Editorial

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Biographical notes: Hisham A. Abdel-Aal graduated from Alexandria University, Alexandria, Egypt in 1984. He is currently an Invited Professor at Arts et Métier ParisTech where he leads efforts within a 'biomimetics for green manufacturing' research cluster. His research expertise falls within the broad field of tribology and sustainable design. His current interests emphasise bio-inspired design of functional and deterministic surfaces. He has authored more than 100 archival papers and book chapters and lectured on the subject in several countries.

"The heavens themselves, the planets and this centre,
Observe degree, priority, and place,
Insisture, course, proportion, form,
Office, and custom, in all line of order."

Shakespeare, Troilus and Cressida

Human fascination with nature is rooted in the harmonic expression of form, function, and proportion often observed in our surroundings. On and off, throughout history, humans have sought to identify elements of a perceived 'heavenly order' manifested in beauty, order, or optimality of function.

In modern times, this quest acquired considerable momentum due to the adverse effects of intense industrialisation on natural resources. In an effort to change human engineering practices especially the philosophy of design, many are turning toward nature to explore its methods. This resulted in the inauguration of a new, interdisciplinary, realm of scientific queries that entail mimicking, and learning from the biological world, i.e., biomimetics. The term, biomimetics has a Greek origin: 'bios' meaning life and 'mimesis' meaning to imitate. It follows that the domain of biomimetics comprises the study and imitation, where possible, of nature's methods, designs, and processes. In its essence, this rapidly growing field, is but a rigorous '*contemporary*' reformulation of perpetual human curiosity about *the ways of nature*.

Our surroundings hold a vast reservoir of ideas. Not all ideas, however, avail themselves to feasible mimicry in the human world. In such a case, the focus of a student of nature is to comprehend the intricacies of how such an idea is implemented in nature to deduce a design rule fit for the human engineer. These design rules stem from correlating the structure of a particular bio-analogue to its function. Such a process, termed as bio-inspired or natural-inspired design is one of the building blocks of human interaction with nature. Further, this process, a human engineer being inspired by the study of the construction of a natural species, constitutes the premise for viewing nature as an ‘engineer’ and the objects in or surroundings as ‘designs’. Whence, one can speak of the correlation of structure, function, and form in natural constructs as elements of design-in-nature.

Considering the elements of design in nature, from a pure engineering perspective, is often confused with the so-called ‘intelligent design’. This later term stands at the heart of an intense ongoing debate between ‘creationists’ and ‘evolutionists’. It often invokes arguments and counter arguments between ‘religious biology’ and ‘Darwinian biology’, at times, or between ‘atheism’ and ‘divinity’ at others. The claim is that design necessitates a ‘designer’, and since design by default is purposeful, then this ‘designer’ is cognizant and intelligent whence, ‘Divine’. The counter claim is that Darwinian dynamics (evolution and natural selection), is the origin of the forms, structures, and processes we observe in our surroundings. On a sublime level, such a debate may relate to the view of nature from the perspective of a human engineer who seeks to correlate structure to function in the natural world. However, identifying such a correlation should not polarise those who scour nature for possible technical inspiration, toward a particular side of the philosophical debates.

A student of design-in-nature should distinguish between two fundamental queries. The first is “how does construction of an entity relates to its observed function” and the second is “what caused this entity to assume its observed traits?” The answer to the first question defines a domain of investigation that is entirely on scientific principles, logical arguments, and objective formulations. Answers to the second question, however, considerably include elements originating from faith, opinions, or spiritual inclinations. Suffice to mention that investigations of the second kind are of an open ended subjective nature. This cannot constitute a solid foundation for a technical paradigm. As such, it is only by detaching from spirituality and religious perceptions that a human engineer may purposively investigate the mechanistic aspects of nature. He may consider nature as a master catalogue where basic elements, geometrical shapes, and measurements cleverly formulate precise grammar through which eloquent yet lucid compositions manifest purposeful construction. From a technical perspective, therefore, one may argue that natural species portray optimised constructs that co-exist in an orderly fashion.

The logic of optimisation in natural systems, however, need not coincide with that of human engineering. In this sense, the study of nature introduces new dimensions, within the logic of technical inception, worthy of consideration in the human engineering domain. It is no accident, therefore, that the human engineer, upon contemplating nature, delves into a rich resource where familiar principles are applied in diverse and astonishing ways. This resource, often, avails its elements for extraction, adaptation, or transfer to the technological world where the resulting conceptions are hailed for their novelty. Therefore, studying the elements of design in nature is essentially concerned with infusing the technical world with innovative concepts derived from the natural world.

