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Research review paper

Product and technology innovation: What can biomimicry inspire?

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ABSTRACT

Biomimicry (bio- meaning life in Greek, and -mimesis, meaning to copy) is a growing field that seeks to interpolate natural biological mechanisms and structures into a wide range of applications. The rise of interest in biomimicry in recent years has provided a fertile ground for innovation. This review provides an eco-system based analysis of biomimicry inspired technology and product innovation. A multi-disciplinary framework has been developed to accomplish this analysis and the findings focus on the areas that have been most strikingly affected by the application of biomimicry and also highlight the emerging trends and opportunity areas.

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Introduction

Biological systems are the result of 3.8 billion years of evolution. Humans have long relied on lessons derived from the organisms around them. One of the earliest of Greek legends centres on the attempt by Daedalus and his son, Icarus, to mimic the flight of birds to escape their island prison (Ovid, 2004). In the Renaissance, one of Leonardo da Vinci's most famous inventions was a flying machine which mimicked his observations of the movements of birds and bats (Taylor, 2009). More recently, in the 20th century, George de Mestral, a Swiss engineer was walking in the Alps and was intrigued by the mechanism by which burrs attached to his dog's fur. After studying their mode of attachment, he was inspired to create Velcro which closely imitated this property (Benyus, 2002).

In modern science, the search for biomimetic applications has developed into a scientific discipline and biomimicry based innovations are now the subject of systematic study (Ball, 2001; Benyus, 2002; CBID, n.d.; Swiegers, 2012; Vogel and Davis, 1998; Wyss, n.d.). Learning from these concepts may drive a significant shift in modern science (Aizenberg et al., 2004; Grinthal et al., 2012; Smith, 2006; Vogel, 2013). The underlying methodology of biomimicry is to gain an understanding of the fundamental principles of a biological process or adaptation and to subsequently adapt these concepts for bio-inspired product applications or to solve specific technical challenges (Agnarsson et al., 2009; Assous et al., 2008; Bar-Cohen, 2006; Epstein et al., 2010; Holten-Anderson et al., 2011; Gattiker et al., 2005; Schmitz et al., 2012). The rise of interest in biomimicry in recent years has provided a fertile ground for a number of product innovations (Biolytix, n.d.; Eaton, 2009; FastSkinz, n.d.; Gymnobot, 2009; Karr, 2009; NanoSphere, n.d.). This review provides an eco-system based analysis of biomimicry inspired technology and product innovation (initial base size 222 references). A multi-disciplinary framework has been developed to accomplish this analysis and the findings focus on the areas that have been most strikingly affected by the application of biomimicry and also highlight the emerging trends and opportunity areas. For the purposes of this review, references dealing with synthetic biology and industrial biotechnology have been excluded from the discussion.

An analysis of bioinspired innovations can be approached from a variety of angles, focusing on organism groupings, the stage of development or the properties of the innovation. Innovations can be also categorised based on the nature of the source of inspiration: how things are created in nature (materials), how organisms sense their environment (sensors), how they move in their environment (biomechanics and kinetics) and how they behave and function (processes). The findings of this analysis focus on the areas that have been most strikingly affected by the application of biomimicry and also highlight the emerging trends and opportunity areas.

Data collection methodology

A simple search using 'biomimicry' as a search string has resulted in more than a million hits on Google and few hundred publications in different scientific publications ranging from *Nature to Journal of Transportation*. Therefore, it was essential to develop a methodology to collect the relevant data references and create a meaningful data set of references to accomplish the aim of this review — biomimicry inspired innovation, i.e. a translation of the research into a product application. It was also important to look at different stages of the biomimicry relevant developments — from an idea stage to a marketed product. The above points could be addressed only by collecting data from multiple sources to create a holistic view of the biomimicry space (eco-system).

The data collection was done in partnership with a company specialising in mapping business, technologies, and products environments using its unique proprietary platform for data collection and an intuitive visualisation tool (the Visual Insights interface). It also made it possible to access different data sources that was not possible to do using a single search engine or/and databases.

The references database was created using a set of specifically developed search strings and involved the following steps:

1. Assessment of different web-based sources: magazines, websites, databases, blogs;
2. Text analysis algorithms using the company's proprietary smart semantic web crawling, scrapers to access any kind of freely available database on the web and application programming interfaces to access both free and paid databases, web applications and social networks;
3. Development of a visual representation of the biomimicry eco-system different levels of the data break downs, i.e. from category sub segments to individual companies/technologies.

Subsequent to the development of this eco-system, a substantial effort was made to compliment machine intelligence with human intelligence and further refine the data set of references to select the appropriate references for the analysis. This included an in-depth profiling of the eco-system and development of the taxonomy to address specific objectives of the review. The 109 references selected for this review (including the web references in the text) aim to provide an overall perspective on biomimicry inspired innovation with 71% being publications in peer-review journals including books and patents and 29% being web based references where 15% corresponds to the product web sites and 14% refers to different research activities related to biomimicry.

Diversity of species inspiring the biomimicry based innovation

The data analysis illustrates the diversity of species that have inspired the biomimicry approach (Fig. 1). Due to the diversity of life forms (species) ranging from the basic structural, functional and biological unit (cells) to humans, it was difficult to derive to the same taxonomy principles across the full data set. To give a representation of different species, a further break down was done for the animal kingdom: the phylum of the species (Fig. 1a) and their taxonomic groupings (Fig. 1b). Examining the data set reveals the most inspiring species in terms of variety of applications and a number of references are plants and insects (Fig. 1). The large numbers and variety of innovations inspired by these groups may be a consequence of two factors, diversity and survival capacity. While it is difficult to make a correlation between numbers of species in each class and a number of biomimicry references, it is worthwhile to note that these groups are relatively large, have a global distribution and consequently possess a high degree of diversity, thereby providing a greater resource for researchers. For example, there are estimated to be ~1,000,000 species of insects and around ~300,000 plant species (Chapman, 2009). In addition, these