ISSN 1848-0071
57.017.3+62-11=111
Recieved: 2014-01-20
Accepted: 2014-03-25
Review

BIOMIMICRY – AN OVERVIEW

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Biomimicry implies the creative implementation of biological concepts into products. This paper provides a broad overview of the field of biomimicry, and has described the conversion of physiological and organizational solutions from nature into products and services. Implementation and economic efficiency is shown through selected examples. Four examples of successful implementation of nature solutions are the following: Velcro, lotus-effect, structural coloration and tubercles on the fins of the humpback whales. In this work, we analysed the reductive approach to biomimicry which strictly focuses on mimicking few characteristics or functions of particular organisms or biological processes but does not necessarily create sustainable environment through the imitation of nature. Biomimicry is one of the most promising research areas that could transform the way products and services are designed, manufactured, transported and distributed. This could represent a major turning point in the 21 century, by linking environmental and business interests.
Key words: biomimicry, innovation management, design, Velcro, lotus-effect, structural coloration, tubercles.

Biomimikrija - Pregled. Ovaj rad pruža širok pregled području biomimikrije te opisuje pretvorbu fizioloških i organizacijskih rješenja iz prirode u proizvode i usluge. Provedba i ekonomska učinkovitosti prikazana je kroz odabrane primjere. U radu su prikazana četiri primjera uspješne provedbe rješenja iz prirode u gotove proizvode a to su: čičak traka, lotos efekt - svojstvo samočišćenja, strukturna obojenost i tuberkuli na perajama grbavih kitova. U ovom radu primjenili smo reduktivni pristup biomimikriji, a on se strogo usredotočuje na oponašanje nekoliko obilježja i/ili funkcija pojedinih organizama ili bioloških procesa, ali ne nužno i na stvaranje održivog okoliša kroz imitaciju prirode. Biomimikrija je jedan od najperspektivnijih područja istraživanja koje bi moglo promijeniti način na koji su proizvodi i usluge dizajnirani, proizvedeni, prevezeni i distribuirani. Biomimikrija bi mogla predstavljati veliku prekretnicu u 21. stoljeću, povezujući ekološke i poslovne interese.
Ključne riječi: biomimikrija, inovacija, dizajn, čičak-traka, lotus-efekt, strukturna obojenost, tuberkuli.

CONCEPT OF BIOMIMICRY

Nature is increasingly being viewed as a model and a benchmark. It is not surprising that during millions of years of evolution the nature has created mechanisms and systems that are highly efficient, eschew waste, and are highly sustainable in a virtually closed system [1]. We are currently at a point where we use the brainpower and tools to analyse nature, and to learn from its 3.8 billion years of development. Developed networks allow professionals from different areas to work together, which is a prerequisite for biomimicry to be successful [2]. Nature entails 'optimizing' rather than 'maximizing' and also it is a model of sustainability since it is a 'closed loop' system [3]. All organisms contribute to recycling Earth's major nutrients – carbon, hydrogen, oxygen, and nitrogen. If people are to prosper indefinitely, they need to act responsibly by imitating nature's closed loop.

Biomimicry (gr. *bios* - life; *mimesis* - to imitate) is a discipline of applying nature's principles and it does not only changes the ways we think about designing, producing, transporting, and distributing goods and services, but also provides opportunities to deal with complex environmental and economic problems.

There are two different approaches to biomimicry. One is the reductive approach which perceives biomimicry as a transfer of nature's solutions into the domain of design and engineering, while the other holistic approach perceives biomimicry as a measure to achieve ecologically sustainable products, i.e. the products that do not harm the environment through their production, usage or disposal.

Biomimicry does not imply direct transfer of an observation in nature to the development of a product, but rather the creative implementation of biological concepts into products. The reason why biomimicry seldom involves direct copying of nature could be explained in the perspective that „*Evolution isn't a perfecting principle; it works on the principle of "just good enough". If you really want to design something for a task, you have to look at the diversity of organisms out there and then get inspired by principles."* [4]

Although the issue of terminology is a matter of debate, the idea of imitating nature has been developed for millennia: 3000 years ago, the Chinese attempted to make artificial silk and roughly at the same time another imitation of nature that most likely resulted from humans observing the spider using its web to catch flies occurred – fishing nets [28].

KEY CHARACTERISTICS AND THE ETYMOLOGICAL ORIGIN OF BIOMIMICRY

Different definitions and expressions try to cover wider, different or specialized area. The term bionic is often used in describing science of creating artificial limbs and parts of human body, discipline that is closely connected with cybernetics. Bionics, subject of copying, imitating, and learning from biology was coined by Jack Steele [5, 6]. This field is increasingly involved with emerging subjects of science and engineering and it represents the study and imitation of nature methods, designs and processes.

The term biomimicry (gr. *Biomimesis*) was coined by polymath Otto Schmitt in 1957, and first appeared as a generic term including both cybernetics and bionics [7]. Thus, the term bionics was actually used earlier to cover, more or less, the same area as the term biomimicry does today. Through Janine Benyus's book *Biomimicry: Innovation Inspired by Nature* [1] the biomimicry has become more preferred name. In Webster's dictionary in 1974, the word *biomimetics* first appeared. The field of biomimetics is highly interdisciplinary. It involves the design and fabrication of various materials and devices of commercial interest by engineers, material scientists, chemists and others on principals of understanding of biological functions, structures and principles of various objects and organisms found in nature [12].

