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Biomimetics — Terminology, concepts and methodology

Biomimétique — Terminologie, concepts et méthodologie

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Contents

Page

Foreword

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The committee responsible for this document is ISO/TC 266, *Biomimetics*.

Introduction

Biomimetics is understood to be the application of research and development approaches of interest to practical applications and which use knowledge gained from the analysis of biological systems to find solutions to problems, create new inventions and innovations, and transfer this knowledge to technical systems. The idea of transferring biological principles to technology is the central element of biomimetics (see Clause 3 for a definition of biomimetics).

The basic motivation behind the transfer of biological solutions to technical applications is the assumption that biological structures are optimized to their needs and can be the source of significant and convincing applications. To date, over 2,5 million different species have been identified and described to a great extent together with their specific characteristics. In terms of biomimetics, there is therefore a gigantic pool of ideas available for solutions to practical problems.

Historically, the development of biomimetics can be divided into the following phases:[1] model-based biomimetics was introduced starting around 1950 primarily for use in the design and construction of aircraft, vehicles, and ships by deriving modelling rules based on similarity theory for transferring the principles of biological systems to technical designs. Around 1960, the two pillars of biomimetics (biology and technology) were combined linguistically for the first time due to the influence of cybernetics and placed on a common linguistic and methodical foundation. This foundation then became an important basis for the central element of the field of biomimetics: the transfer of knowledge. Since about 1980, biomimetics has also been extended down to the microscale and nanoscale (e.g. the Lotus-EffectText ®) [2]. New methods in measurement and manufacturing technology were the keys to these extensions. Since the 1990s, biomimetics has received further impetus, in particular due to the rapid technological development in the related fields of computer science, nanotechnology, mechatronics, and biotechnology. In many cases, it is new developments in these fields that enable the transfer of complex biological systems in the first place[3].

Today, the field of biomimetics is increasingly considered a scientific discipline that has generated numerous innovations in products and technologies. This highly interdisciplinary collaborative work, which brings together experts from the fields of biology, engineering sciences, and numerous other disciplines, possesses a particularly high potential for innovation[4]. For this reason, biomimetics has now become an object of research and education at numerous universities and extramural research institutions. However, manufacturing companies are also increasingly turning to biomimetic methods to develop new products or to optimize existing products. In spite of the increasing number of researchers and users active in the field of biomimetics, the transfer of knowledge from the field of biology to technology is still a complex process that places high demands on the people involved.

Nature has numerous "ingenious solutions" available that can often be understood intuitively. It is seldom easy, though, to explain the underlying mechanisms and in particular, to explain how they could be applied to technology. This discrepancy is one reason for the current and ongoing relevance of the field of biomimetics, which will also continue into the next decades[5].

Biomimetics — Terminology, concepts and methodology

1 Scope

This International Standard provides a framework for the terminology on biomimetics in scientific, industrial, and educational purposes.

This International Standard is intended to provide a suitable framework for biomimetic applications. The field of biomimetics is classified and defined, numerous terms are described, and a description of the process of applying biomimetic methods from the development of new ideas to the biomimetic product is provided. The limits and potential of biomimetics as an innovation approach or as a sustainability strategy are also illustrated. In addition, this International Standard provides an overview of the various areas of application and describes how biomimetic methods differ from classic forms of research and development. If a technical system is subjected to a development process according to this International Standard, then it is allowed to be referred to as a "biomimetic" system.

This International Standard provides guidance and support for developers, designers, and users who want to learn about the biomimetic development process and integrate biomimetic methods into their work aiming at a common language for scientists and engineers working in the field of biomimetics. It can be applied wherever nature has produced a biological system sufficiently similar to the technical target system that can be used to develop a technical equivalent.

2 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

2.1
abstraction
inductive process in which a general conclusion is drawn based on the observation of a specific object

Note 1 to entry: In biomimetics, this conclusion is ideally a physical context for describing the underlying functional and operating principles of the biological systems.

2.2
analogy
analogy in terms of technology is understood to be a similarity in the relationships between the relevant parameters used to describe two different systems

Note 1 to entry: The specification of the relevant parameters is the object of *abstraction* (2.1). In terms of its definition in the field of *biomimetics* (2.9), one of these two systems is a *biological system* (2.6), and the other system is the technical target system.

