *Mathematical and Computer Modelling* 19, no. 6-8 (1994): 25–48. [https://doi.org/10.1016/0895-7177\(94\)90188-0](https://doi.org/10.1016/0895-7177(94)90188-0).

Understanding the Biomimetic Organization Through Life's Principles

Simard, Suzanne W. “Mycorrhizal Networks Facilitate Tree Communication, Learning, and Memory.” *Memory and Learning in Plants*, 2018, 191–213. https://doi.org/10.1007/978-3-319-75596-0_10.

Stein, Lisa Y., and Martin G. Klotz. “The Nitrogen Cycle.” *Current Biology* 26, no. 3 (2016). <https://doi.org/10.1016/j.cub.2015.12.021>.

Vincent, Julian F.V, Olga A Bogatyreva, Nikolaj R Bogatyrev, Adrian Bowyer, and Anja-Karina Pahl. “Biomimetics: Its Practice and Theory.” *Journal of The Royal Society Interface* 3, no. 9 (2006): 471–82. <https://doi.org/10.1098/rsif.2006.0127>.

White, Jeremy A., and Keith Geluso. “Seasonal Link between Food Hoarding and Burrow Use in a Nonhibernating Rodent.” *Journal of Mammalogy* 93, no. 1 (2012): 149–60. <https://doi.org/10.1644/11-mamm-a-031.1>.

Wikelski, Martin, Uschi Mueller, Paola Scocco, Andrea Catorci, Lev V. Desinov, Mikhail Y. Belyaev, Daniel Keim, Winfried Pohlmeier, Gerhard Fechteler, and P. Martin Mai. “Potential Short-Term Earthquake Forecasting by Farm Animal Monitoring.” *Ethology* 126, no. 9 (2020): 931–41. <https://doi.org/10.1111/eth.13078>.

APPENDIX 1

Interview with Gian Luca and Teresa Bagnara: Ca' Colonna

Methodological premise:

My thesis deals with biomimicry applied to the corporate structure. As I have already said, biomimicry or even biomimicry is the practice of imitating structures, logics or mechanisms found in nature for our purposes, whether they are engineering, social, or organizational. In my thesis I will explore the application of biomimicry in the organizational field because I believe it could be one of the next development steps we will take as humanity. The method I will apply is qualitative. Starting from the six principles of life ³¹I will use the **vignettes technique** to present each question of the interview. Using the cartoon technique, I'll give you a concrete example of how that mechanism takes place in nature, and then I'll ask you if or how you think it takes place in Ca' Colonna. This model aims more at creating an understanding of biomimetic application at the organizational level, which is currently almost completely unexplored. There are more or less 10 questions, depending on your answers there could be a few more or even a few less.

Note on terminology and answers

First off, a couple of notes on the terminology I'll be using. I will use the term **strategies** quite often. I would like you to interpret it as openly as possible, which includes internal strategies, market strategies, marketing strategies etc. You feel free to ask for further developments, expansions, etc. and to answer fully. With this method what matters is not so much the accuracy of the data as the depth of the questions.

QUESTIONS

- 1. The first principle of life is that everything evolves to survive. A feature of evolution is that successful strategies do not emerge out of nowhere, but emerge from variation and error. Mistakes in nature often turn out to be opportunities for growth. Think of genetic mutations for example. Mutations very often lead to failures, death, selection, but they also have a direction, and basically, after a series of mistakes, the right mutation arrives which can carry forward an entire species. Do you apply this mechanism of directed attempts and errors in some way in Ca' Colonna?*

"everyday. It is inevitably what is done every day, every minute. You need to have a direction, a macro design, otherwise you go in no direction. It would be chaos, it would be moving blindly. When you move, especially in complex systems such as a farm, which has to do with the climate, biological aspects, diversity of cultures, with the final markets, with the people in the company. It's a complex system, this idea of making mistakes and trying to overcome them is inevitable. What's the challenge? It's trying to make small mistakes, because it costs less - every mistake carries with it a cost, which can be economic, financial, etc. – the smaller the error, the less impactful it is, the better you can adjust the course.

³¹ the logics of nature, developed by the Biomimetic Institute ,

2. *And do you have any specific mechanisms for carrying out this process of directed trial and error?*

Well, I don't know if it's a mechanism or a method. It is trying to have a more complete vision of the supply chain. A complete vision of the supply chain means at this moment of the season - i.e. the end of the year - trying to set up a schedule for next year which means: trying to read how the market is going - not only for direct consumption of the product but also for the system and of the context in which the market moves, if the consumer has to spend to buy a product, he in turn has to deal with his own budget. So it is necessary to understand the macroeconomic, microeconomic system, etc., and from there discuss with the buyers to make a plan if they are able (it is not certain), and then try to set up a plan in the field. Then during the season it is the reverse path. We need to try to see how the business is going in the field and then adjust the sales schedule elsewhere. **This implies a complete vision of the supply chain. And so the reference points are the ground on one side and the shelf on the other.** And therefore try to always give a more integrated reading as possible because it is the integration processes that determine these changes. It's not the factors themselves. How one element interacts with another.

3. *As a follow-up to the previous question... In nature, once identified successful strategies are replicated while obsolete ones decay and are discarded. Think of the teeth of humans, since meat stopped being eaten raw the third molars started to decay. Have you ever had to abandon strategies, processes?*

T: When it's new we go for trial and error sometimes. Mistakes are made because they have to be made and even when you see the 'boys' making mistakes you let them make it because they have to hit rock bottom by themselves. Consider that in the beginning we had some people who presented themselves, as consultants and also as operators, who were scammers.

G: You have to do programming at different levels. Broad vision programming. Monthly, weekly (trying to give the schedule for the week). And then daily to see what priorities to give. So always think in priority.

T: Have control over the people who work... Everyone must be controlled. Warehouse operations must always be under control. When I'm [at the warehouse] I go for a lunch break to close the doors and then at the end of the break I go to reopen the doors. And if they're there, you work, but at the same time you keep an eye out to see how people move.