It is not only that biomimicry is not a clearly defined term, but it has many different synonymous notions, amongst these are biomimetics, bionics, biognosis and bionical creativity engineering. There are also disciplines bordering on biomimicry that use similar names, for example biomechanics and biophysics. In defining biomimicry, this paper follows Janine Benyus's definition: *Biomimicry refers to studying nature's most successful developments and then imitating these designs and processes to solve human problems. It can be thought of as 'innovation inspired by nature'.* [1]

COPYING NATURE THROUGHOUT THE HISTORY

Historically, both marine and flying animals have served as inspiration for technological design. During the Renaissance, animals were identified as streamlined bodies for drag reduction that could be applied to manufactured devices. Between 1505 and 1508, Leonardo da Vinci was particularly interested in the flow of water, as revealed in his notebooks, *Codex Leicester* [8]. Da Vinci wrote on the function of streamlined bodies in drag reduction and noted the streamlined shape of fish. He argued that fish can move through the water with little resistance because its shape allowed water to flow smoothly over the after body without prematurely separating [9]. Da Vinci recognized and demonstrated a similar design with the hull shape of ships, although it is much more evident in his flying machine. The Wright brothers derived inspiration for building the world's first successful aircraft from observations of pigeons in flight.

In 1680, Giovanni Borelli made an examination of the swimming motions of animals with their application to submarine technology [10]. In his book *De Motu Animalium* (The Movement of Animals), Borelli compared swimming to flying in that both were accomplished by the displacement of fluids, although he noted the differences in density of air and water and their effects on stability and buoyancy. Borelli described the design of an early submarine that incorporated ideas based in part on animals for buoyancy regulation and propulsion [5, 6].

The human body has also motivated inventors in the past. Many do not realize that the father of modern communication, Alexander Graham Bell, was inspired by the mechanisms of the human ear. Graham Bell based his first telecommunications systems on the process that occurs inside the ear. Graham Bell soon realized that just as the eardrum could send electrical signals to the brain, so a vibrating piece of metal in front of an electromagnet could transmit certain noises electronically from place to place. It was from this basic idea that the electronic communication boom of the 20th century was born, and this original, base system is still used today [29].

THE BRIDGE BETWEEN THE ECONOMY AND THE ENVIRONMENT

Biomimicry has just recently started to be perceived as a medium that should eventually lead to revolutionary changes in the economy. The transposition of biomimicry into business and commercial use could transform large portions of various industries in the coming years and could ultimately impact all segments of the economy (Figure 1). Industries that could be particularly affected include utilities, transportation equipment, chemical manufacturing, storage and waste management, architecture and engineering [11].

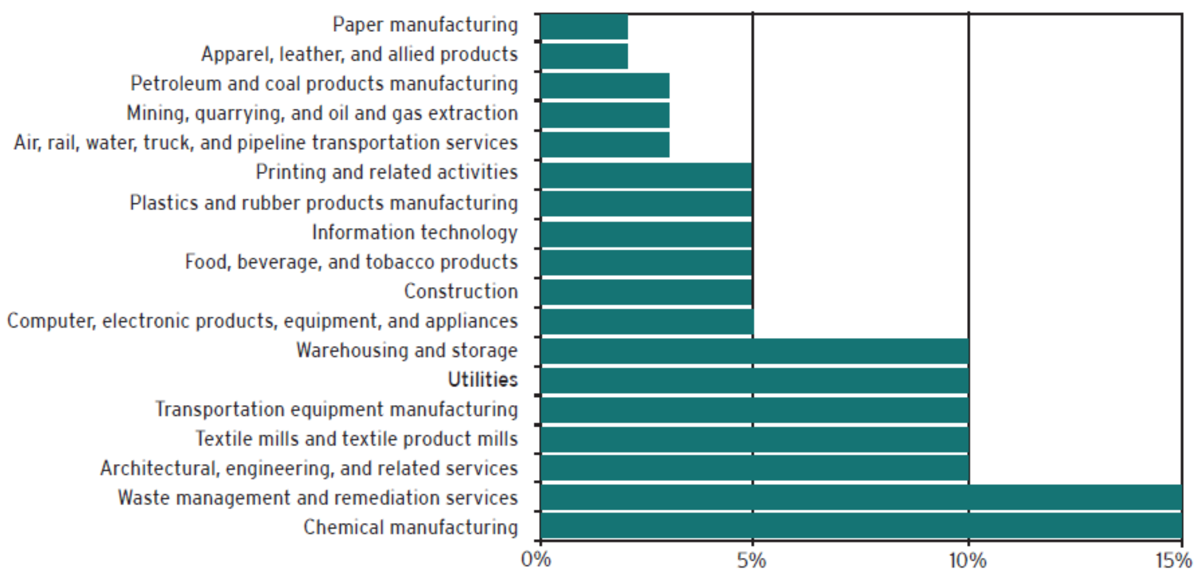
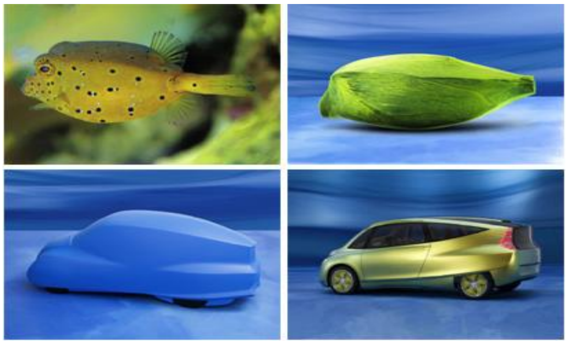


Figure 1. Biomimicry's Estimated Market Impact in 2025 [11]
Slika 1. Procjena utjecaja biomimikrije na tržište 2025. godine [11]

There are two very different aspects of the use of biomimicry: the approach from design to biology, and the other way round. In the first instance, in search for a solution to a specific problem one is trying to find an answer in the natural world, e.g. in the pursuit for ideal aerodynamics the scientists found inspiration in the tropical fish *Ostacion cubicus L.*, whose remarkably balanced shape reduces air friction to minimum. In general, the designer starts with the challenge of human design, identifies the function, then observes and analyses how different organisms or ecosystems achieve the function. On the other hand, in the approach from biology to design, a biological phenomenon suggests new way of solving a challenge of human design. The well-known examples of this approach are Velcro and gecko tapes, which got inspiration in both, plant and animal world.

