MOVECO Toolbox

Schools of thoughts

Biomimicry

Introduction to the topic

DATE, PLACE,COUNTRY

NAME OF PRESENTER, ORGANIZATION

Content of this tool

- - **Biomimicry** - *general overview*
- - **Biomimicry** - *general information*

Biomimicry– *general overview*

Biomimicry comes from bios, meaning **“life,**” and mimesis, meaning **“to imitate”**.

Biomimicry is the design science that takes inspiration from nature to solve design problems in a sustainable manner.

Nature is both the model, the measure and the mentor in biomimicry. The term biomimicry was coined by polymath Otto Schmitt in 1957, and first appeared as a generic term including both cybernetics and bionics. It became more popular since 2002, with the launch of the book written by Janine Benyus, named “Biomimicry: Innovation Inspired by Nature”.

Biomimicry– *basic lows*

According to Janine Benyus, there are nine basic laws of the “circle of life” that should be considered in any biomimicry-driven design, as follows:

- „Nature runs on sunlight
- Nature uses only the energy it needs
- Nature fits form to function
- Nature recycles everything
- Nature rewards cooperation
- Nature banks on diversity
- Nature demands local expertise
- Nature curbs excesses from within
- Nature taps the power of limits”

Source: Benyus J: Biomimicry: Innovation Inspired by Nature, Morrow 1997

Biomimicry– *the design lens*

The life’s principles are aligned with circular economy. Life counts on sunlight, water, fire, ground and gravity, on dynamic equilibrium, limits and boundaries, as well as cyclic processes. Thus, the design lens of biomimicry are:

- Evolve in order to survive
- Adapt to changes:
- Attune and be responsive to local conditions:
- Use life-friendly chemistry:
- Be resource efficient in terms of materials and energy:
- Integrate development with growth:

Source: Benyus J: Biomimicry: Innovation Inspired by Nature, Morrow 1997

Biomimicry– *two approaches*

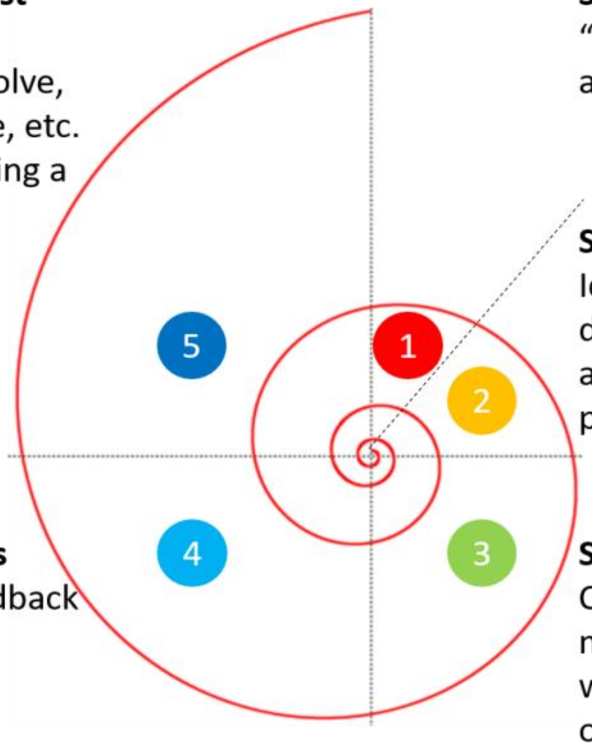
- One is the **“reductive”** approach that sees biomimicry as a transfer of nature’s solutions into the domain of design and engineering.
- The second one is the **“holistic”** approach that perceives biomimicry as a measure to achieve ecologically sustainable products

Biology design spiral

Figure 1.

Step 5: Evaluate your design against life's principles
See if the design can adapt and evolve, create conditions conductive to life, etc. and make improvements by spiralling a new iteration

Step 1: Distil the design function
"What do you want your design to do?" and "Why do you want that?"