G: Here. It's important to watch people. This is a priority that must prevail over the technical/operational aspect as well. (Look for papers on the interaction between operatives)

T: However, another interaction is the application of the machines in the field. And as well as with the organization of camps, you work. Maybe you organize your work in one way, but then you don't have the economic capacity to achieve it. Initially, you say this job should be done this way, but then you see that it can't be achieved on the field with the availability you have.

G: I'd say that more than things you leave behind, it's the priorities you give yourself. The reverse reasoning.

4. *Another important aspect of adaptation is the speed and interconnectedness of information. An interesting example of this phenomenon is the communication*

Understanding the Biomimetic Organization Through Life's Principles

systems of anthills, these can transmit messages across an entire colony in a couple of seconds. This allows him to be extremely sensitive and open to adaptation. How does information normally travel inside Ca' Colonna? And what about outside?

T: sometimes there is fast information, other times it isn't. Because maybe one is in the field, another in the warehouse, these spaces and distances don't allow fast communication. These days we have the person who is in charge of the warehouse who goes to the field to collect, so he also tells those who collect what the product should be like. He drives the tractor, the others harvest. We have organized the harvest with a cart that has a belt where people stand in front of the belt and collect in rows, everyone has their own line and collects, and whoever is in the tractor must be careful to look at the quality of the harvest. My rule was to take away the cell phones from the workers. Because there are those who collect everything and those who stay on cell phones.

G: There are two levels. One is the level of internal communication within the company (which is a priority), the other is that of external communication with stakeholders (which are also customers)

And how do you experience these two levels?

G: for now we are trying to give priority to internal communication, because it is closely linked to organizational aspects. This is what Teresa says about making people communicate in the various stages. If one does not know what comes first one will not be ready for what comes next, and vice versa.

T: There must be a relationship of constant communication, respect and non-discrimination. Because another thing I realized this summer is that there was discrimination between Africans and Italians. I asked a Tunisian guy to bring some guys like him, and he said 'but then the treatment is what it is on the pitch?'. That's when I realized that there was something screeching on the pitch.

G: Then there is the communication between us. Every day at dinner or at coffee time we take the opportunity to take stock. Then maybe we try to give us a program via whatsapp . Because finally communication is programming. When Teresa is down with whoever is in the factory, everyone with their own group tries to manage this. External communication up to now we have neglected it a bit. So much so that now we have to fix the site, the social networks, the catalogue, all this stuff here. More than anything else, the focus was on external communication of a technical nature with visits to the field when there are school-university groups. Welcome. Then some also from experimental companies. When interacting with groups, there is always a flow of people who come to the company from outside.

T: Those relate Edoardo and Carlo. I'm putting myself aside, also because there's work to be done. Edoardo and Carlo manage that , the external relationship, and the relationship with the markets.

G: Exactly. Then everyone has their own communication network, whether they are customers, buyers or technicians. It is important then to exchange this information between us via the app .

T: Ca' Colonna never stops.

G: Still with the communication/external interaction aspect there are the working groups for the EU. Carlo went up to brussels two or three weeks ago for the annual programming. There is also this type of external communication. We based it on relationships with stakeholders in these groups here. These are the levels of communication , internal, external stakeholder relationship.

5. *Still talking about adaptation. Very often in nature it is observed that animals foresee transformations in the surrounding environment. A well-known example is farm animals or cats that behave bizarrely and seek shelter before an earthquake. Having to be in close contact with the dynamic difficulties of nature, what preventive mechanisms have you established at Ca' Colonna?*

T: The first are the meteorological events as such you have to prevent them, and having crops that are harvested all year round, bodies have been formed in the fields (but this already from the first year). In 2015, when I entered, arrangements were made in the field, with ditches, marked ditch lines, they are the rib of the company for detecting the waters in case. In fact, there was a year in which Cesena was flooded and we didn't even notice it. The detection of water, the arrangement of land with the right inclination, an irrigation system to allow a targeted and immediate intervention for each individual body. Bodies that have their own size, 2-3 hectares, some 4.

G: Bodies of land, each with its own crop. Which respect both agronomic rotation and diversification for the purpose of ...

T: Then we have the road system. Each body is surrounded by roads – passing through the ditch system we have, we have two main branches – and we have driveways: points of convergence of ditches for water management, but also calibrated for a load of a truck or trailer of heavy vehicles. Therefore any heavy vehicle can circulate on the farm in all seasons.

G: both the infrastructural aspect inside the farm, agronomic techniques to mitigate climate impacts, water management, micro- irrigation , biodegradable mulching. (All crops are now either seeded or planted with biodegradable mulches to cover the soil).

T: Or even the springer for watering broad-leaved plants...

G: Here you are, all the tricks to **diversify** your business, both incoming and outgoing. And on the other , managing them in terms of arrangements to stabilize this aspect here. I'd say it works on the micro, now we need to take into account the macro, i.e. the macroeconomic scenarios that have a lot of impact right now here. Also to understand market trends. Communicate with stakeholders in order to have an observatory from above in order to direct daily operations.

T: This operation and this communication to my children taught that no one told you the truth. Among farmers, no one says what they are doing. They only talk to you to snoop on what you do. To say ... we have found the neighbors who are organizing the camps as we have them.

So you deal with external information more openly than your colleagues?

T: Generally yes. But it must also be said that we must limit ourselves in telling stories.

G: Well... Even if they copy it's fine.

T: Yes, but it is security that I look at. We in terms of safety. Many enter the farm thinking you are going for a walk or for recreation. But no. Because there are tractors, there are wagons and operators. And I don't want people who arrive and start entering and advancing through these streets of the fields in this way, or enter the warehouse because maybe they want something seasonal...

G: When you try to communicate with the outside world. And you have to do it... Then afterwards everyone feels a bit at home, and then there's an invasion afterwards. But this is also important. Managing a company, whether agricultural or of another type, nowadays precisely for these aspects, risk management, infrastructural/territorial system, but also at the level of services, therefore the external relationship of the company is even more important, because the company cannot have everything inside... therefore the company must have a territorial system of action, therefore external relationships are a way to grow, to acquire and grow... but also to make the territorial system grow. And it is not easy to maintain this balance. To say, in the Marche area it is much more suitable for this type of production, however due to the growth of the territorial system which has been abandoned ... due to packaging, logistics, transport ... the result is that the horticultural sector in the Brands. Even being more suitable from a climatic point of view

T: We have known young companies with which we have tried to get in touch. But it's no use. It's like talking to deaf people, they are extremely closed in on themselves, whatever you say to them you are not taken seriously.

