INTERNATIONAL STANDARD

ISO 18458

First edition
2015-05-15

Biomimetics — Terminology, concepts and methodology

Biomimétique — Terminologie, concepts et méthodologie

Reference number
ISO 18458:2015(E)

ISO copyright office
Ch. de Blandonnet 8 • CP 401
CH-1214 Vernier, Geneva, Switzerland
Tel. +41 22 749 01 11
Fax +41 22 749 09 47
copyright@iso.org
www.iso.org

Contents

Page

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

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.

Depending on the intensity with which biomimetics is applied, it can be understood as a scientific discipline, an innovation process, or a creativity technique. In innovation management, biomimetics is used as one of many creativity techniques. However, its potential is not fully realized when viewed solely as a creativity technique because the development of new ideas in this case often remains at the level of a search for obvious analogies between biological systems and technical problems without performing a systematic analysis, abstracting, or transferring an operating principle.

The innovation process in biomimetics starts by linking a biological system to a specific technical question. The characteristic feature of biomimetics is that it unites interest in knowledge from the field of biology with the goal of obtaining a real technical implementation.

In biomimetics, the conceptual interest in and research on the biological system is oriented to obtaining applications. Structure/function relationships are particularly important in this context. These relationships are derived primarily from the analysis of the functional morphology in the framework of organismic biology. An essential part of a successful biomimetic process is the design of the interface between biological research and product and process development engineering. Biomimetics is not only about transferring abstracted biological results to technology, but also about applying the engineering methodology to biological systems and integrating knowledge of biological systems into technical developments. An efficient and multi-layered transfer of knowledge, and especially of methods, between the disciplines therefore forms the basis for a successful biomimetic development process.

Biomimetics is founded on basic research in the field of biology. Due to its defined focus on applications, though, it primarily integrates application-oriented and applied research into the actual development of the product or process.

Since it is inherently a type of innovation process, biomimetics is currently becoming a separate scientific discipline. On the one hand, it is steadily developing a system of interrelated scientific statements, theories, and methods, while on the other hand, associations, research and educational institutions, as well as communication tools, are being established by certain groups of people under the banner of biomimetics.

3.2 Boundaries to and areas of overlap with related sciences

The expression “technical biology” was introduced by *Werner Nachtigall* to distinguish it from biomimetics[8]. Technical biology consists of the analysis of structure/function relationships between biological objects with help of methodical approaches taken from physics and the engineering sciences. Technical biology is therefore the starting point of many research projects in biomimetics because it allows a deeper understanding of the method of operation of the biological system at the quantitative level, as well as a suitable implementation in technical applications.

Over the last few years, it has become apparent that knowledge gained through the implementation of biologically inspired principles of operation in innovative biomimetic products and technologies can contribute to a better understanding of the biological systems. This relatively recently discovered transfer process from biomimetics to biology can be referred to as “reverse biomimetics”. In contrast to technical biology, reverse biomimetics does not apply classical engineering methods and analysis tools to biological systems, but uses biomimetic prototypes as a whole and/or the simulation of their method of operation as explanatory models or models for study with which it can be easier to understand the underlying biology. In an iterative process, the methods of technical biology are then applied again in the next step in order to test this new or extended explanatory model on the biological system. The new knowledge of the biological structures and functions gained then flows back into the development of improved biomimetic products and technologies, which then in turn serve as improved biomimetic models to which reverse biomimetics can be applied, etc. This results in new knowledge in the form of a heuristic spiral of technical biology, biomimetics, and reverse biomimetics[9].

The boundary separating biomimetics and biotechnology is also important. Both fields are areas of applied biological research (translational biology). Biotechnology is understood to be the application of scientific and technical principles to convert substances using biological agents with the goal of providing goods and services (based on Reference [10]). In contrast, biomimetics uses living organisms as generators of ideas for innovative technical implementations, but the organisms themselves are not necessarily involved in the manufacturing of biomimetic products. Even though the concepts of biotechnology and biomimetics are not the same, they can be combined, as has been demonstrated by research projects on the development of artificial spider silk, for example, see Reference [11] (see Table 1 and A.2).