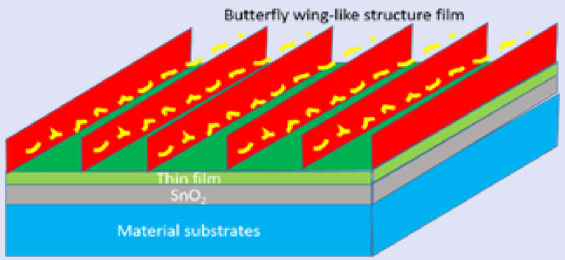


Step 2: Translate to biology
Identify functions, investigate "How does nature do this function?" and translate life's principles into design principles

Step 4: Emulate nature's strategies
Brainstorm multiple solutions, feedback loop to step 3, refine

Step 3: Discover natural models
Consider both literal and metaphorical models, combine models, brainstorm with biologists, go in the nature and observe, create a taxonomy of life's strategy

An example of biology design spiral application

Distil	Create colour without chemical pollution
Translate	Colour reflection, spectrum absorption
Discover	See how butterfly is coloured
Emulate	
Evaluate	Life-friendly chemistry; Use energy in an efficient way; bottom-up approach; minimal use of materials; low energy process; can recycle materials with no pollution from pigments

Biomimetic attributes	Structurally coloured fibres and fabrics
Inspiration	Butterfly wing scales refract and scatter light  Figure 2
Practical application	Dye free fabrics
Design problem	Industrial toxins and energy consumption resulting from the fabric dyeing and manufacturing, colour fading and skin sensitivity to dyes
Biomimetic solution	The protein layers on butterfly wing scales to create colour by refracting light is used as source of inspiration. The interaction between the layers and light refraction create the presence of pigments. The illusion of colour is fade resistant.

Two major *design processes* in relation with *biomimicry*

1. We have an engineering problem and then we look to a solution in nature.

An example was the noise problem of the bullet train every time it came out of a tunnel, due to the change in air pressure. Engineers investigated different types of water-birds that dive from air to water and observed that kingfisher makes very little splashing. Thus, they redesigned the front of the train using the beak of the kingfisher as a model (see Figure 3). The result was a quieter, faster and more energy efficient train.

Figure 3.

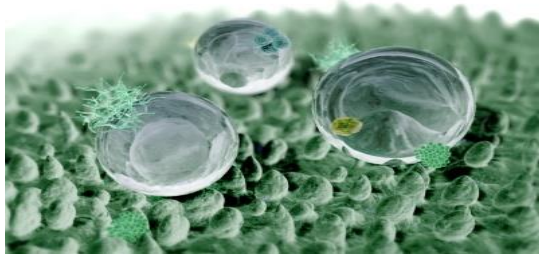
Two major *design processes* in relation with *biomimicry*

2. We start from biology with a biological solution and move towards an application by analogy.

Discovery: the self-cleaning mechanism of the lotus, based on small epidermis protrusions that cause the droplet to collect pollutants while it rolls of the lotus's leaf.

Results: several industrial applications were developed, such as self-cleaning paint, glass and fabric. Figure 4 shows a self-cleaning glass. Coating is activated by UV light. Coating breaks down the organic dirt; and by doing so it also reduces the adherence of inorganic dirt. Then, rain washes away the dirt.