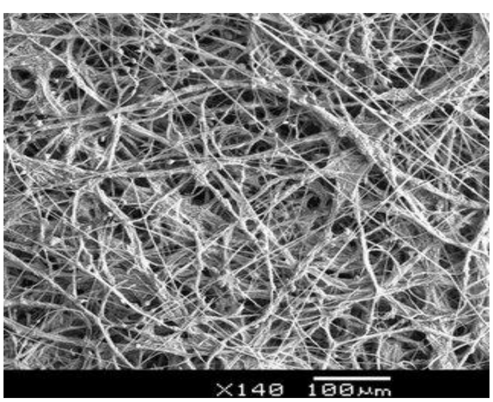
a) 

b) 

Figure 2. a) Tropical fish *Ostacion cubicus L.*, an inspiration for automobile design [2, 6] and b) gecko feet with setae [13]
Slika 2. a) Tropska riba *Ostacion cubicus L.*, inspiracija za dizajn automobila [2, 6] i b) stopalo macaklina s prijanjaljkama [13]

Companies selling biomimicry-inspired products have frequently doubled their sales annually in the early years [11]. Many of these products offer customers reduced energy requirements, less waste and enhanced performance while being sold at prices competitive with or even less than those of existing products. A cost-benefit evaluation points to the advantages of biomimicry hold the potential of reducing three major sources of costs: pollution, waste disposal, and natural resource depletion.

An interesting example of reducing three major sources of costs and connecting the storage industry and waste management is completely renewable Mushroom® packaging [14]. It is produced by connecting the waste of agricultural crops and roots (mycelium) of mushrooms (Figure 3). With the growing problem of waste plastics that do not biodegrade in the natural environment (eg. Styrofoam) this innovation, inspired by nature, should be an example to the producers. Some of the world's leading corporations (e.g. Dell, 3M), recognizing how much plastic waste is in the environment, use Mushroom® packaging.

a) 

b) 

Figure 3. a) Mycelium of mushrooms under SEM [15] and b) examples of Mushroom® packaging [14]
Slika 3. a) micelij gljiva pod skenirajućim elektronskim mikroskopom (SEM) [15] i b) primjeri Mushroom® pakiranja [14]

EXAMPLES OF BIOMIMICRY AND ITS USE IN THE WORLD OF BUSINESS

Nature provides many features that are unique to some species, and understanding of the conditions for their adaptation can help us in many ways. It was realized that nature's patterns and behaviours can inspire approaches for evolutionary success in business and beyond.

Velcro – hook and loop fasteners

Velcro is a company that created and produces a first commercial hook and loop fasteners. That concept was discovered in 1948 by Swiss engineer George de Mestral, who patented his invention in 1955, and then developed its practical use until its placing on the market in the late 1950s. De Mestral got the idea in the 1941 after a hunt in the Alps. After he closely inspected the seed from genus *Arctium*, commonly known as burdock (Figure 4a), that got stuck both in his dog's fur and on his clothes, he noticed hundreds of hooks caught on loops on both clothes and fur. He realized that he could make a benefit of mutual fastening of two materials in a simple way if he finds the way to reproduce hooks and loops on a small scale. First Velcro sample made of cotton was not practical, so it was replaced by nylon and polyester, also invented at that time (Figure 4b). Hook and loop fasteners made of Teflon loops, polyester hooks and the glass backing were used in the Space Shuttle (Figure 4c). Although he earned less than 60 dollars a week in his first years, de Mestral earned millions after he sold his rights on the invention to the American Jean Revaud. Currently Velcro employs 2856 people, with more than 300 world-wide active patents, and has more than 50 years of experience. Their income in 2012 was 305 million US dollars.

a) b) c)

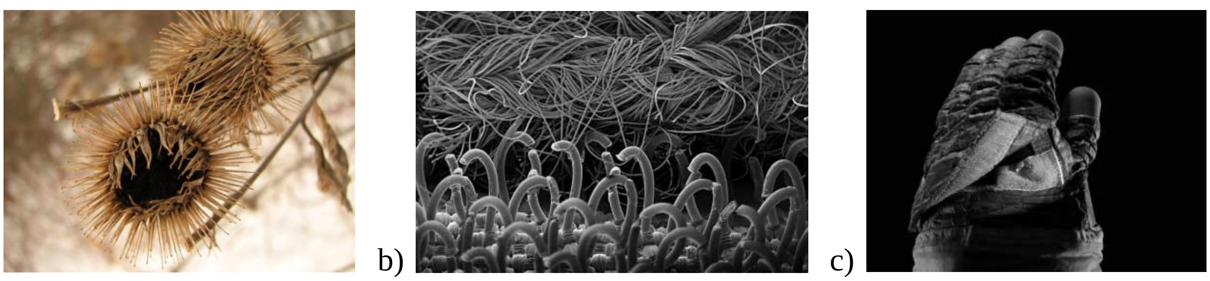


Figure 4. a) Burdock (*Arctium* sp.) seed [16], b) Velcro tape under an electron microscope and c) one of the first application for Velcro was for astronaut suits and gloves [12]
Slika 4. a) sjeme čička (*Arctium* sp.) [16], b) čičak traka pod elektronskim mikroskopom i c) među prvim aplikacijama čičak trake bila odjela i rukavice za astronaute [12]

