Preface

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Biographical notes: Hisham A. Abdel-Aal obtained his Undergraduate degree in Mechanical Engineering from Alexandria University, Alexandria, Egypt in 1984. He obtained his PhD from the University of North Carolina in Charlotte, USA in 1998. Currently, he is a Research Professor at Arts et Métier ParisTech where he leads research efforts within a 'biomimetics for green manufacturing' research cluster. His expertise falls within the broad field of tribology and sustainable design. He is the author of more than 100 archival papers and book chapters and has lectured on the subject in several countries. His current interests emphasise bio-inspired design of functional and deterministic surfaces.

> "He flew faster than the phoenix in his flight when he dressed his body in the feathers of a vulture."
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> Mu'min ibn Said describing Ibn-Firnas attempted flight

Bionics is defined as the science of systems which have some function copied from nature, or which represent characteristics of natural systems or their analogues. The word, possibly originating from the technical term *bion* (*from Ancient Greek: βίος*), meaning 'unit of life' and the suffix *-ic*, meaning 'like' or 'in the manner of', hence 'like life'. The term stands for a relatively recent discipline that promotes the practical use of mechanisms and functions originating in biological forms in engineering, design, and human technology in general. The transfer of technology between life forms, at all scales, and manufacturing is, therefore, the core realm of bionics. The discipline is sometimes referred to as bio-mimetics, bio-inspired design, etc.

There are many products that emerged out of successful application of the bionic paradigm. One famous example, that became indispensible to many, is that of Velcro which was conceived by George de Mestral in 1914. Velcro which employs a so-called hook-and-loop fastener mechanism is a direct mimicry of the burrs of burdock which have many miniature hooks that adhere to many surfaces upon contact.

Although of recent origin as a discipline, bionics as a design paradigm is quite ancient. Indeed the concept of technology transfer between life forms and human engineering extends deeper in history. The history of heavier than air flight is but one of the many examples that supports such a notion. The myth of Pegasus and the legend of 'Icarus and Daedalus' are glimpses that manifest success of bionics (conceptually at least). An embodiment of the myth and legend took place as early as 875 A.D. That is when Abbas Ibn Firnas (810–887 A.D.), also known as Abbas Qasim Ibn Firnas, a

Muslim Andalusian polymath (also inventor, engineer, aviator, physician, Arabic poet, and Andalusian musician) had an attempt at aviation using the concept of Icarus (i.e., fixing bird like wings to his body). He attempted to glide down the tower of Cordoba using his contraption. An account of his endeavour was given by the Moroccan historian Ahmed Mohammed al-Maqqari (d. 1632),

> "Among other very curious experiments which he made, one is his trying to fly. He covered himself with feathers for the purpose, attached a couple of wings to his body, and, getting on an eminence, flung himself down into the air, when according to the testimony of several trustworthy writers who witnessed the performance, he flew a considerable distance, as if he had been a bird, but, in alighting again on the place whence he had started, his back was very much hurt, for not knowing that birds when they alight come down upon their tails, he forgot to provide himself with one."

Further study of the history of the subject reveals more successful instances where life form technology was extracted then employed to advance human engineering (and in some cases to solve pressing technical problems faced by humans). More famous are the designs of Leonardo da Vinci which were based on his studies of bird flight. Although these were never implemented they formed the basis for many designs to follow. Clement Ader, perhaps following the footsteps of da Vinci built several steam-powered aircrafts using a wing design based on that of the bat. Although reportedly achieving an altitude of some 300 m he encountered problems controlling his vehicle.

Borrowing from the technology of living forms, is not confined to aviation. Biological structures have been instrumental in inspiring architects and advancing building technology throughout history. Evidence for bio-inspiration may be traced to Egyptian temples. Moreover, there are suggestions that Gustav Eiffel based the design of his well known tower on the taper of a tulip stem. Modern marvels such as the Shinkansen Bullet train of the West Japan railway also made use of technology present in life forms. In its original design the train produced large thunder claps upon emerging from a tunnel. The effects were felt at a distance of more than 500 meters away. The problem was solved when the front end of the train was modelled after the beak of kingfishers. Kingfishers dive from air into water to catch fish. The shape of their beak causes minimal splash of water upon entry. Implementing this shape to the front end of the train resulted in power savings and enhancement of the train speed.