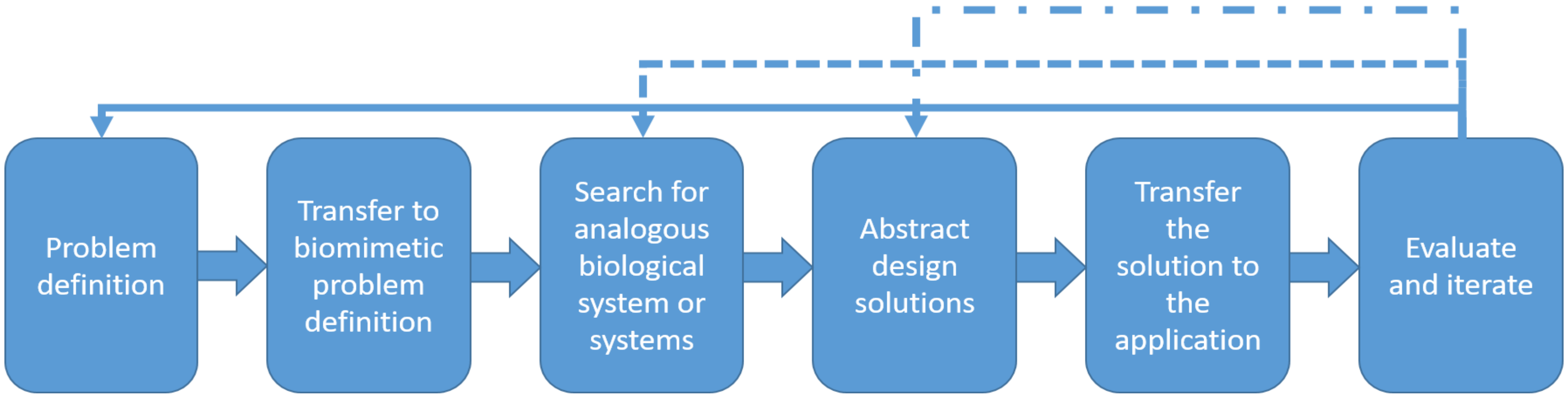
Figure 4.



Biomimetic design process from a *problem* to *biology*

The biomimetic design process that moves from problem to a biomimetic solution is shown in Figure 5. There are six major steps in this methodology, including feedback loops, if the solution is not satisfactory.

Figure 5. Biomimetic design process from problem to biology

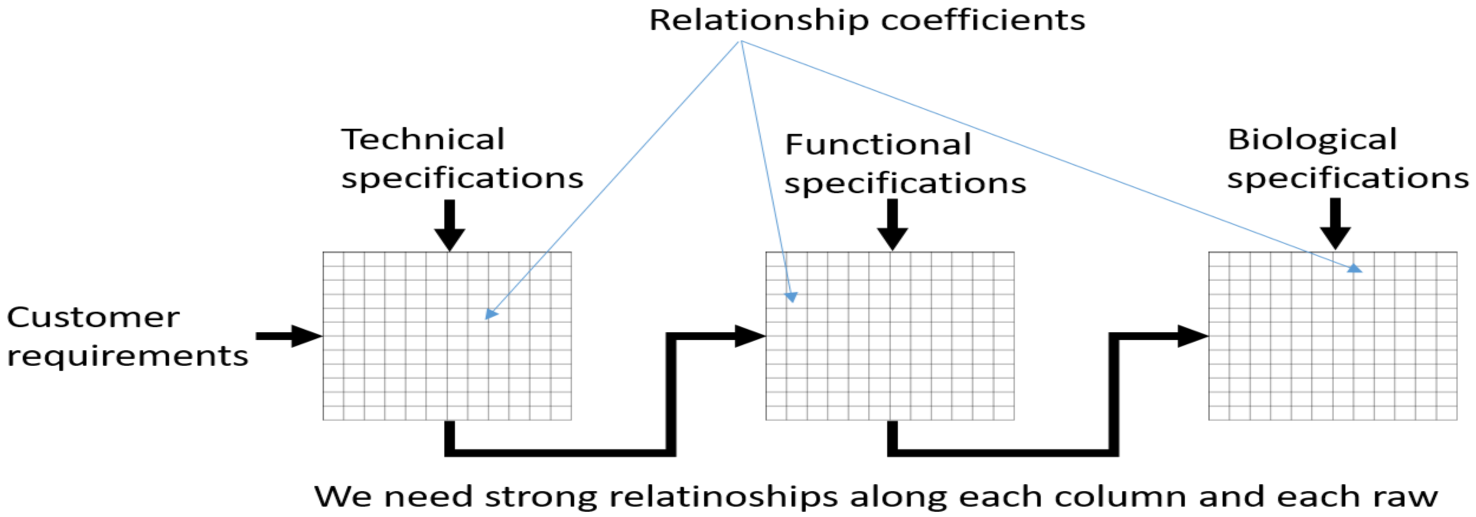


Source: Springer International Publishing Switzerland 2016 Y.H. Cohen and Y. Reich, Biomimetic Design Method for Innovation and Sustainability, DOI 10.1007/978-3-319-33997-9_2, processed scheme