The Lotus effect and capacity of self-cleaning

Lotus (*Nelumbo nucifera L.*) is a symbol of purity in several Asian cultures, due to the self-cleaning properties of his leaves, which stay clean even after being immersed in mud (Figure 5a). This effect can easily be proven in many other plants, e.g. *Tropaelum*, *Opuntia*, *Alchemilla*, as well as on the wings of some species of insects. Many biological surfaces are hydrophobic due to their complex composition and the microstructures which minimizes the droplet's adhesion to surface (Figure 5c). Lotus leaves have particular waxed nano- and microstructures, while butterfly wings and of some other insects have numerous structural scales. Due to their super hydrophobic characteristics, such structures clean their own surfaces using the physical properties of water molecules. Because of its high surface tension, water droplets tend to reduce their surface trying to achieve spherical shape. On contact with a surface, adhesion forces result in wetting of the surface. Either complete or incomplete wetting depends on the structure of the surface and the fluid tension of the droplets. The cause of self-cleaning properties is the hydrophobic waterproof dual surface structure. This enables the contact area and the adhesion force between the surface of the droplets, which are significantly reduced, resulting in a process of self-cleaning. This double hierarchical structure is formed by the characteristic epidermis (its outermost layer is called the cuticle) and waxes. The epidermis of lotus plant possesses papillae with a 10-20 microns high and 10-15 microns wide at which the so-called epicuticular waxes are imposed [17]. These superimposed waxes are hydrophobic and form the second layer of the double structure. This fine structure was discovered in 1975, after scientists used electronic microscope to scan the surface of the leaves (Figure 5c).

Nanotech engineers have developed treatments, paints, coatings, tiles, textiles and other surfaces that can stay dry and have the self-cleaning effect. That can be achieved with special fluorochemical or silicon treatment on structured surfaces, or with the composites that contain micro particles. One of the examples of products inspired by lotus effect is the facade paint Lotusan®, the only such product on the market (Figure 5b). It is produced by Sto Corporation, German-based Company which has had a long tradition (est. in 1835) in construction-related products. The Lotusan® paint was a result of the company's major shift toward 'greener products'. Lotusan® is proved to be cost effective because it does not have direct competition on the American market, with the sales doubling each year after its introduction in 2005.

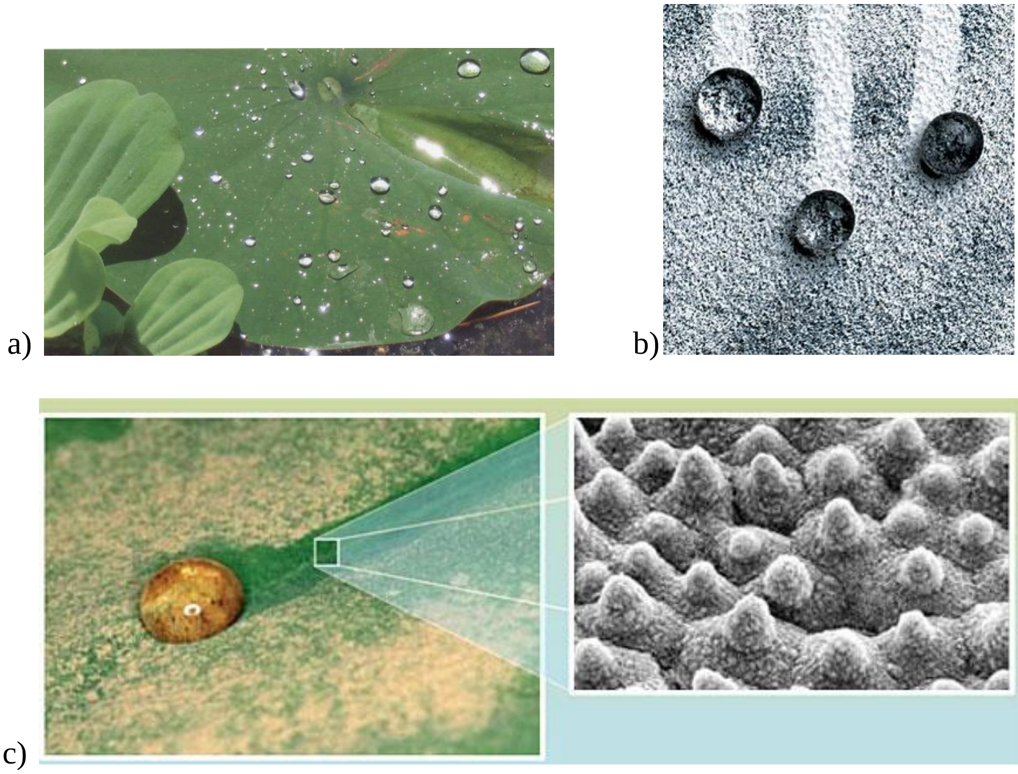


Figure 5. a) Droplets of water on the surface of lotus leaf, b) facade painted with Lotusan® and c) surface of lotus leaf under electron microscope [17]
Slika 5. a) kapljica vode na površini lista lotosa, b) fasada premazana Lotusanom i c) površina lista lotosa pod elektronskim mikroskopom [17]

Structural coloration – colour without pigment

Structural coloration has a potential for industrial, commercial and military application. Biomimicry surfaces can provide brilliant colours, adaptive camouflage, effective optical switches and small reflection glass. Structural coloration is the production of colour by microscopically structured surfaces, fine enough to interfere with visible light spectrum, sometimes even in combination with pigments. Two or more thin layers lead to the refraction of light – a good example are peacock feathers (Figure 6a) that have brown pigment but it results in bright-coloured appearance. Structural coloration is responsible for blue and green colour of bird feathers (e.g. *Merops apiaster*, *Alcedo atthis*), as well as the wing colours of many butterflies and coleopteran insects. Colours are often iridescent, as can be seen inside shells of family *Nautilidae* (Cephalopoda) and *Pteriidae* (Bivalvia).