Note 2 to entry: In biology, the term "analogy" refers to similarities in functional characteristics between different organisms that resulted from the need to adapt and not because the organisms are somehow related. In contrast, similarities based on relationship dependencies, and therefore on similar genetic information, are referred to as homologies. In biology, the term "analogy" has come to be understood dynamically and emphasizes in particular the differences between the starting points of two evolutionary developments.

2.3
analysis
systematic examination in which the biological or technical system is decomposed into its component parts using suitable methods, after which the parts are then organized and evaluated

Note 1 to entry: The opposite of analysis, in terms of its aspect of "resolution into individual parts", is referred to as synthesis (recomposition).

2.4
bioengineering
application of engineering knowledge to the fields of medicine or biology

2.5
bioinspiration
creative approach based on the observation of *biological systems* (2.6)

Note 1 to entry: The relation to the *biological system* (2.6) may only be loose.

2.6
biological system
coherent group of observable elements originating from the living world spanning from nanoscale to macroscale

2.7
biology push
biomimetic development process in which the knowledge gained from basic research in the field of biology is used as the starting point and is applied to the development of new technical products

Note 1 to entry: In technology, biology push is considered as a bottom-up process.

Note 2 to entry: In design research, biology push is considered as “solution driven”[6].

Note 3 to entry: See also *technology pull* (2.19).

2.8
biomimicry
biomimetism
philosophy and interdisciplinary design approaches taking nature as a *model* (2.15) to meet the challenges of *sustainable development* (2.17) (social, environmental, and economic)

2.9
biomimetics
interdisciplinary cooperation of biology and technology or other fields of innovation with the goal of solving practical problems through the function analysis of *biological systems* (2.6), their *abstraction* (2.1) into *models* (2.15), and the transfer into and application of these models to the solution

Note 1 to entry: Criteria 1 to 3 of Table 1 shall be fulfilled for a product to be biomimetic.

2.10
bionics
technical discipline that seeks to replicate, increase, or replace biological functions by their electronic and/or mechanical equivalents

2.11
component
element of an assembly that cannot be decomposed any further

2.12
function
role played by the behaviour of a *system* (2.18) in an environment

2.13
invention
act of creating something new or improved or product of this creation

Note 1 to entry: An invention therefore differs from an innovation, for which market diffusion is a prerequisite.

2.14
material
collective term for the substances needed to manufacture and operate machines, but also to build constructions

Note 1 to entry: The term "material" is used in the following as a general term for all biological materials and structures.

Note 2 to entry: It includes raw materials, *working materials* (2.20), semi-finished products, auxiliary supplies, operating materials, as well as parts and assemblies. The term "material" is used in the sense of *working materials* (2.20).

Note 3 to entry: Biological materials are organic and/or mineral substances produced by living organisms. Due to their hierarchical structure from the molecular to the macroscopic level, it is not possible to clearly distinguish between the terms "material" and "structure" in the field of biology.

2.15
model
coherent and usable *abstraction* (2.1) originating from observations of *biological systems* (2.6)

2.16
structure
type and arrangement of the *components* (2.11) in a *system* (2.18)

2.17
sustainability
sustainable development
development that satisfies the requirements of the present without risking that future generations will not be able to satisfy their own requirements

Note 1 to entry: Nature technology is the concept of human and the earth conscious technology learning from the perfect circulation of the nature that has super-low environmental burden, high functionality, and sustainability[7].

2.18
system

set of interacting or interdependent *components* (2.11) forming an integrated whole with a defined boundary

2.19
technology pull
biomimetic development process in which an existing functional technical product is provided with new or improved functions through the transfer and application of biological principles

Note 1 to entry: Technology pull is considered as a top-down process.

Note 2 to entry: In design research technology, pull is considered as "problem driven"[6].

Note 3 to entry: See also *biology push* (2.7).

2.20
working material
prepared raw material in a formed or unformed state (solid, liquid, or gaseous state) that is used to manufacture components, semi-finished products, auxiliary supplies, or operating materials

3 What is biomimetics?

3.1 Essentials of biomimetics

The successful application of biomimetics is characterized as the transfer of knowledge and ideas from biology to technology or other fields of innovation, i.e. practical development inspired by nature that usually passes through several steps of abstraction and modification after the biological starting point. The field of biomimetics is highly interdisciplinary and multidisciplinary, which is indicated by the high level of cooperation between experts from different fields of research, for example, between biologists, chemists, physicists, engineers, and social scientists.