G: This stuff here grows with external interaction. The outside grows if it is interested and opens up to the company. It means stakeholder, it means service, it means institutions, i.e. these processes of interaction... and if the surrounding territorial system does not grow, you are no longer a business.

Interesting that young companies are the most closed...

G: You know what I'm realizing, even in various conferences, especially young people replace technology with technique. They are tools, the tool is not a substitute for the technique. That is, I must have the process I have to do in mind... Afterwards I can use tools, screwdrivers rather than the drone or the sensor, etc. but these are not substitutes for technique. Because I can have these tools but then when I find myself faced with what I want to do I don't know the processes.

T: Then there are guys who have productions, who had begun to take synergies from Edoardo and Carlo (their sons, who also work in the company). But the

- 6. One mechanism that is used in nature to become more resilient is to incorporate diversity functionally. We observe this in the processes and in the variegated forms that nature assumes in every organism, an extreme example of the incorporation of diversity can be the platypus, a mammalian animal with a poisonous beak and claws that hatches eggs and lives in water. How is functional diversity integrated in Ca' Colonna?*

G: in the meantime, certainly in the agronomic rotation. We are in the horticultural sector but 7-8 different species are cultivated, trying to specialize in any case. As Teresa said earlier, at the production level we have fields, each in a specialized construction site, which are rotated. Then we have the warehouse for processed products, hence vertical diversification. On the other hand, market diversification. A broad commercial network... because the basic rule I have is never a customer who exceeds 20% of the turnover. To say, when a company is powered by a financial instrument – see also the fund – it becomes a specialized single-product and single-customer company. In this way there is the conviction of dominating the complexity and it is easier to produce everything with financial ratios. But in this way there is the maximum risk, it is extremely dangerous. Those who do finance address everyone in this way here. Economic specialization because it is thought that efficiency is improved and therefore a single product and a reduction in marketing and external costs, etc. because a single customer. So much so that in the past years this has led to the concept of lean organization, to the company without warehouse (because warehouse is a ballast). Result is, before covid, the only logistics was the ship that brought the raw materials, chips, etc. at the time of the covid the whole system broke down. So in the summer we have a day's warehouse, in the sense that the change in the cold room is day by day, in winter instead we need to have a slightly larger warehouse, the products stay in the cold room for at least a week, because you don't know what the climate will be like. Risk management is contrasted with financial management. And until now companies run with pure financial optics have been ruined.

- 7. A species cannot exist on its own. It always exists in an ecosystem where it depends on other organisms. Mutualistic relationships characterizing many of these interactions in nature. Whether it's bees that pollinate flowers and feed at the same time, or the bacteria in the human gut that feed by helping us digest. What mutualistic relationships has Ca' Colonna established in its environment?*

T: In business operations, you move people based on what they are more capable of.

G: Then moving out. Speaking of the social farm and of the relationship with social cooperatives such as Caritas, precisely to build this relationship on the territory and a large part of the personnel comes from these cooperatives. The last one is an entry from a boy we released from prison, and we have a relationship with the police headquarters. Teresa marks her presence every day. But we have to say thank you because he is very good. So this social aspect is really a direct aspect of the company, then we are part of a group that expresses mutuality, the Apofruit Almaverde chain group which is a cooperative. Then there is the extension of this supply chain in Africa because if we manage to bring our way of doing agriculture there, it means that they too develop this method of sustainable agriculture for their markets but at the same time it means having products for our markets. Organic exotic fruit.

- 8. In nature, the surrounding environment is what feeds us. You use what is abundant, and you survive on that. The various species of fox exemplify this concept, they are specialized in their own areas. The forest fox has specific mechanisms for hunting small mammals, the arctic fox is white and eats anything from berries to the feces of other animals, the desert fox eats insects and hydrates itself on cacti and fruits. How has Ca' Colonna specialized in its strictly surrounding environment?*

Understanding the Biomimetic Organization Through Life's Principles

T: At the beginning we were a showcase where everyone came and everyone was curious to get to know us. I understood that that land has always been a company. Our fields really had a historical tradition.

G: Now the need is to grow other farms around and in Africa. Paradoxically, we have more interest in growing those in Africa than those around us. Insert them, add them, put them on the net, since we already have a processing center, marketing, commercial network, etc. If companies set up with this type of organic farming, they make a complementary range to ours, they'll already have the market open. And this is very difficult because the leap to make is the difficulty of programming. People plant a crop regardless of various timelines and schedules, rather than scaling and staggering over time they find themselves with price drops low demand in the markets. The other important aspect that is often missing is acquiring skills to see the plant as a whole. Because to seriously go organic, you need to know the plant, the soil... and we really started from this aspect here. There is a shortage of technical support, because the mentality has become 'is there a problem? I use a product. Or treatment.' But no. You have to start from how it happens in humans, I can even give you antibiotics, but first I have to make sure you have the right diet to understand that your body is structured in the right way.

You, among other things, have rediscovered organisms that obviously cannot be used in the same way...

G: It must be studied. Each organism must be studied, some may be more tolerant in some respects others more sensitive in others. So this means studying continuously. In the first question you asked us if we make mistakes, we try to make them small so as to maximize ...

T: Also because the wild herbs that are defined as weeds. They can serve as they cannot serve. Sometimes we have had field invasions in the early years that the cultivation based on these herbs which, however, managed in a certain way allow you to have more control. Sometimes herbs come out that can help clean the soil. We try to go this way.