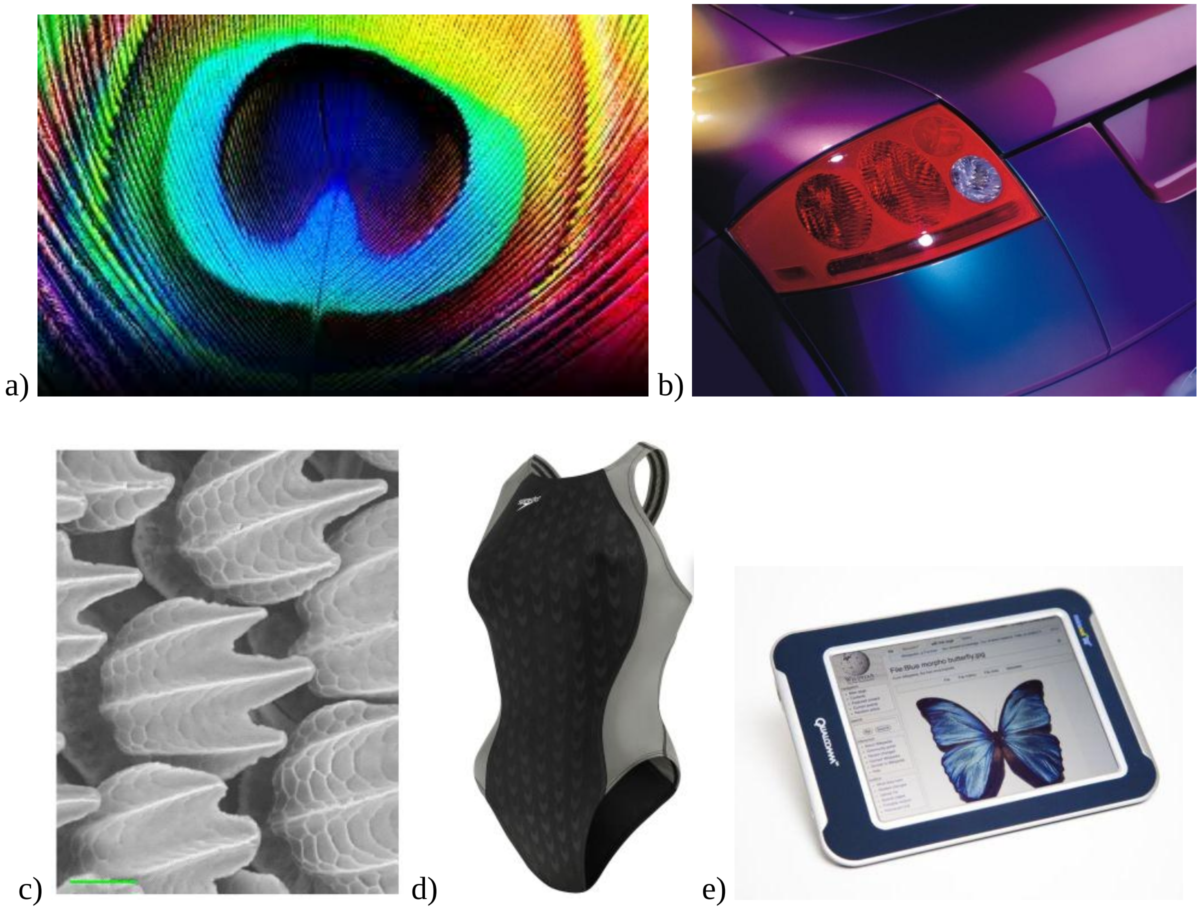


Figure 6. a) Peacock train feather, b) ChromaFlair, colour-shifting paint from JDSU [18], c) close-view ESEM image of denticles from the surface of a bonnet head shark (*Sphyrna tiburo* L.) [19], d) design of swimming suit Fastskin LZR Racer by Speedo is inspired by shark skin [20] and e) Mirasol technology display from Qualcomm [21]
Slika 6. a) paunovo repno pero, b) ChromaFlair, premaz koji mijenja boju od JDSU [18], c) uvećana ESEM slika dentikula sa površine kože morskog psa mlata (*Sphyrna tiburo* L.) [19], d) kupaći kostim Fastskin LZR Racer od Speedo-a inspiriran je kožom morskog psa [20] i e) Mirasol tehnologija zaslona od Qualcomm-a [21]

There are lot of products inspired by or using structural colouration. The first example is Chroma Flair, which is a trademark for the pigment principally used in paints and coatings for cars – it changes the colour of the car depending on the light source and the angle of watching (Figure 6b). In the beauty industry, the Yves Saint Laurent Company was the first to implement the iridescence effect in its products. Speedo company used the shape and textures of shark skin (Figure 6c) to develop swimming suit Fastskin LZR Racer (Figure 6d), which was so efficient in the drag reduction that was banned from the swimming contests because of the unfair advantage that it gave to its wearers.

Mirasol technology is used in displays production and it is specific because for the first time it uses interferometric modulations (IMOD), the technology based on micro electro mechanic system (MEMS) which creates colours from light refracted by microscopic mirrors. This was inspired by nature and it is closely related to the phenomenon of glimmering, created by the butterfly wings in the sunshine. Mirasol displays (Figure 6e) provide intensive colours and content visible even when exposed to direct sunshine. This unique technology enables the devices to have more lasting battery (three times longer than the LCD displays).

Qualcomm Company is focused on development and licensing of wireless technology and it is the world leader of patents in advanced 3G and 4G mobile technologies. Main component of its business activity is inflow of licences on the patents from their inventions. Company employs more than 20,000 people in 157 locations world-wide. Annual income in 2012 was 19.12 billion US dollars.