Biomimetic design process from a *problem* to *biology*

Problems are derived from customer requirements or from some observed opportunity and transformed by designers to technical specifications. In order to search for relevant solutions in nature, technical specifications have to be deployed into biomimetic oriented specifications that support the biological search. This process is called “bridging problem to biology”. In order to perform this step, the guiding question is: “How do biological solutions accomplish function X?? The flow is shown in Figure 6.

Figure 6.



Exercise

Exercise 1: think about your company. Can you Imagine a biomimetric design for one of your product? If yes imagine how can you solve such a design problem.

Can you elaborate a model of a biological system that is transferred into a model of a technical system?

Do you think there are ufficient in company resources to do so?

Biomimetic design process from *biology* to an *application*

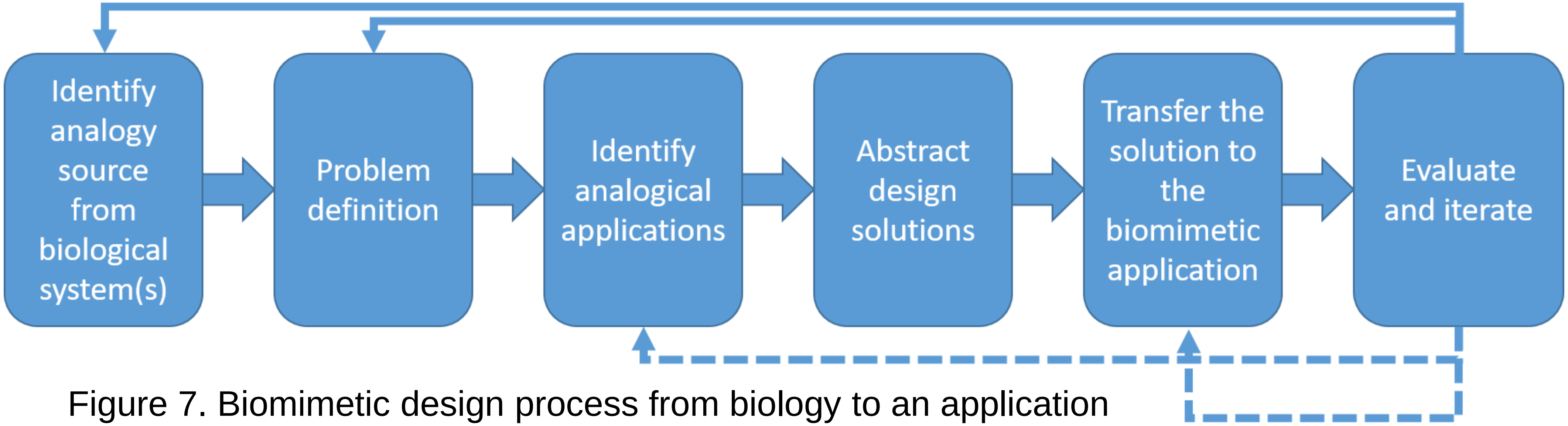


Figure 7. Biomimetic design process from biology to an application

?

Can you imagine the steps from above implemented in your company?

Can you imagine the benefits both for company and environment?

Examples of biomimicry in product design

There are a lot of examples in product design that are led by solutions already met in nature. Some of them have been further selected and shared in this material.

In order to improve dynamic behaviour of cars, Mercedes studied various shapes of fishes. Thus, the car manufacturer proposed some concepts such as the one in Figure 8.