9. An obvious observation in nature is resource efficiency, this is seen in both material and energy resources. Life tends to seek the most elegant and efficient way to achieve its goals. Virtually everything is recycled, reused, and tends to be multipurpose . A somewhat crude but very indicative example of this phenomenon is the use of red fox urine. An apparently waste material is reused for 1. Marking the territory 2. Hatching the sea urchins. Trivially, another example is the leaves of trees that fall every autumn, creating a protective substrate against heavy rains and snowfalls, and after a few years they decompose and become new soil. ³²Do you have this elegance in using resources, even waste ones? Are you multifunctional at Ca' Colonna?

T: The waste process we have in the field that we didn't bring back into the field in the early years

G: We have segmented everything, we have segmented the markets so that each product can have its place on the market. Already speaking of fresh products, the first selection goes to

³²<https://eu.greenbaypressgazette.com/story/news/local/door-co/entertainment/2018/11/21/crossroads-dead-leaves-seem-worthless-but-they-protect-forest/2082278002/>

Understanding the Biomimetic Organization Through Life's Principles

Almaverde rather than Lidl, the second, or the larger product, goes to Babaco ... for fewer environments (?), as a market positioning

T: But it's not just less environments (?) it's a trend

G: it's a trend because the quality of the product is the same, maybe the product isn't as beautiful as the other.

T: Because we have spent 30 years of perfect product in color, aesthetics and calibration. It was appalling ignorance because it's not...

G: We have platforms that market at HORECA (Hotel Catering), where even if the product isn't beautiful, since it's in the kitchen it shouldn't be seen. So we tried to build a segment like in nature. There's a place for everyone on the market, the important thing is to define how, how much and aim for that. In this way the waste product is all used and then now we also have the transformation paths, this year we started making juices, preserves and so we have fine-tuned the development of the product for each segment and gradually as it grows we go to occupy this thing here commercially. Inside the company there must also be a phase of study and experimentation to fine-tune the products.

APPENDIX 2

Interview with Lorenzo Corona: Tecno Group Napoli

Methodological premise:

My thesis deals with biomimicry applied to the corporate structure. Biomimesis or even biomimicry is the practice of imitating structures, logics or mechanisms found in nature for our purposes, whether they are engineering, social, or organizational. In my thesis I develop qualitative indicators to evaluate the biomimetic degree of a company. Starting from the six principles of life ³³I will use the **technique of the cartoons** to present each question of the interview. With the cartoon technique I will give you a concrete example of how that mechanism is implemented in nature, and then I will ask you if or how you think it is implemented in Tecno. These questions as you can imagine will be very interpretive rather than precisely explicit. And they will aim to create a qualitative understanding of biomimetic application at the organizational level, which is currently almost completely unexplored. There are more or less twenty questions, based on your answers there could be a few more or even a few less.

Note on terminology and answers

First off, a couple of notes on the terminology I'll be using. I will use the term **strategies** quite often. I would like you to interpret it as openly as possible, which includes internal strategies, market strategies, marketing strategies etc. You feel free to ask for further developments, expansions, etc. and to answer fully. With this method what matters is not so much the accuracy of the data as the depth of the questions.

PRESENTATION

What is your name?

Lorenzo Corona

How many years have you worked for Tecno?

2 and a half.

What role do you play in Tecno?

I deal with environmental sustainability.

Give me a brief description of what Tecno does

Tecno does many things. The part that you might be interested in is that techno is a series of companies. A company that deals with excise duties, one that deals with sustainability, another that deals with monitoring. All of this falls into the techno group. It's also up to you what you want to talk about. Tecno does all this in a specific way.

³³ the logics of nature, developed by the Biomimicry Institute ,

QUESTIONS

1. *The first principle of life is that everything evolves to survive. A feature of evolution is the integration of the unexpected. Think of genetic mutations for example. Mutations very often lead to failures, death, selection, but they also have a direction, and basically, after a series of mistakes, the right mutation arrives which can carry forward an entire species. Do you apply this mechanism of directed trials and errors in any way in Tecno?*

So what I can tell you is that as Tecno we are company consultants, therefore we create our service starting from the customer's needs. Starting from the customer's need, we try to find answers that from time to time conform to his needs. We orientate ourselves towards the market, each time re-adapting to what the market offers. This is to retarget our response more compliantly. This conformation in various companies that we have adopted as a tecno Group is also a symptom of a specialization of the business model to adapt to market demands. Tecno Accise was born first, then Tecno Srl just to give the market an answer that would make the company a Sco in compliance with the regulations that came out in the energy world. And last year Tecno ESG was born precisely to give specificity and greater identification to the sustainability aspect because the market is moving towards that.

2. *As a follow-up to the previous question... In nature, once identified successful strategies are replicated while obsolete ones decay and are discarded. Think of the teeth of humans, since meat stopped being eaten raw the third molars started to decay. Have you ever had to abandon strategies and processes that were previously functional in Tecno?*

I haven't been in tech for that long, just two and a half years. In these two and a half years, what used to be a founding part has become an important part... but it has not been abandoned.

3. Evolution is a shuffling of information, a re-articulation of DNA into a new configuration for successful renewal. This mixing of information occurs everywhere in nature to readjust to the dynamism of the surrounding environment. Do you have techniques for mixing information and the company's DNA? Which ones are they?

Let's just say it does it all the time. It does so because it restarts with ideas that over time, according to market demand. Requests grow in one direction rather than another, following the regulatory update for example. Or the offer possibility that we are able to generate in terms of professional mail. Or the new requests that come from both multinationals and SMEs. So the company mutates like this.

4. *Another important aspect of adaptation is the speed and interconnectedness of information. An interesting example of this phenomenon is the communication systems of anthills, these can transmit messages across an entire colony in a couple of seconds. This allows him to be extremely sensitive and open to adaptation. How does*

Understanding the Biomimetic Organization Through Life's Principles

information normally travel inside Tecno? And instead out with customers and interlocutors?

That is a more difficult part to manage because having to continually re-adapt, one follows the adaptation and response and takes care of internal communication. So to explain evolutions, changes in a multi-articulated structure that is active throughout the national territory, we do it with a periodicity precisely to avoid not communicating things and leaving a part uncovered. But it is not an immediate thing.

What mechanisms do you use to communicate internally ?

We use email, we use Teams, also Whatsapp , Skype. Let's say that the confused evolution of our internal communication also lies in the use of so many communication channels. And the absence of a centralized channel.