Tubercles on humpback whales flippers

Humpback whales (*Megaptera novaeangliae* Borowski) are very agile swimmers, considering each wale weighs in cca 36 tonnes. Part of their swimming prowess may come from a row of warty ridges, called tubercles, on the front edge of their wing shaped fins. Tubercles are unique morphological structures in nature. The outer edge tubercles act as a passive flow control device which improves performance and manoeuvrability of fins.

Tubercles provide bio-inspired design that is commercially viable for structures like wings. Advantages of passive flow control is eliminating complex, expensive, difficult and complicated control mechanisms, while improving the performance of the buoyancy of the body either in the air or water [22]. The outer edge tubercles can be applied in the design of boats and aircraft, fan blades and wind turbines.

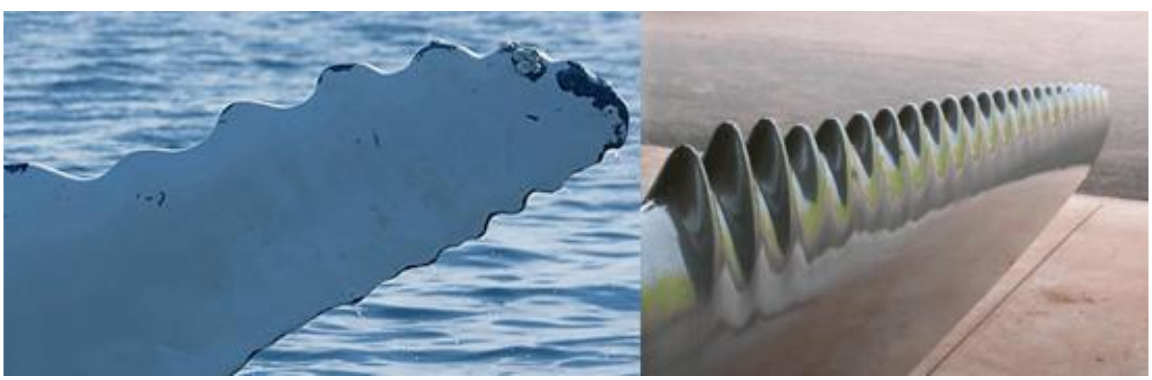
a) 

Figure 7. Humpback whale pectoral fin with tubercles and a prototype of a wind turbine blade [22]
Slika 7. Pektoralna peraja grbavog kita sa tuberkulima i prototip lopatice vjetroturbine [22]

It was discovered that by adding rows of similar bumps to turbine blades he could reduce drag and noise, increase speed to changing wind direction by almost 25 percent and boost the power harnessed by 20 percent [22]. Technology for the use of tubercles is licensed by the corporation WhalePower, founded by the inventor Frank Fish.

These results are verified by the largest Canadian manufacturer of industrial fans, Envira-North Systems, because they bought license of the design and made Altra Air Fans (Figure 8a). A single Altra Air fan installed at the 2,500 m2 air conditioned site resulted in considerably reducing the energy required to keep the employees comfortably cool. This in return resulted in a six-month savings of 14,708 US $ apart from having a positive impact on productivity [25]. Lessons learned from fin whales will soon find its way into the design of the wings for special purposes, such as propellers, helicopter rotors and turbines. One of specific designs are fins for surf boards, developed by Fluid Earth Company, which increases the agility and performance (Figure 8b).


a)

b)


Figure 8. a) Industrial ceiling fan - model "Altra Air" [26] and b) humped fin from surfboard company Fluid Earth [27]
Slika 8. a) Model „Altra air“ industrijskog stropnog ventilatora [26] i b) grbava peraja za daske za surfanje poduzeća Fluid Earth [27]

The WhalePower Corporation is in private ownership and they are reluctant to publish specific financial information. WhalePower Co. is rising at double-digit rates [23] and growth is expected to increase over the next years. WhalePower is currently negotiating licenses for tubercles technology with manufacturers of computer fans, servers, small appliances, heating and air conditioning units.

INFLUENCE OF BIOMIMICRY ON ECONOMY

Biomimicry is one of the most promising scientific fields that could transform the ways goods and services are designed, produced, transported, and distributed. It could represent a major turn in the 21st century by forging a bridge between environmental and business interests.

The Da Vinci Index: Measuring the impact of biomimicry

In order to increase awareness among business leaders, government policymakers, investors, and the media, the Da Vinci Index has been designed, in year 2000, to measure activity occurring over the past decade and going forward in the field relating to biomimicry and bio-inspiration.

The Da Vinci Index is a comprehensive database of activity occurring over the past decade and moving forward in fields relating to biomimicry and bio-inspiration. The Index is comprised of four areas of data:

Number of Scholarly Articles (Source: Thomson Reuters Web of Knowledge Database.) Much of the work being done in biomimicry has roots in academia, monitoring the publications in various journals in the field is viewed as an important element.

Number of Patents (Source: United States Patent & Trademark Office.) Patent awards are often one of the first steps in the commercialization of bio-inspired concepts and are therefore included.

Number of Grants (Source: NSF and NIH.) NSF and NIH grants are incorporated in the Index to capture the extent of government support for the field, with the prospect for further development as research is translated from concept to implementation. While other agencies also issue grants, NSF and NIH appear to capture the bulk of activity.

Dollar Value of Grants (Source: National Science Foundation and National Institute of Health.) To incorporate not only the scale but the scope and magnitude of the grants involved, the dollar value of each award is also included as one of the sub-components.

The three overall concepts of scholarly articles, patents, and grants are thus assigned relatively equal weights of 30%, 30%, and 40%, respectively. The grant data is divided to give a larger weight to value than number since grants are the only concept that has some information on scale or magnitude [24].