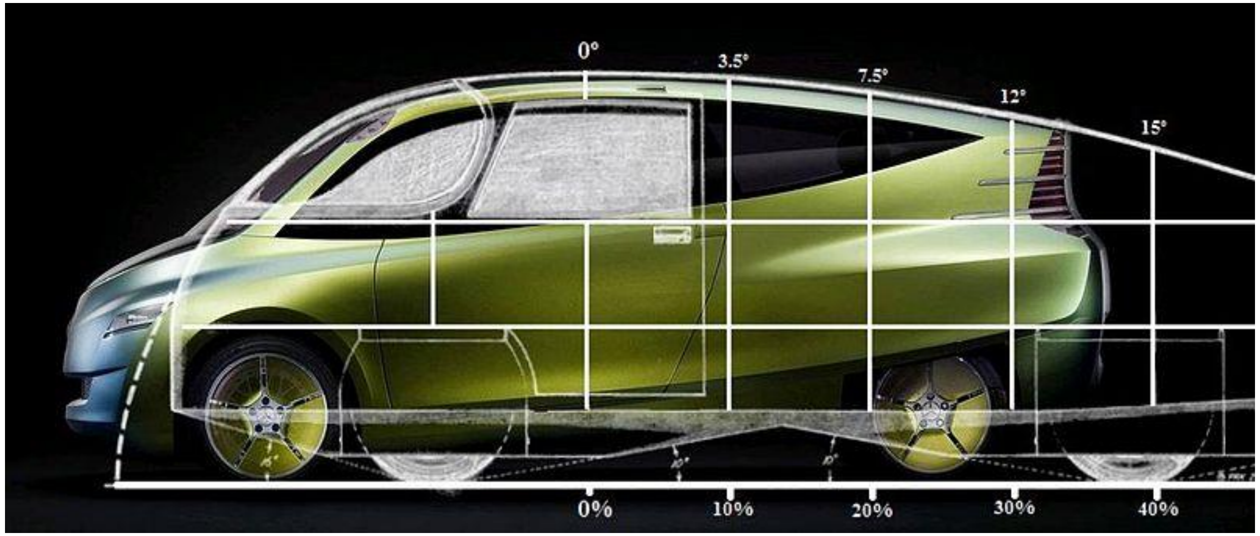


Figure 8.

Examples of biomimicry in product design

Another interesting example is the renewable packaging from Figure 9 (Mushroom® packaging). It is produced from waste of agricultural crops and roots (mycelium) of mushrooms. In this case, engineers observed the properties of mushroom's roots to imitate fabrics.

Figure 9.

Examples of biomimicry in product design

Figure 10 illustrates a mobile legged robot inspired from the anatomy of dogs. In this case the challenge is not the discovery process, but rather the analysis of dog anatomy for motion: skeleton, dynamic balance, muscle structure and coordination.

Figure 10.

Examples of biomimicry in product design

JDSU, a company that manufactures testing and measurement equipments, was inspired by the structural colouration of peacock train feather, which is not based on pigments, as in the case of example from Table 1. They designed special structure materials at nanoscale level to indicate various colours as required by specifications. An example is shown in Figure 11.

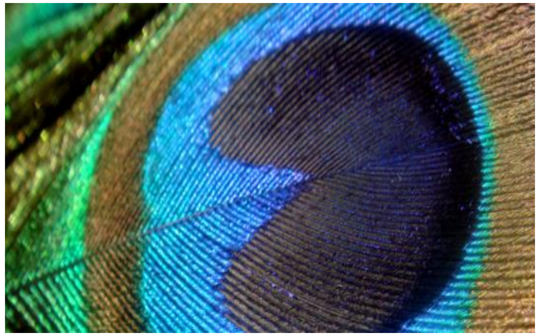


Figure 11.

Examples of biomimicry in product design

In Figure 12 there are introduced two examples of biomimicry in designing optimal shapes of the blades in the **case of horizontal and vertical wind turbines. In both cases** wales are sources of inspiration. The concept is extended to cooling fans, airplane wings and propellers.