And what about outside? How do you communicate with the outside world?

Yes, there are two channels to the outside. One is that of communication with the world

- 5. Still talking about adaptation. Very often in nature it is observed that animals foresee transformations in the surrounding environment. A well-known example is animals preparing for the arrival of winter with hoarding behaviors. Having to be in touch with the dynamic difficulties involved in the monitoring work, what preventive mechanisms have you established at Tecno?*

compliance and innovation analyzes at a high level which induce the company to move in one direction rather than another, precisely to anticipate any upheavals. Then the continuous regulatory update which serves not only to prevent but also to provide opportunities to the market. Constant and continuous monitoring of regulatory evolution, that is the basis of our profession. And then an analysis of company rights which is to verify what are the possible gaps of the company to be filled first because they can be a possible greater entrepreneurial risk.

- 6. One mechanism that is used in nature to become more resilient is to incorporate diversity functionally. We observe this in the processes and in the variegated forms that nature assumes in every organism, an extreme example of the incorporation of diversity can be the platypus, a mammalian animal with a poisonous beak and claws that hatches eggs and lives in water . How is functional diversity integrated in Tecno?*

Yes, in the continuous changes we try to adapt everyone's skills to new needs by creating new proposals and new answers and also new environmental forms to ensure that everyone's peculiarities are valued.

And this happens through a specific hiring ? Choosing people with different backgrounds/experiences?

Yes with experience above all.

Understanding the Biomimetic Organization Through Life's Principles

- 7. A species cannot exist on its own. It always exists in an ecosystem where it depends on other organisms. Mutualistic relationships characterizing many of these interactions in nature. Whether it's bees that pollinate flowers and feed at the same time, or the bacteria in the human gut that feed by helping us digest. What mutual relations has Tecno established in its environment?*

So, Tecno in this perspective, growing and developing, has developed the pole of sustainability, that is, it has put together different parts and methods, some have entered with large capital in a majority manner, others have entered instead of a minority, with others it has sustainability partnership, with another it has a collaborative partnership on several projects. In order to be able to create an ecosystem that exchanges continuously. Because then everyone follows his own path with his own peculiarities and with his interaction with techno that are different from subject to subject.

The sustainability pole includes Tecno which is Tecno, then Tecno Energy, two companies called Wufinance and Aires, which are majority acquisitions of Tecno, other spinoff partners such as research centers or universities with which Tecno collaborates on certain specific projects.

- 8. In nature, the surrounding environment is what feeds us. You use what is abundant, and you survive on that. The various species of fox exemplify this concept, they are specialized in their own areas. The forest fox has specific mechanisms for hunting small mammals, the arctic fox is white and eats anything from berries to the feces of other animals, the desert fox eats insects and hydrates itself on cacti and fruits. How has Tecno specialized in the strictly surrounding environment?*

Yes, even outside actually. Tecno has its headquarters in Naples where you can find an answer to everything, all the central functions and there is a part of Tecno Napoli that follows all of our services. Then there is a part of Tecno on Milan which is dedicated to sustainability, another part on Bergamo dedicated to energy efficiency, another part on Bolzano which is dedicated to excise duties by exploiting the particularities of the companies with which we entered into relations. But basically Tecno Napoli is the brain and the arm that follows everything and then we have local units where there are our colleagues who are specialized in certain activities according to the particularity of the company we bought or the need we had in the area

- 9. Modularity in nature plays an important role. This allows simple components like cells to become tissues, tissues to become organs, and organs to become systems within living beings. This process is observed everywhere. This modularity allows nature to build from the bottom up, from the simple to the complex, thus being more flexible and adaptable. Do you use this modularity in Tecno? Think you want to use it?*

Yes, I think this is the mechanism we followed.

- 10. Nature also demonstrates a use of self-organization. In practice, the ability to organize themselves without a leader or an executive figure who coordinates movements, but following each other in harmony. An example is the choreography of starlings that occasionally fly over us. Do you plan to apply this self-organization in some way? As?*

No. There are pushes that lead in one direction rather than another, but then our strength is that they are always discussed from the starting point, by those who manage as with our CEO to understand if there is actually something to be done you want to develop....

But we are very horizontal in structure but then with central coordination in the next step.

11. Energy efficiency in nature is a matter of life or death. Low energy cost processes are used everywhere, from our metabolic processes (which minimize energy expenditure) to photosynthesis, which manages to retain 99% of the absorbed energy (better than any of our batteries). What low energy cost processes are used in the company? Which ones would you like to use in the future?

We have no energy-intensive processes. We do it more on the environmental impact part. What we try to do is to minimize our carbon footprint. With this in mind, we are going to optimize everything that is the business process.

12. In addition, efficiency is given by the elegance that nature has in adapting form to function. An example is how the shapes of dolphins are made to travel through water at speed, or the shape of the owl is perfected for night flight, but put in the opposite context neither species would survive. How has the shape of Tecno specialized for its functions?

Yes. We are not the ones who decided to create the sustainability pole, create new partnerships or open new offices in other areas. They came out when we saw that certain colleagues and certain opportunities were better suited to a different context and therefore we created a new context.

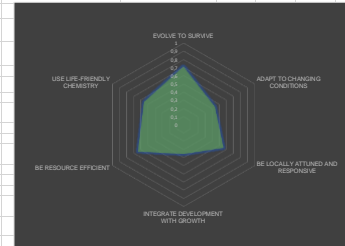
And what is this new context?

It's a new form of proposal, a new form of company, even more fluid, the pole of sustainability is something that didn't exist before. It is something in which various subjects are grouped in a different relationship with respect to Tecno and often without any relation to each other.