The Da Vinci Index exists to increase awareness of how biomimicry is serving as a bridge between environmental and business interests. Due to increasing interest and the huge potential of biomimicry, the Da Vinci index has been rising each and every year since it was developed (Figure 8). Fermanian Business & Economic Institute (FBEI), of Point Loma Nazarene University's, updates the Da Vinci Index database quarterly.

Using the year 2000 as a baseline, with a score of 100, the index skyrocketed to 713 for 2010, equalling a compound annual growth rate of 22 %. Additional application to the first half of 2011 shows another rise to 752. In 2000, only three patents were found issued related to biomimicry. By 2010, the number jumped to 41. The same time period saw an increase in scholarly journal articles from 285 to 1,507. The number of grants awarded to work in the field went from 71 to 224, with their total values increasing from $24 million in 2000 to $93 million in 2010. The components affect the index on a weighted scale, with patents and scholarly articles each comprising 30 %, the number of grants making up 15 %, and the grant values weighted at 25 % [24].

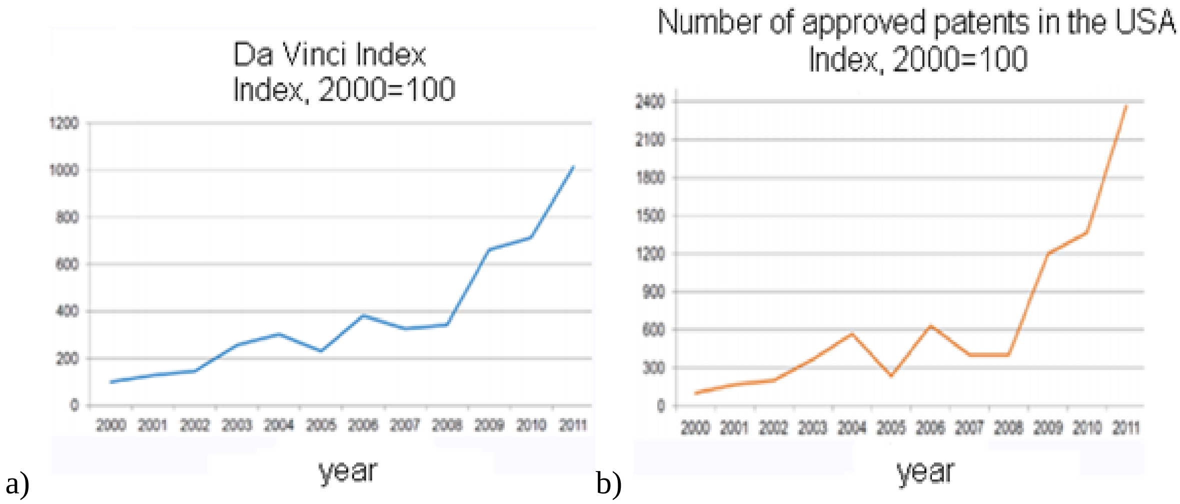


Figure 9. Graphs are displaying growth of the Da Vinci's index in the last decade a) Da Vinci Index and its annual growth rate of 22%, and b) number of approved patents in the USA regarding biomimicry [24]
Slika 9. Grafovi prikazuju rast Da Vinci-jevog indeksa u proteklom desetljeću a) Da Vinci-jev indeks s prikazom godišnje stope rasta od 22% i b) broj odobrenih patenata u SAD-u sa područja biomimikrije [24]

Investment implications

Biomimicry holds the potential to attract substantial capital inflows, driven by the prospects of rapid growth and high rates of return. The motivation will not come just from the focus on green products and sustainable systems. The ability to improve efficiency, create products that perform better than those now available, and sell at lower costs than competing items all speak to the value of biomimicry.

Returns on investment

From the case studies in the following chapter it will be shown that the companies which produce and put on market biomimicry based products (Velcro, Lotusan®, Mirasol) have increased income each year. Although firms are reluctant to say much about results for individual products (WhalePower), returns of 40-50% on new biomimicry-inspired products are rather achievable. Annual sales growth rates of 75% to 100% in the initial years can often be expected. Significant licensing fees may also be earned and a good example is Qualcomm Corporation which focused on innovation and development of new technologies and has significant revenue from licensing.

Capital flows in biomimicry and biotechnology

Venture capital could flow into biomimicry at a pace similar to that of biotechnology (figure 10.), which is estimated at about $4.5 billion in the U.S. for

2010 [11]. Compared to the keen interest now expressed for 'green tech', biomimicry could offer less risk since it is much less reliant on possibly varying regulations (e.g., mandates for alternative energy sources or reduced pollution) as well as fluctuations in subsidies.