The transfer of design concepts or mechanisms from a living form to human technology is quite an involved task. Naturally not all ideas or concepts available in biology have success potential upon transfer (that is if feasible to start with). Direct replication, or imitation, is not always possible. Often translation or concept-interpretation is needed. That is interpretation between biological conceptual language and human manufacturing language is needed. Such a situation is necessitated by the inherent differences between biology and engineering with regards to conceiving solutions, processing of design constraints, and addressing performance problems.

Biology and engineering entertain some essential differences. While organisms are argued to develop through an evolutionary selective process; engineering progresses through a learning process that is not necessarily holistic. Additionally, biology is by in large descriptive and based on classifications. Biological data is subdivided in terms of technical functionality and its requirements, object parts, their environment, the limits and causes of an action, the ultimate purpose of the action, and the resources and auxiliary systems. Engineering, on the other hand, is a consequence of decision-making;

it is of dogmatic nature and is based on generated rules. The nature of design problem solving in biology and technology, moreover, is rather different. It depends on size. At size levels of up to one meter, where most technology is sited, the most important variable for the solution of a problem is manipulation of energy usage, closely followed by use of material. Thus, in solving an engineering problem, human inclination is to solve through changing the amount or type of the material used or alternatively, to increase the energy requirement. In biology, however, solutions are reached at these scales through manipulations of information and space. Moreover, the design constraints in the human realm are essentially different than those in the biological world. These differences call for devising assistive methodologies to facilitate the transfer of design ideas from a 'life form' domain to a 'human engineering' domain. We are grateful that Inderscience agreed to dedicate a special issue of the *International Journal of Design Engineering* to this interesting topic. The current issue of the journal presents several interesting studies that discuss the framework of support to the bionic design process.

Kittle et al. argue that natural evolution (the backbone of life form-based technology) bears principal similarities to product development within the human domain. To support their thesis, the authors analyse the perceived similarities in two main aspects of design: selection of feasible design alternatives subject to application constraints and optimisation of the viable designs. Thus, stemming from their hypothesis they advance autogenetic design theory (ADT) as an evolutionary paradigm for product development in the human domain.

Coelho and Versos present a comparative analysis of six design methods proposed in bionics literature. They set the achievement of four design goals (form optimisation, organisational effectiveness, and multiple requirement satisfaction and paradigm innovation) as a rubric for effective comparison. The analysis identifies particular needs to be integrated within novel methodological proposals. The study concludes that the compared methods are of variable effectiveness with respect to design implementation. Moreover, none of the compared methods was inclusive. That is no single method provided, by itself, adequate support to all of the identified comparison metrics. The authors therefore promote the need for developing integrated supportive design methodologies to facilitate bionic design.

Formulation of a framework for process knowledge in design is the subject of the paper by Srinivasan et al. In this work, the authors attempt systematic exploitation the rich source of product knowledge existent within biological systems. Thus, they develop a design support that combines process and product knowledge into a compatible, yet empirical, manner. This support frame work is based on combining two recently developed approaches. The first is a so called generate, evaluate, modify, select (GEMS) whereas the second is the so-called state change, action, parts, phenomenon, input, organs, effect (SAPPhIRE) model. The result is a novel approach that amalgamates a descriptor of causality in biological and engineering systems to a tool that integrates the constructs (activities) of a design process. This reduces the design generation process to achieving a balance between the requirements (req) and solutions (sol) of a bio-inspired product.

Enhancing diagnostic assays through bionic-based technology is the subject matter of the work of Assadollahi et al. The authors develop a new fabrication technology for point-of-care (POC) fluidic chips based on resonance-enhanced absorption (REA) of metal nano-particles. The new technology comprises colour creation without the use of dyes (a technique borrowed from butterfly wings). This, results in the creation of intensive colour, visible to the human eye, which is easy to quantify. By adopting such an approach considerable improvements in the sensitivity and time efficiency of POC tests are achieved.

The work of Tagliafari et al. attempts to quantify the permeability of snake skin. The work uses Ficks law to characterise the mass transfer of progesterone through the shed skin of *Bittis gabonica*, which is used as a model membrane for human skin in in-vitro drug delivery experiments.

The topic of bionics is a vast one. There many aspects that could be covered. As with any journal of limited space, addressing all aspects of the topic is not possible. It is hoped, however, that the selection included in this special issue would stimulate the reader to seek more knowledge about the process of design generation in bionics.

Finally, I would like to thank the editorial staff of Inderscience Publishers and Professor Daizong Su, Editor-in-Chief of this journal, for their help and guidance.