Understanding the Biomimetic Organization Through Life's Principles

APPENDIX 3

THE BIOMIMETIC VALUE CREATION TOOL									
LIFE PRINCIPLE	STRATEGY	INDICATORS: Questions of biomimetic fit	IS IT RELEVANT? <small>(Yes/No/Not relevant)</small>	SELECT ANSWER IF RELEVANT	VALUE x Indicator	VALUE x Strategy	LIFE PRINCIPLE	VALUE x Principle	
EVOLVE TO SURVIVE	Replicate strategies that work	Does the company have a written code of conduct?	Yes	No	0		EVOLVE TO SURVIVE	0.7035	
		How often are successful strategies/practices applied or replicated in other areas/divisions/levels of the firm?	Yes	Sometimes	0.67		ADAPT TO CHANGING CONDITIONS	0.435111111	
		How are small mistakes treated in the organizational context?	Yes	As moments to capitalize on	1.00		BE LOCALLY ATTUNED AND RESPONSIVE	0.550333333	
		How timely are obsolete practices and strategies abandoned?	Yes	Immediately	1.00	0.6665	INTEGRATE DEVELOPMENT WITH GROWTH	0.351722222	
	Integrate the unexpected	How often are new organizational practices tested/tried?	Yes	Regularly	1.00		BE RESOURCE EFFICIENT	0.638583333	
		How often does your company conduct SWOT or other types of strategic analyses for development?	Yes	Regularly	1.00		USE LIFE-FRIENDLY CHEMISTRY	0.550333333	
		How does your company view unexpected events?	Yes	As moments to capitalize on	1.00	0.66666667			
	Reshuffle information	To what degree is your company open with its internal activities and processes?	Yes	To a high degree	1.00				
		To what degree does your company delegate research and development to outside sources?	Yes	To a medium degree	0.67				
		To what degree does your company interchange and mix teams and sectors which usually wouldn't collaborate?	Yes	To a medium degree	0.67	0.777333333			
ADAPT TO CHANGING CONDITIONS	Maintain integrity through self-renewal	How fast does information travel within your company?	Yes	Quickly	0.67				
		How fast does information travel from your company to the outside?	Yes	Quickly	0.67				
	Embody resilience through variation, redundancy and decentralization	To what degree has your company developed preventive measures for crises/unexpected events?	Yes	To a medium degree	0.67				
		How diversified is your supply chain?	Yes	Very diversified	1.00				
		How diversified are your clients?	Yes	One client	0.00	0.555333333			
	Incorporate diversity	How diversified are your products/services?	Yes	Very diversified	1.00				
		How diverse is your workforce in terms of ideas, culture, nationality?	Yes	Somewhat diverse	0.50	0.75			
	Leverage cyclic processes	How are moments of high demand handled by the company?	Yes	As possible opportunities	0.67				
		How are moments of low demand handled by the company?	Yes	As possible opportunities	0.67				
		Are there any mechanisms or processes in place to prepare for production highs and lows?	Yes	Yes	1	0.777333333			
BE LOCALLY ATTUNED AND RESPONSIVE	Use feedback loops	Does your company conduct CIQA?	Yes	No	0				
		How much is feedback catered to within your company?	Yes	To a medium degree	0.67	0.333			
	Use readily available materials and energy	Does your company source its products/services locally?	Yes	Yes	1				
		How much of your energy consumed is self-produced or is sourced from a nearby source? (within 100km)	Yes	Some	0.33				
		How much of your workforce is local (coming from the same city or region)?	Yes	All	1.00	0.777666667			
	Cultivate cooperative relationships	Does your company have any ties with universities/research centres?	Yes	No	0				
		Does your company organize or participate in local community activities/events?	Yes	No	0				
	INTEGRATE DEVELOPMENT WITH GROWTH	Combine modular and nested components	Is your organization part of an association with other firms in its sector?	Yes	Yes	1	0.333333333		
			Are your products/services standardized?	Yes	Yes	1			
		Build from the bottom up	To what degree are your products/services compatible with your companies other products/services?	Yes	To a low degree	0.33			
To what degree are your products/services compatible with other companies' products/services?			Yes	Never	0.00	0.444333333			
How often do initiatives/projects originate from lower employees?			Yes	Rarely	0.33				
To what degree do you use incremental development?			Yes	Never	0.00	0.1665			
Self-organize		How free are employees to work on their own projects in work time?	Yes	They are encouraged	1.00				
		Do work groups self-assign roles?	Yes	Rarely	0.33				
Fit form to function		Would you describe your organizational structure as more horizontal or vertical?	Yes	Horizontal	0	0.444333333			
		To what degree does your company use design thinking?	Yes	To a high degree	1.00				
BE RESOURCE EFFICIENT	Use multifunctional design	To what degree are your products/services multifunctional?	Yes	To a medium degree	0.67	0.333			
		To what degree are employees eclectic in their roles?	Yes	To a medium degree	0.67	0.4995			
	Use low energy processes	Does your company use reduced energy practices? (lightbulbs, energy efficient machinery or appliances, etc.)	Yes	Yes	1	0.6665			
		How much energy consumed is renewable?	Yes	Some	0.33				
	Recycle all materials	Does your company abide to a recycling program?	Yes	Yes	1				
		How much of your waste is recycled?	Yes	Some	0.33				
USE LIFE-FRIENDLY CHEMISTRY	Do chemistry in water	How much of your products is recyclable?	Yes	Some	0.33	0.555333333			
		Does your company use any hazardous materials?	Yes	Yes	0				
	Build selectively with a small subset of elements	To what degree does your company use water as a dilutant?	No	Never	0.00	0			
		How intricate and complicated is your supply chain?	Yes	Simple	0.67	0.666			
	Break down products into benign constituents	How long is your supply chain?	Yes	Short	0.67				
		Does your company emit toxic wastes or emissions? If yes, to what degree does your company break them down?	No	To a high degree	1.00				
		Does your company in your supply chain emit toxic wastes or emissions? If yes, to what degree does these companies break them down?	No	To a medium degree	0.67	1			



Summary

The objective of this research paper is to provide a framework for the application of biomimetics at the organizational level and a tool to evaluate it.

What is biomimetics and how can it be applied to organizations?