Biomimetics, bio-inspiration, natural engineering, bionics, etc., stand for widely spreading trends in the technological world, the main tool of which, is to scour technical solutions available in the natural world then transfer them to the human engineering domain. Although these terms are of recent origin, the underlying concept is deeply rooted in antiquity. Indeed, inspiration by nature dates back to primitive man. Human perception of shape, form, geometry, beauty, and function may have originated from observing, and interacting, with nature. In this sense, the role of 'nature as a mentor' in design is not alien to the human intellect. Despite that, however, the philosophy of design generation in nature fundamentally differs from that in the technical world.

In nature, design for function strictly dominates. Underpinning this paradigm is the general principle of 'separation of function'. Simple single-cell organisms, for example, have to provide all their function in one cell, whereas higher animals and plants have many different kinds of cells for special purposes. Separation of function enhances survivability of species in a fiercely competitive world that promotes economy of living material. Natural designs, also, portray a complimentary relation between form and function. The pursuit of a single purpose requires careful considerations of the imperatives of balancing economy of design (concerning materials and effort) and efficiency of function. This often results in designs that reflect elegance, and for the keen observer manifests a dimension of beauty. This beauty, in the most part, stems from form following function rather than conscious aesthetic intentions.

The imperatives of design in nature are severe. They pertain to reproduction (conservation of the species), growth, and survivability. There are also limitations on the kind of materials that can be used, the sorts of mechanisms, and structures, which can be developed. This reflects on the degree of complexity of the outputs. Complexity, in itself, does not appear to be costly in natural designs. In the human design domain, cost is balanced against performance. Design outputs, have relatively less complicated shapes to accommodate ease of manufacturing rather than optimal fit to the intended task. Simplicity is generally considered a virtue in human engineering. Meeting complex tasks, for example, with few and simple parts, makes for a strong aesthetic appeal.

Perhaps a major difference between human and natural engineering is the dependence on energy in the former, while depending on information within the later. Such a difference highlights the essence of change that bio-inspiration can bring to human engineering. That is, the establishment of a reproduction based, rather than a manufacturing based design culture were designs that facilitate recycling, sustainability, and remanufacturing without reformulation of chemistry are generated. In all, the interaction with nature is hoped to bring a cultural change in human engineering where 'co-existing with' rather than 'taming' nature is possible.

We are grateful that Inderscience agreed to dedicate a special issue of the *International Journal of Design Engineering* to such an important topic. In this regards, a note of appreciation is due to the supporting staff of Inderscience and to Professor Daizong Su, Editor-in-Chief of this journal, for help and guidance.

The current issue of the journal presents several interesting ideas covering a wide spectrum of possible nature-inspired applications:

Torres-Sanchez and Corney, describe a novel manufacturing method to produce cellular materials with gradient porosity distribution. Producing such a class of materials is essential for many applications, due to the potential of customising properties. Our current techniques do not allow mass production however. In their paper, the authors introduce a potential solution based on the control of energy supply to the foam. The regulation of energy input allows for variation of porosity on a bulk scale.

A methodology for abstracting biological functional concepts for application in human engineering is introduced by Nagel and co-authors. The proposed strategy reduces the particular biological function of interest to an engineering design problem. Therefore, the need for a design engineer to be well versed in biology is not mandated.

Bhattacharya and co-authors, investigate the essence of robustness in cell states through studying double-negative feedback loops in cells. They present a relatively generic model based on an ordinary differential equations.

The question of how to identify the degree of affordance of a task in ergonomics is explored by Morineau. In his paper, he presents a new method, Turing machine task analysis, which combines ecological physiology to logical formalism used in logical machines. The result is a design approach that considers the environmental constraints on a design as well as intended ergonomic function.

Liskiewicz and co-authors, demonstrate the tribological efficiency of natural systems by surveying the frictional mechanisms observed in nature. They present examples of natural tribological systems of different scales. They further point out how the study of these natural systems can impact design of manmade frictional systems.

More papers that cover additional aspects of that vast discipline were presented, however due to space constraints their publication is to follow. In choosing the material to be included, we have attempted to broadly introduce the subject. We recognise that one cannot include all possible aspects of a multifaceted topic as that of design in nature. As such, no claim of completeness is advanced.

Finally, I would like to acknowledge that the ideas expressed in this editorial are my reflections on the subject. In writing these, I have attempted to claim neutrality, as much as possible, to the philosophical and spiritual notions currently associated with the study of such a topic. Therefore, no claim is made to the validity of either camps, creationists or evolutionists, the only view brought forward is that of an engineer who attempts to advance his design trade. It is hoped that the included papers will inspire the reader to delve into this interesting subject and then he will form his own opinions.