Biomimetics is a highly interdisciplinary science possessing numerous facets. In fact, there are also publications containing biomimetics terminology in the economic sciences and in organization management that, based on the analysis of biological systems, provide suggestions for improvement to existing concepts and strategies[12][13][14]. However, it is not always easy to recognize the aspect of technology in these fields as it is used in the definition of biomimetics or it might be necessary to expand the definition of the term “technology” to recognize it.

In contrast, areas of research that deal only with inanimate elements of nature (geo-inspired) are incompatible with the definition of biomimetics provided above. This includes, for example, research on snow crystals, which can provide valuable information for the production of nanostructures like those needed for microchips[15] or for the development of sound-absorbing materials.

The use of shapes designed based on biological systems alone cannot be considered a biomimetic approach, particularly when the shapes appear from the outside as if they could be based on a shape found in nature but are really based on sophisticated CAD technology or other mathematical methods for designing surfaces, for example. In these cases, biomimetics only plays a role when the design of the shape is an integral part of the functionality developed according to biomimetic principles.

3.3 Biomimetic products and processes

The decision as to whether a product or technology can be considered biomimetic can be made based on three criteria (steps) (see Table 1).

A product can be considered biomimetic if, and only if, it follows the following three steps defining the biomimetic process:

— function analysis has been made of an available biological system;

— biological system has been abstracted into a model;

— model has been transferred and applied to design the product.

Parallel developments in nature and technology are not biomimetics. In the course of the development of technology, many technical products were developed and in many cases without any knowledge of natural phenomena that were amazingly similar to biological structures with comparable tasks in terms of their function and sometimes even in terms of their shape.

Table 1 — Differentiating between biomimetic and non-biomimetic products based on Reference [16]

	How new ideas are developed	Criteria for a biomimetic product			CONCLUSION: Biomimetics yes or no[a]
		1. Function analysis of biological system	2. Abstraction from system to model	3. Transfer and application without using the biological system	
CAO method (see A.1)	technology pull	+	+	+	yes
Biomimetic spider silk (see A.2)	biology push				
Process step1: Molecular biomimetics		+	+	+	yes

[a] Criteria 1 to 3 shall be fulfilled before “yes” is entered as the conclusion.

Table 1 *(continued)*

	How new ideas are developed	Criteria for a biomimetic product			CONCLUSION: Biomimetics yes or no[a]
		1. Function analysis of biological system	2. Abstraction from system to model	3. Transfer and application without using the biological system	
Process step 2: Recombinant protein production		-	-	-	no
Process step 3: Material processing		+	+	+	yes
Evolutionary algorithms (EA) for optimization (see A.3)	technology pull	+	+	+	yes
Fin ray structure (see A. 4)	biology push	+	+	+	yes
Lotus-Effect® (see A.5)	biology push	+	+	+	yes
Self-sharpening cutting tools (see A.6)	technology pull	+	+	+	yes
Art Nouveau (see A.7)		+/–	+/–	–	no
Fibonacci sequence (see A.8)		+/–	+/–	–	no
Olympia roof in Munich (see A.9)	independent development	–	–	–	no
Reinforced concrete (see A.10)		+	–	+/–	no
Result of optimization with EA (see A.3)		+	–	–	no
Soap film analogies (see A.11)	independent development	–	–	–	no

[a] Criteria 1 to 3 shall be fulfilled before "yes" is entered as the conclusion.

4 Reasons and occasions for using biomimetic methods

4.1 Possibilities, performance, and success factors for biomimetics

In the search for innovative solutions, biomimetics acts as a supplement to the classic methods for developing new ideas and is a way of approaching scientific engineering work methods (see Reference [17], Chapter 2). The diversity of biological solutions is particularly interesting for biomimetic developments. Today, millions of species inhabit every type of environment and their amazing adaptations offer a virtually infinite number of potentially relevant solutions from a technology point of view[18].

A general reason for the ability to transfer a biological property to a technical system is the fact that the same physical laws and constants are valid in biology and in technology. The study of plants and animals sometimes leads to problem solutions that are amazingly similar at first glance to the corresponding technical solutions, but when subjected to more detailed analysis, often exhibit significant differences (see Reference [19], p 477-478). Characteristics of biological structures include multi-criteria optimizations with sometimes contradictory functions (multifunctionality) while simultaneously providing a high