Figure 12.

Examples of biomimicry in product design

Figure 13 illustrates how the wings arrangement of a dragon-fly was a source of inspiration to design high-lifting capacity in case of helicopters.
Other bioinspired solutions in avionics are shown in Figure 14.

Figure 13.

Figure 14.

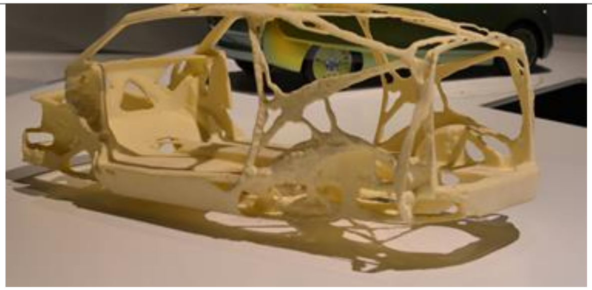
Examples of biomimicry in product design

Pharmaceutical companies have shown promising results in treating various parasites in humans such as pinworm, hookworm and giardia with a plant named “Vernonia genus”. Scientists who were watching chimpanzees discovered how they behaved when ill and how the chimpanzees seek out the plant “Veronia genus”.

Another example is the study of trees and human skeleton to improve the strength of technical structures at lower weights and minimal consumption of materials (see Figure 15).

Examples of biomimicry in product design

Figure 15. Strengthening structures with minimal material use

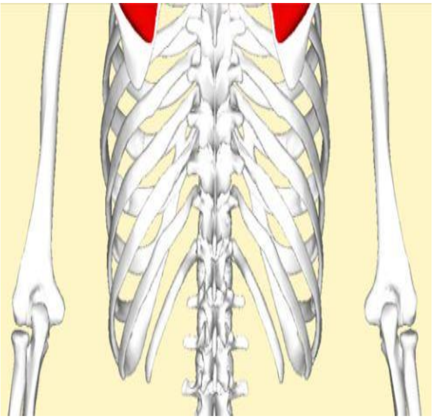



Figure 15.

Examples of biomimicry in product design

EvoLogics is a company that developed a high-performance underwater modem for data transmission, being inspired by the way dolphins communicate and process sounds with accuracy. The problem is that the sound waves are affected when traveling through water because of the destructive interference with one another due to reverberation. By imitating dolphins, the new technology uses several frequencies in each transmission.

Sensors can be dropped at 6000 meters in the sea and can communicate with satellites. Figure 16 illustrates the construction of this sensor. There are many other cases where biomimicry can be considered to save lives in case of natural calamities. Some examples are further given.

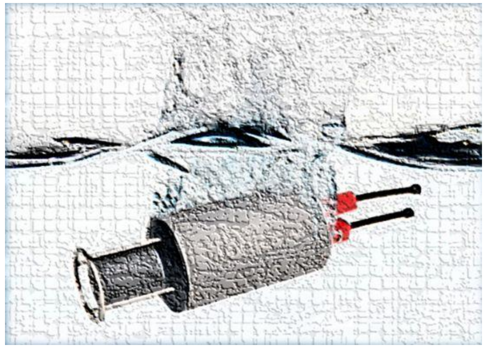


Figure 16. Sensor for underwater signal transmission inspired from dolphins

Examples of biomimicry in product design

An interesting example is how ants design their nest to drain water in multiple directions, thus avoiding floods. This is shown in Figure 17. This solution can be considered in landscaping and planning to drain water.

Figure 17.

Another example is shown in Figure 18. It deals with study of human tendons such as to design more robust building structures in case of earthquakes.

