INTRODUCTION TO BIOINSPIRED STRATEGIC DESIGN

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Bioinspiration, the practice of drawing inspiration from the marvels of nature inherent in living organisms, has always been a wellspring of creative ideas that have catalyzed human innovation. A compelling typification of this phenomenon lies in humanity's enduring yearning to emulate the flight capabilities of birds. The aspiration to soar through the skies can be traced back to ancient times and is enshrined in various age-old legends, notably including the tale of Icarus and Daedalus, which showcases the ancient fascination for bird-inspired flying contraptions. In the 9th century, the Andalusian polymath Abbas Ibn Firnas made a noteworthy attempt to achieve flight by fashioning wings crafted from silk, wood, and feathers. More famously, in the 15th century, Leonardo da Vinci meticulously studied the intricate flight patterns of birds as a means to inform his designs and engender the advancement of flying machines.\(^1\) At the dawn of the 20th century, the Wright Brothers embarked on a remarkable journey inspired by the flight of birds. They ingeniously designed bioinspired warping wings for their aircraft, the Wright Flyer, leading to the most celebrated milestone in aviation history.\(^2\) On December 17, 1903, their relentless pursuit paid off as they achieved the first sustained flight at Kitty Hawk, North Carolina.

In recent times, the principles of bioinspiration have increasingly influenced the development of large number of innovative products and solutions.\(^3\) The approach of studying and drawing inspiration from the adaptations and mechanisms found in biological organisms to solve technical problems or create new technologies is also known as biomimetics or biomimicry.\(^4\) The term biomimetics was coined by American inventor Otto Schmitt, who developed the Schmitt Trigger based on his study of neural impulse propagation in squid nerves.\(^5\) Other notable examples of biomimetic products include Velcro, invented by Swiss electrical engineer George de Mestral, inspired by the way burrs stick to animal fur; the Harare Eastgate center in Zimbabwe, designed using the principles of termite mounds for temperature regulation and energy efficiency; and the Shinkansen trains in Japan, whose aerodynamic design draws inspiration from the beak of the Kingfisher bird.

Adopting processes found in nature can also improve the performance of human systems. One notable example is the utilization of swarm intelligence techniques, such as ant colony optimization (ACO), in various fields. ACO is an optimization algorithm inspired by

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the foraging behavior of ants.\textsuperscript{6} Ants are able to find food efficiently despite the lack of a centralized control system, and they are able to adapt to changes in their environment, such as the presence of obstacles or the depletion of food sources. ACO has been applied to a wide range of problems, including routing, scheduling, and resource allocation. Over the years, systematic approaches have been developed to assist in identifying potential biomimetic solutions to technological challenges and to determine where to find them. One such approach is Bio-Triz, a method that leverages patterns found in nature to identify and solve problems.\textsuperscript{7}

While solutions inspired by nature and living organisms have achieved notable success in various fields, their prevalence still remains almost paltry compared to their vast potential. One area that remains largely untapped is the application of bioinspiration to design and solve challenges faced human organizational systems, including businesses, governments, militaries, markets, cities, and society as a whole. This is surprising, given that both organisms and organizations share a common overarching goal: survival.\textsuperscript{8} Organisms have evolved efficient systems for survival, and human organizations, in turn, have developed complex systems for achieving their goals and addressing the challenges they face. However, despite this shared goal, there has been limited exploration of how the principles and mechanisms found in living organisms can be applied to improve the performance and resilience of human organizational systems. The book aims to address this gap by exploring the potential of bioinspiration in enhancing the design of human organizational systems.

\textbf{FROM LIVING ORGANISMS TO HUMAN ORGANIZATIONS}

The fundamental objective of all living entities is to survive and continue their existence. This book's lessons draw heavily from the presumed analogical similarity between living organisms (including plants) and human organizations, which can provide valuable insights into decision-making at a systemic level. This approach consists of two parts: firstly, comparing diverse organisms that are distinct from one another, and secondly, applying common principles found in living organisms analogically to organizational systems.