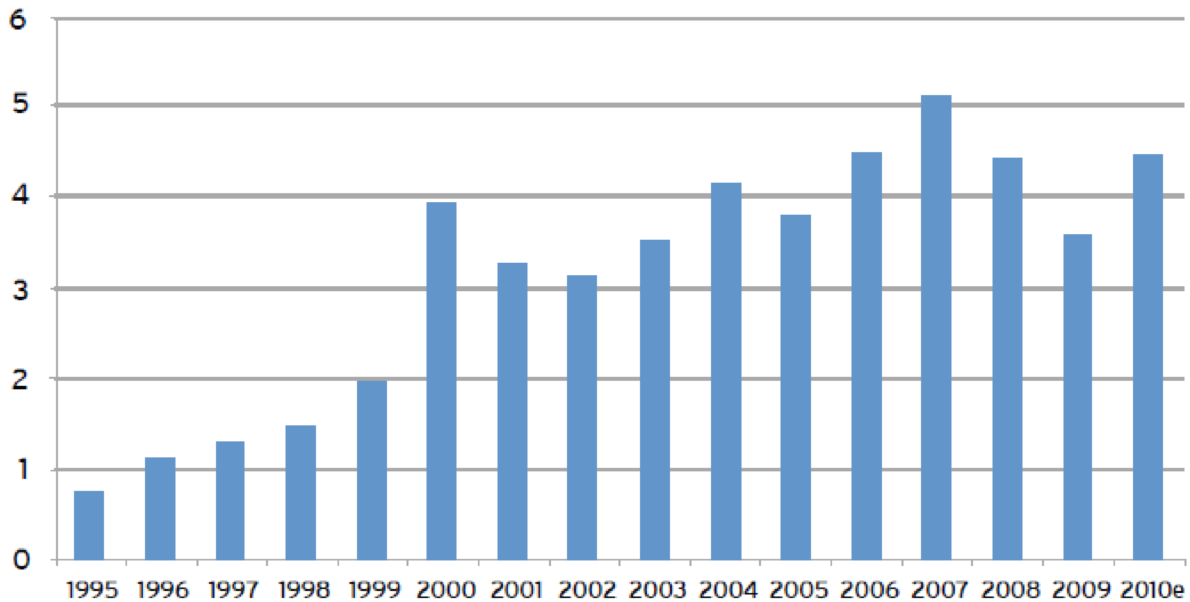


Figure 10. Graph is displaying the rise of U.S. venture capital in biotechnology[11]
Slika 10. Prikaz rasta ulaganja u biotehnologiju u SAD-u [11]

CONCLUSION

The evolution of nature led to the introduction of highly effective and power efficient biological mechanisms. Imitating nature's mechanisms offers enormous potentials for the improvement of our life and the tools we use. The aim of biomimicry in mechanical engineering is the use of biological inspiration in the design of machines that mimic the effect of animals, especially in the cases where performance of animals exceeds current mechanical technology (Qualcomm and WhalePower). Benefits from the study of biomimetics can be seen in other applications, including self - cleaning surfaces (Lotusan®) and multifunctional materials (Velcro).

Velcro products are an example of a generic brand name, which in itself is an indication of the influence this corporation yields. The company is at the moment exclusively focused on one product and largely invests in innovation and patenting various Velcro tapes that can be applied in almost every type of industry. The Velcro Company has shown a constant growth in the number of innovations, profits, number of branches and employees. Their biggest competition are their former subsidiaries which have also recorded a constant growth (e. g. Aplix).

The lotus – effect was discovered in Germany in 1976, however it was not used in any kind of industry until 1999. One of the problems that occur in the science of biomimicry is the duration of the period in which an idea gets processed from a concept to a final product. The tubercles technology developed in three years, which is considered to be quite a short period, while Lotusan® coating was finally put on the market after 23 years. Lotusan® was created as a result of a thorough research funded by the investments of the STO Corporation. Given that there is no similar product on the market, the sales of Lotusan® have been constantly growing and providing considerable revenue.

The STO Corporation is a world leader in the manufacture of flexible plasters and external insulation systems with an emphasis on innovation and ecology. Even though Lotusan® is only a small part of their portfolio, based on the current sales of this coating product, they hope to have 50% of the global exterior paint market by 2025. Although in the beginning the higher price of the product might deter some customers, in the long run the products using the lotus – effect are more cost - effective seeing that they do not require re-coating nor cleaning due to their special self – cleaning properties.

In the matter of structural coloration, it should be mentioned that the diversity of its application and ways in which it could be exploited is a direct corollary of the diverse inspiration derived from the structural coloration in nature (butterflies, birds, and insects). Its application ranges from products such as car paints (ChromaFlair), to cosmetics and electronics. The implementation of structural coloration in the field of electronics shows how much biomimicry has developed, not only with the imitation of burdock seeds but also with its usage in nanotechnology. MEMS technology, which is inspired by the structural coloration of butterflies, has intrigued several enthusiasts who founded the company Iridigm, however due to the lack of capital and investments, they were not able to fully improve the aforementioned technology. Fortunately, the corporation giant Qualcomm foresaw the potential and the possibilities this technology offers and bought Iridigm.

This example clearly shows how crucial investments are for the development of a product's concept, as for example in the case of the Lotusan® product. Unfortunately, even the best ideas cannot be implemented without an investor, while the scientists lose their right for licensing. What in fact brings a substantial capital to Qualcomm is the income from various licenses, including the one from the Mirasol displays. The Qualcomm Corporation recorded a constant growth in revenue and innovations and intends to shift the focus to the idea of learning from nature's solutions which are more effective, more competitive and energy cost-effective.

A perfect example of functionally applicable energetics is the humpback whale with its tubercles – a small detail that changes the fluid flow and gives multiple advantages to blades. The WhalePower Corporation is an example of a small company with a great idea. The tubercles technology exemplifies a fast transition from the conceptual phase to the final product (only three years). Founded by a team of experts in the field of aeronautics, biology and economics, they have created a perfect blend: biomimicry on a small scale. With the help of the colleges at which they were employed, they have tested the blades with the implemented tubercles model and accomplished their goal. They have developed propellers that consume 20% less energy, generate less noise and that are 25% more effective. They have since licenced their invention and are currently negotiating with the companies that have propellers in their devices – from wind power plants and industrial ceiling fans to the smaller fans in computers. Although they do not publicize their profit reports, the shareholders have noted that their stocks have been growing at double-digit percentage since 2009.

The inspiration by nature is expected to lead to improvements in technology as we can see from the annual growth rate of 22 percent of the DaVinci's index and it is also expected that people will feel its impact in every aspect of their lives. Some of the solutions may be considered science fiction, when it comes to today's way of performance. However, as we improve our understanding of the nature and develop better skills because of that, these solutions can become a reality in the near future.

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