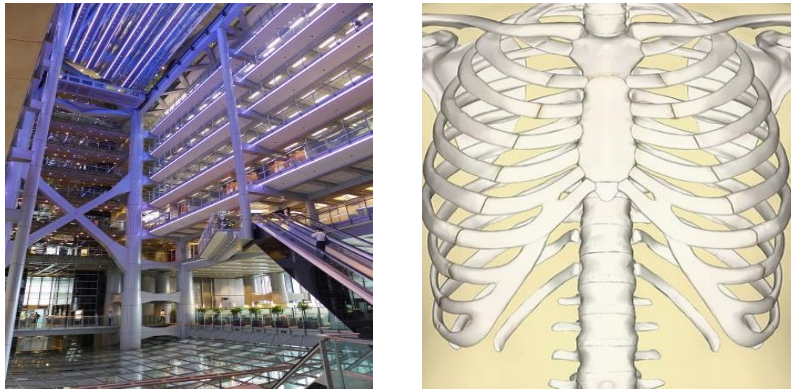


Figure 18.

Examples of biomimicry in product design

The “Eastgate Centre”, a shopping and apartment centre in Zimbabwe is inspired from termites’ nest design. There are chimneys on the roof and open vents at ground level. Air enters in the building and is either cooled or heated depending on internal temperature. At night, the building cools. As the day begins and people move around, the building heats up. Hot air exits out chimneys and is replaced by cooler incoming air. By designing the building in this efficient manner the builders were able to save costs because no air conditioning system had to be installed. The lower energy bill continues to save the owners money and as a result, the tenants are charged less rent. This is highlighted in Figure 19.

Figure 19.

Examples of biomimicry in product design

Sto Corp. has duplicated that “lotus effect” in Lotusan, a self-cleaning silicone exterior paint (see Figure 20). The coating, after it is applied, mimics the microstructure of the surface of a lotus leaf. Tiny peaks and valleys on the surface minimize the contact area for water and dirt. As a result, the coating is highly resistant to dirt, mold and mildew, and it offers excellent resistance to weather, chalk and UV rays.

Figure 20.

Examples of biomimicry in product design

The Stenocara beetle is a bug with exceptional abilities for water collection. The bug lives in desert and has a unique design of its shell. Its back is covered in small, smooth bumps that serve as collection points for condensed water or fog. The entire shell is covered in a slick, Teflon-like wax and is channelled so that condensed water from morning fog is funnelled into the beetle's mouth. Researchers from MIT were able to design a special material that is able to collect and channel very tiny amount of water (Figure 21). This material can be used to collect water in very dry areas.

Figure 21.

Examples of biomimicry in product design

Beavers have a thick layer of blubber that keeps them warm while they're diving and swimming. But they have another trick up their sleeves for staying toasty. Their fur is so dense that it traps warm pockets of air in between the layers, keeping these aquatic mammals not only warm, but dry. Engineers at the Massachusetts Institute of Technology created a rubbery, fur-like pelts that could be used to manufacture wetsuits for surfing, where people move frequently between air and water (**Figure 22**).

Figure 22.

Examples of biomimicry in product design

Figure 23 illustrates some famous solutions for fastening. The left side part of the picture shows solutions inspired from a small reptile called gecko. The right side illustrates Velcro straps. Velcro was invented by the Swiss engineer George de Mestral in 1941 after he removed burrs from his dog and decided to take a closer look at how they worked.