In nature, it is common to find that organisms instinctively take actions that aim to achieve one of four essential objectives for survival: managing resources, particularly sources of energy; protecting themselves from the environmental forces; forming and maintaining relationships with others; and defending themselves against threats from other entities. Furthermore, many living organisms have similar functional components or organs, such as those for sensing, movement, and adhesion, that contribute to these basic objectives. This similarity among organisms allows for comparison of different organisms, regardless of their habitat or specific methods of achieving these objectives. As most physiological and behavioral adaptations observed in living organisms are related to one or more of the four basic objectives, it is possible to compare solutions across different entities that are otherwise dissimilar. As an example, we can compare the water conservation strategies of the Saguaro cactus (Carnegiea gigantea) and the dromedary camel, despite the two organisms not being closely related. This comparison may reveal common principles. In fact, the more dissimilar the entities being compared, the more likely it is that common principles will be identified, if they indeed they exist. These common principles can then be confidently applied to human systems due to their generalizability. For example, one potential application that could be

\textsuperscript{6} Dorigo, M., & Stützle, T. (2019). \textit{Ant colony optimization: Overview and recent advances}. Springer International Publishing.


influenced by the water-conserving strategies of the dromedary and the saguaro is the development of water-efficient systems in vehicle manufacturing, irrigation or sustainable architecture.9

It is not surprising that the objectives of business organizations are analogous to those of living organisms, as both strive for survival. Both also require effective resource management, protection from external forces, the ability to attract customers or partners, and the ability to evade predatorial entities. However, the similarities between specific business organizations and living organisms become more strained when we consider more specific characteristics and behaviors. For example, while business organizations are primarily motivated by profit, governmental organizations may prioritize other goals such as serving the public interest. The predator-prey model is one example of a biological concept that has been applied to business environments, but there are limitations to this analogy. In nature, predator-prey relationships typically occur within a single species, whereas in business environments, these relationships can occur between different types of organizations.

Although the specific ways in which living organisms manifest their survivability-related objectives can be challenging to compare, these differences also offer opportunities for identifying unique and valuable strategies. By considering the reasons behind these adaptations or mechanisms in the context of the common, overarching goals shared by both organizations and organisms, we can gain valuable insights into novel strategies for achieving survival and success in challenging environments. One helpful approach is to examine the unusual adaptations or behaviors observed in certain species in nature, which may not be present in similar species that reside in different environments. To illustrate this approach, let us consider the Arctic fox and the fennec fox, two related species that inhabit contrasting environments and exhibit remarkable adaptations.

The Arctic fox lives in the frigid Arctic regions, while the fennec fox inhabits the hot and arid Sahara Desert. The Arctic fox has a thick, insulating fur coat that helps it withstand the extreme cold temperatures of the Arctic. Its fur changes color with the seasons, transitioning from brown in the summer to a snowy white in winter, providing camouflage against predators. In addition, the Arctic fox has a compact body with short legs and ears to minimize heat loss and reduce exposure to the extreme cold. These adaptations allow it to conserve energy and stay warm, improving its chances of survival in a harsh climate.

On the other hand, the fennec fox has adapted to the scorching heat of the desert in different ways. It has large ears with a high density of blood vessels, which help dissipate heat and regulate its body temperature. These large ears also aid in detecting prey underground by amplifying sound waves. Moreover, the fennec fox has long and bushy fur, which not only provides insulation but also protects it from the intense sun during the day and the cold desert nights. Its kidneys are highly efficient at conserving water, allowing it to survive in an environment where water sources are scarce. Their adaptations highlight the trade-offs involved in their survival. While the Arctic fox prioritizes insulation and energy conservation, the fennec fox focuses on heat regulation and water conservation. Given that these animals are similar to each other apart from their habitat-related characteristics, we can more easily connect the unusual adaptations found in each of the species relate to their residing environment.

It is important to recognize that adaptations in living organisms are part of a larger, interconnected system. No adaptation exists in isolation, but rather works in conjunction with other adaptations and functions to contribute to the overall well-being of the organism. This means that there are often trade-offs involved; for instance, an animal's size can influence its

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ability to acquire certain types of resources. Extremely large animals may have an advantage in acquiring certain types of resources with minimal effort, such as the blue whale consumption of plankton, while smaller animals may have to exert more effort to obtain food, such as a squirrel gathering and hoarding nuts. Similarly, an animal's highly developed sensory function may come at the cost of less developed senses in other areas. It is also important to note that animals are highly optimized to their specific habitats, and even slight modifications can disrupt their ability to survive.