Biomimetics, or biomimicry is the interdisciplinary field that studies nature and its processes and applies them in design and engineering to solve problems and create sustainable solutions. Biomimetics can also be applied to organizations in a number of ways to help improve their performance and sustainability. Some of the ways that biomimetics can be applied to organizations include:

- **Organizational structure:** Just like in nature, organizations can adopt decentralized and networked structures that are more adaptable and resilient to change. This can help organizations to respond more effectively to challenges and opportunities.
- **Decision-making:** Organizations can learn from the way that organisms in nature make decisions, such as through consensus-building and collective intelligence, to create more effective decision-making processes.
- **Innovation:** Organizations can learn from nature's process of continuous adaptation and innovation, and apply these concepts to their own product development and innovation processes.
- **Resource management:** Organizations can learn from the way that ecosystems manage resources, such as through recycling and closed-loop systems, and apply these principles to their own resource management processes.
- **Collaboration:** Organizations can learn from the way that species in nature collaborate to achieve common goals, and apply these principles to create more effective cross-functional collaboration within and outside the organization.

The Life's Principles, developed by the Biomimicry Institute³⁴ in 2010, are a set of principles based on the patterns and strategies found in nature meant to guide sustainable design and

³⁴ The Biomimicry Institute is a non-profit organization based in Missoula, Montana, United States founded in 2006. It works to advance the field of biomimicry through research, education, and consulting services. The Institute also provides education and training programs for students, professionals, and organizations, including biomimicry workshops, certification courses, and a global network of biomimicry specialists. Additionally, the Institute provides consulting services

innovation. These acted as the foundations for the framework developed in this paper. These principles and their respective strategies are:

1. Evolve to survive

- a. Replicate strategies that work
- b. Integrate the unexpected
- c. Reshuffle information

2. Adapt to changing conditions

- a. Maintain integrity through self-renewal
- b. Embody resilience through variation, redundancy and decentralization
- c. Incorporate diversity

3. Be locally attuned and responsive

- a. Leverage cyclic processes
- b. Use feedback loops
- c. Use readily available materials and energy
- d. Cultivate cooperative relationships

4. Integrate development with growth

- a. Combine modular and nested components
- b. Build from the bottom up
- c. Self-organize

5. Be resource efficient

- a. Fit form to function
- b. Use multifunctional design
- c. Use low energy processes

to help organizations apply biomimicry principles to their products and operations. The Institute is recognized as a leading organization in the field of biomimicry and has helped to advance its use in various fields and industries, including architecture, engineering, product design, and business.

d. Recycle all materials

6. Use life-friendly chemistry

a. Do chemistry in water

b. Build selectively with a small subset of elements

c. Break down products into benign constituents

In chapter 2 of the paper, each strategy was explained and examples of their applications in nature were presented. For each of the strategies, organizational applications were also extrapolated. These were gathered through research and logical applications of the natural strategies of each of the Life's Principles.

To further inform the organizational applications of natural strategies, two interviews were conducted with experts from innovative Italian firms. These interviews were of an associative type. In essence, an example of a natural application of each strategy was presented with the aim of creating spontaneous associations in the mind of the interviewee. Therefore the questions were intentionally open and slightly ambiguous to seek out an interpretation of the strategy. The selected firms are from very different industries (Ca' Colonna is a small, innovative agricultural firm based in Emilia Romagna; Tecno Group is a large energy and sustainability monitoring group based in Naples) and the interviewed experts themselves hold important managerial positions within their firms and are well-versed in sustainable and innovative frameworks.

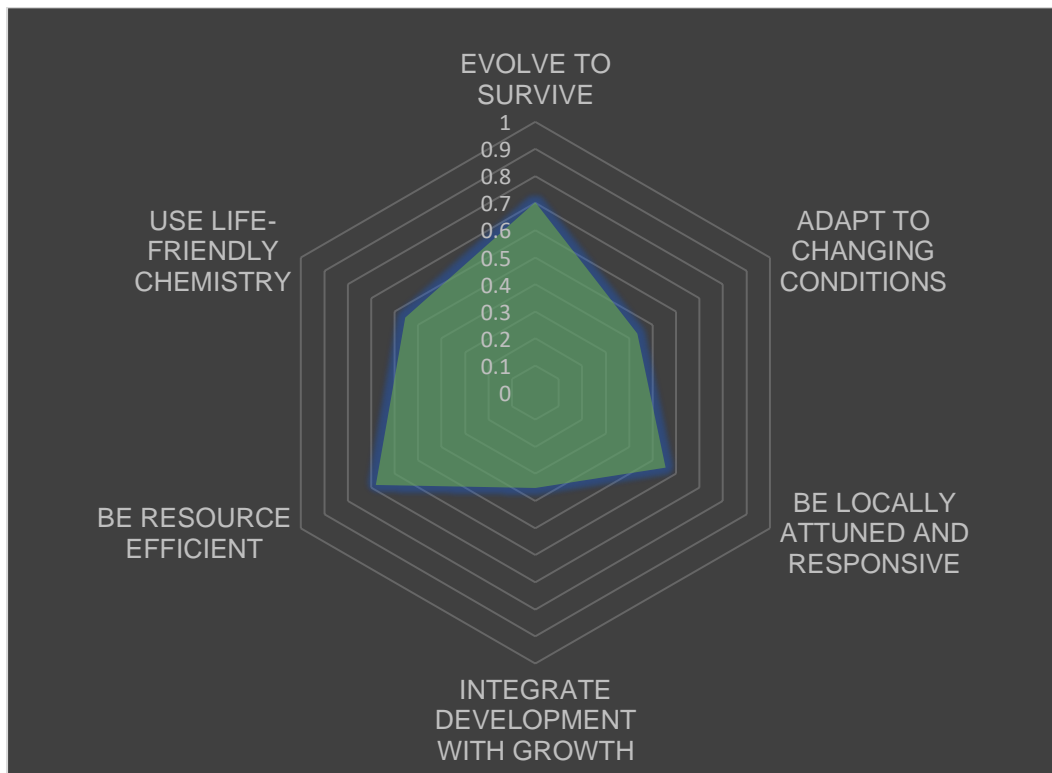
These extrapolated organizational applications, both from the research and the interviews went on to inform the creation of a set of qualitative indicators for a tool which can evaluate biomimetic application now. These indicators are:

Understanding the Biomimetic Organization Through Life's Principles

LIFE PRINCIPLE	STRATEGY	INDICATORS: Questions of biomimetic fit
EVOLVE TO SURVIVE	Replicate strategies that work	<i>Does the company have a written code of conduct?</i>
		<i>How often are successful strategies/practices applied or replicated in other areas/sectors/levels of the firm?</i>
		<i>How are small mistakes treated in the organizational context?</i>
		<i>How timely are obsolete practices and strategies abandoned?</i>
	Integrate the unexpected	<i>How often are new organizational practices tested/tried?</i>
		<i>How often does your company conduct SWOT or other types of strategic analyses for development?</i>
		<i>How does your company view unexpected events?</i>
	Reshuffle information	<i>To what degree is your company open with its internal activities and processes?</i>
		<i>To what degree does your company delegate research and development to outside sources?</i>
<i>To what degree does your company interchange and mix teams and sectors which usually wouldn't collaborate?</i>		
ADAPT TO CHANGING CONDITIONS	Maintain integrity through self-renewal	<i>How fast does information travel within your company?</i>
		<i>How fast does information travel from your company to the outside?</i>
	Embody resilience through variation, redundancy and decentralization	<i>To what degree has your company developed preventive measures for crises/unexpected events?</i>
		<i>How diversified is your supply chain?</i>
		<i>How diversified are your clients?</i>
	Incorporate diversity	<i>How diversified are your products/services?</i>
<i>How diverse is your workforce in terms of ideas, culture, nationality?</i>		
BE LOCALLY ATTUNED AND RESPONSIVE	Leverage cyclic processes	<i>How are moments of high demand handled by the company?</i>
		<i>How are moments of low demand handled by the company?</i>
		<i>Are there any mechanisms or processes in place to prepare for production highs and lows?</i>
	Use feedback loops	<i>Does your company conduct CRM?</i>
		<i>How much is feedback catered to within your company?</i>
	Use readily available materials and energy	<i>Does your company source its products/services locally?</i>
		<i>How much of your energy consumed is self-produced or is sourced from a nearby source? (within 100km)</i>
		<i>How much of your workforce is local (coming from the same city or region)?</i>
Cultivate cooperative relationships	<i>Does your company have any ties with universities/research centres?</i>	
	<i>Does your company organize or participate in local community activities/events? Is your organization part of an association with other firms in its sector?</i>	
INTEGRATE DEVELOPMENT WITH GROWTH	Combine modular and nested components	<i>Are your products/services standardized?</i>
		<i>To what degree are your products/services compatible with your companies other products/services?</i>
		<i>To what degree are your products/services compatible with other companies' products/services?</i>
	Build from the bottom up	<i>How often do initiatives/projects originate from lower employees?</i>
		<i>To what degree do you use incremental development?</i>
	Self-organize	<i>How free are employees to work on their own projects in work time?</i>
<i>Do work groups self-assign roles?</i>		
<i>Would you describe your organizational structure as more horizontal or vertical?</i>		
BE RESOURCE EFFICIENT	Fit form to function	<i>To what degree does your company use design thinking?</i>
		<i>To what degree does the form of the product/service you provide shaped by customer needs?</i>
	Use multifunctional design	<i>To what degree are your products/services multifunctional?</i>
		<i>To what degree are employees eclectic in their roles?</i>
	Use low energy processes	<i>Does your company use reduced energy practices? (lightsaving lightbulbs, energy efficient machinery or appliances, etc.)</i>
		<i>How much energy consumed is independently produced and renewable?</i>
Recycle all materials	<i>Does your company abide to a recycling program?</i>	
	<i>How much of your waste is recycled?</i>	
	<i>How much of your products is recycleable?</i>	
USE LIFE-FRIENDLY CHEMISTRY	Do chemistry in water	<i>Does your company use any hazardous materials?</i>
		<i>To what degree does your company use water as a dilutant?</i>
	Build selectively with a small subset of elements	<i>How intricate and complicated is your supply chain?</i>
		<i>How long is your supply chain?</i>
	Break down products into benign constituents	<i>Does your company emit toxic wastes or emissions? If yes, to what degree does your company break them down?</i>
		<i>Does your companies in your supply chain emit toxic wastes or emissions? If yes, to what degree does these companies break them down?</i>

Understanding the Biomimetic Organization Through Life's Principles

The indicators were assigned a set of qualitative answers which ranged from yes/no to 4-5 gradual options. The selected qualitative answers then assume quantitative values (from 0-1) which can be measured, aggregated and even graphically represented. This is a visual example of a firm's biomimetic fit as measured through this framework:



Limitations and further developments of the Life's Principles framework presented in this paper

- Though a fully functional tool was developed, it should not be considered as a valid normative tool for firms to base themselves on for *biomimetic development* today. This is because organizational biomimicry is still in its infancy and the foundations for this type of research have yet to be further investigated before a framework of this type can be followed and applied by firms.

Understanding the Biomimetic Organization Through Life's Principles

- Though the interviewees are innovators and experts in their areas, by giving their own interpretations of the questions in the interview, they could have warped the question to fit their own developmental and organizational point of view. This could have constrained the quality of the indicators extracted. For a more future-oriented framework a larger panel of informed experts would likely be a better way of extracting indicators.
- Another limitation concerns the use of qualitative data to compile the tool. A lot of the indicators use measure words which could be highly interpretative or could be blurred by firms in their own organizational dynamics, this constrains the framework's quality and conversion into a qualitative tool.
- An interesting and unexplored subject in this paper is the interconnectedness and interdependence of all processes in the ebb and flow of nature. Each of Life Principles blends in and ties into the others to become more than a sum of its parts. This is what is explored in complex systems theory. This concept would have required a research paper in and of itself, thus it was not included in this paper, however a future framework should likely take into account complexity theory and its possible implications for organizational dynamics.

In this paper, a biomimetic framework of the organization was built and a tool to evaluate it was presented. This was to stimulate and broaden the understanding of biomimetic application at the organizational level. Hopefully, further research will be conducted and the framework presented here will be expanded and transformed to include the aforementioned developments, as well as divergent approaches to organizational biomimetics.