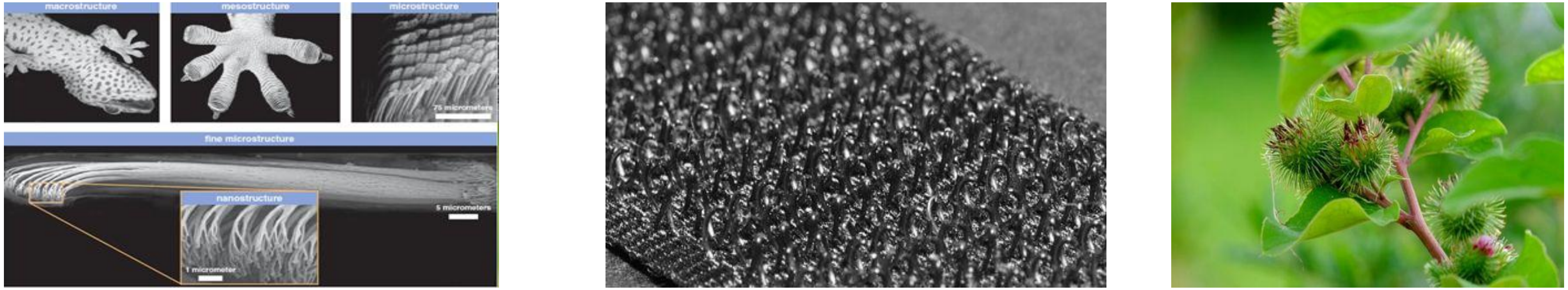


Figure 23.

Project co-funded by European Union funds (ERDF, IPA).
www.interreg-danube.eu/moveco

Examples of biomimicry in product design

Cones produced by such trees as pines, spruce, hemlock, and fir respond naturally to different degrees of humidity by opening and closing, without consuming any electrical energy in doing so. Designing window blinds based on their mechanical properties that could open and close in response to moisture—but use no energy in the process— could conserve a lot of energy (Figure 24).

Figure 24.

Examples of biomimicry in product design

Chameleons have the well-known ability to change colour. They do this by chromatophore expansion (pigment containing cells). This process was used as source of inspiration for paint that can change colour and have thermoregulatory properties (Figure 25). For example, it would be a light colour in the summertime and turn darker to absorb heat during the winter.

Figure 25.

Examples of biomimicry in product design

The hexagon is the ideal support shape in nature. Circles do not work because there are gaps between adjacent circles. Triangles and squares do not work because they stack in even rows. Hexagons have staggered stacking and thus dissipate forces effectively. Resilient Technologies is a company that designed tires that mimic bees' gofer. These tires cannot pop (Figure 26)

Figure 26.

Examples of biomimicry in product design

The last example from this material shows how nature can inspire designers to build furniture (Figure 27). It is both an aesthetic issue and a functional issue, where form fits function.

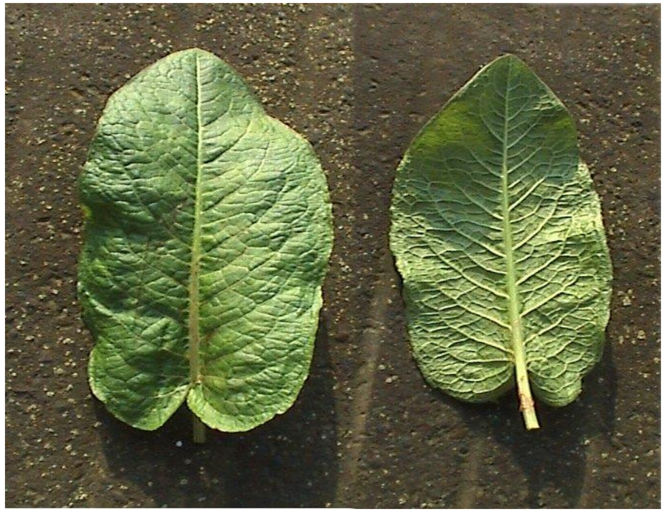


Figure 27.

Exercise

Select a product that is manufactured by your company or, as an alternative, any product you like. Analyse it from the perspective of biomimetic design. Propose improvements for each of the following steps in biomimetic design process from biology to an application

	Task	Description	Connection	Improvement
1	Identify analogy source from biological sistem (s)			
2	Problem definition			
3	Identify analogical applications			
4	Abstract design solutions			
5	Transfer the solution to the biomimetric application			
6	Evaluate and iterate			

SOURCES

Figure 2 Dorsal view of male butterfly which was captured in Peru and is stored in Muséum de Toulouse ©Didier Descouens (https://en.wikipedia.org/wiki/Biomimetics#/media/File:Morpho_didius_Male_Dos_MHNT.jpg CC BY-SA 4.0, visited 18.04.2018)
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Organization

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