The giraffe is a captivating example that demonstrates how adaptations in living organisms are interconnected and involve trade-offs. The giraffe's most distinctive feature is its long neck, which enables it to reach leaves high up in the trees, its primary source of food. However, this adaptation comes with trade-offs as well as other related adaptations. The long neck of a giraffe lets it to access a diet source that is unreachable to many other herbivores. By reaching higher leaves, giraffes can obtain a nutrient-rich diet, reducing competition for resources. However, the long neck presents challenges as well. Giraffes require a strong and efficient cardiovascular system to pump blood up to their heads against gravity. To achieve this, giraffes have an enlarged heart and high blood pressure, which are necessary for maintaining blood flow to their brains and to prevent fainting when they lift their heads after feeding at ground level. However, the giraffe's long neck also makes them more vulnerable to predation, as it becomes challenging to defend themselves against predators when their heads are high above the ground. These trade-offs between the advantages and disadvantages of the giraffe's long neck illustrate the interconnectedness of adaptations and their impact on the overall well-being of the organism.

The book *Bioinspired Strategic Design* builds on the above insights and introduces a new bioinspired model for designing organizational systems by drawing on natural analogies to improve survivability. The goal of the book is to provide organizations with the tools they need to understand the design of living systems and use the lessons to improve their ability to respond to uncertainty in dynamic and challenging environments. At the core of this book lies the ERP framework, which highlights the vital role of three key capabilities – efficiency (E), resilience (R), and prominence (P) - for the endurance of living organisms in demanding habitats. This framework also underscores the significance of these ERP factors for human organizations grappling with their own challenging environments.

THE SQUIRREL’S TRILEMMA AND THE ERP FACTORS

To illustrate the interplay of these ERP factors, we can examine the quandary faced by a squirrel when stockpiling nuts for its winter survival. The trade-offs encountered by the squirrel bear resemblance to those confronted in organizational decision-making within challenging environments. The squirrel faces challenging decisions when it comes to collecting and storing nuts for the winter. On one hand, it needs to gather as many nuts as possible to ensure its survival through the cold months. On the other hand, it must balance this need with the risks posed by predators and competitors, as well as its own physical limitations. In a situation where there is an ample supply of nuts available, the squirrel may be tempted to gather as many as it can as quickly as possible. This strategy, however, is fraught with danger. The squirrel's rapid movements may attract the attention of predators and competitors, putting it at risk of being attacked or having its food stolen. Additionally,

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the squirrel’s focus on gathering nuts may cause it to become distracted and fail to notice potential threats.

A more effective strategy for the squirrel would be to gather nuts at a steady pace, taking regular breaks to rest and scan its surroundings for potential dangers. By moving more deliberately, the squirrel can avoid drawing attention to itself and its food supply. It can also use its breaks to plan the most efficient route for gathering nuts and to assess the amount of food it has already collected. This will allow the squirrel to gather enough nuts to survive the winter without wasting energy or exposing itself to unnecessary risks. In addition to gathering nuts at a steady pace, the squirrel must also take care to hide both the source of its food and its storage location. Early in the gathering process, the squirrel should hide the tree where it is gathering nuts to avoid drawing competitors to the source. Later, it should carefully conceal the location where it has stored its nuts to prevent other animals from finding and stealing them.

Overall, the squirrel's trilemma requires it to balance its need for food and rest, demanding efficiency, while considering the risks posed by environmental forces including immediate and future weather conditions, requiring resilience. Additionally, the squirrel must also be mindful of the attention it may attract from predators and competitors, demonstrating the importance of prominence. By gathering nuts at a steady pace and taking care to hide both the source and storage location of its food, the squirrel can maximize its chances of survival through the winter. The squirrel’s trilemma underscores the significance of three ERP factors – efficiency, resilience, and prominence – in ensuring survivability against the trifecta threats of limited resources, strong forces, and adverse observers. Similar to the squirrel, firms, governments, and individuals must balance survivability factors of efficiency, resilience, and prominence (ERP) to stay alive during tough times. In this book we use the ERP model as an analytical framework. Comparing strategies of different living organisms yields general principles of strategic design that potentially extend to other entities that function in dynamic environments. These principles primarily relate to the relative significance of threats, the importance of ERP factors, the nature of interrelationships among the ERP factors, and the tradeoffs involved while taking actions to improve survivability.