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EXPLORING THE APPLICATION OF NATURE-INSPIRED GEOMETRIC PRINCIPLES WHEN DESIGNING FURNITURE AND INTERIOR EQUIPMENT

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ABSTRACT

Since ancient time the nature has been the essence of human existence, and people were trying to look for inspiration and advice for solving various problems in the nature. Most natural objects contain basic geometric principles creating a sort of systematic character and order in them. Natural structures and shapes represent a perfect design and architectural suggestions refined over the course of 3.8 billion of years of evolution. These unique and functional shape and space solutions create an ingenious system providing, through detailed study and transformation, a creative way of looking for inspiration for making innovative products with high added value in the form of nature being the mentor. The aim of the paper is to show how the biomimicry principles can be used and applied for the creation of new objects. Theoretical basis, the methodology and outputs of the workshops “Discovering Geometric Principles in the Nature as the Source of Inspiration” organized under the guidance of the authors for the students of the study program Design at the Technical University in Zvolen within the selective course of Geometric Composition is presented in the paper. The aim of the workshop was to apply the geometric principles from the selected natural shapes into the design of a unique solitaire.

Key words: design, geometry, natural aesthetics, biomimicry.

INTRODUCTION

Nature and the world surrounding us symbolize an unlimited source of ideas and inspiration for creative activities. Although the forms of natural elements are various at first sight, most of them have certain features and principles in common, and these can be observed and defined in more detail. The precise natural shapes have developed and changed throughout several millennia and include the essence that is natural for human and evoke pleasant feelings. Selected geometric procedures as well as mathematical models can represent a tool for more exact expression and description of such natural forms.

People have been observing and describing the surrounding world and searching for principles and rules since time immemorial. Already early Greek philosophers Plato and Pythagoras studied pattern attempting to explain order in nature. Plato (c.427-347 BC) in his book Timaeus describes the geometric creation of the world and he presents there his idea that the Creator created the visible world similar to a geometric progression. The

Platonic solids – Tetrahedron, Cube, Octahedron, Dodecahedron, Icosahedron – make up the four elements and heaven.

In the 19th century, Belgian physicist Joseph Plateau examined soap films, leading him to formulate the concept of a minimal surface. Plateau's original problem dealt with surfaces of minimum area without pressure differences (so H = 0) and with boundaries that are simple closed curves.

German biologist Ernst Haeckel played an important role in connecting the sciences and art. He discovered, described and named thousands of new species, mapped a genealogical tree relating all life forms, and coined many terms in biology. As an artist he painted hundreds of organisms to emphasize their symmetry. Most notable is his book Kunstformen der Natur (Art Forms in Nature). Haeckel was outstanding as a scientific artist. Instead of drawing just a front view, he also illustrated the other side if visible through gaps and holes in the skeletons. The result was a three-dimensional picture – rarely seen until then.

Haeckel's Art Forms in Nature is not merely a set of examples, which with each detail reveals part of the whole. It demonstrates naturalness itself. By revealing the form of nature, knowledge of nature may be ascertained, which, according to Haeckel, should not be restricted to branches of natural science following experimental agendas. Knowledge of nature is "natural aesthetics". Accordingly, aesthetics is nothing more than reflections of nature itself. Nature, which develops out of and into itself, is beautiful.

Haeckel's illustrations inspired many artists of the time. One of them was the Paris architect René Binet. He used natural form of a radiolarian as the basis for his monumental entrance gate to the Paris World Exposition in1900.

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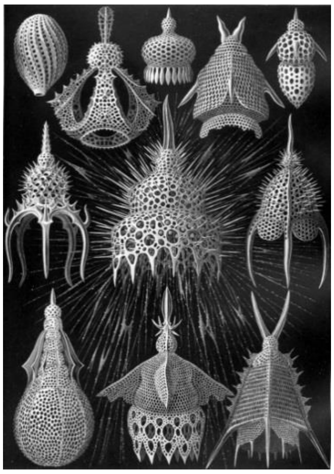
1b 

Fig. 1a René Binet's entrance gate to the Paris World Expositionin1900 (http://architectuul.com/architecture/the-monumental-gate), 1b. Ernst Haeckel's illustration of radiolarian (HAECKEL 1998).

Cooperation between the Hungarian biologist Aristid Lindenmayer and French American mathematician Benoît Mandelbrot was another significant contribution to the research into nature and its mathematical and geometrical interpretation. In cooperation they showed how the mathematics of fractals could create plant growth patterns. Mandelbrot believed that fractals, far from being unnatural, were in many ways more intuitive and natural than the artificially smooth objects of traditional Euclidean geometry. "Clouds are not spheres, mountains are not cones, coastlines are not circles, and bark is not smooth, nor does lightning travel in a straight line" (MANDELBROT 1982).

Natural forms, characterized by specific functional and shape solutions, offer the opportunity to take advantage of their uniqueness. Their exact exploration and subsequent transformation can be a unique inspiration for the design of new innovative products.

The aim of the paper is to show how to apply the principles of biomimicry in creating new objects. Research of the chosen problem related to the application of bio-inspired approach in design of furniture and interior equipment was based on the initial observation of selected natural shapes. Then the selected objects were abstracted using geometric knowledge and constructions. These constructions have been thoroughly analyzed and have become the basis for product development.

Within the education in the field of study 2.2.6 Design at the Technical University in Zvolen, the students have the possibility of enrolling into the course Geometric composition. This paper presents the methods and outputs of a workshop, whose aim was to introduce the students to the issue of geometric principles in the nature, their rules, construction possibilities and use. Further aim was to apply the acquired knowledge and design an object – a unique solitaire inspired by the forms, patterns and geometrical relations derived from natural principles. The methodical process was based on Biomimicry procedures (BENYUS 1997) representing the most complex designer processes for creating bio-inspired innovations.

Beauty is a large part of why biomimicry resonates. Our search for mentors brings us back into contact with the living world, a place we were tuned to appreciate. Having spent 99.9% of our planetary tenure woven deep into the wild, we humans naturally admire the weaverbird's nest, the conch's shell, the scales of a shimmering trout. In fact, there are few things more beautiful to the human soul than good design (BAUMEISTER 2013).

The core idea is that nature has already solved many of the problems we are grappling with. Animals, plants, and microbes are the consummate engineers. After billions of years of research and development, failures are fossils, and what surrounds us is the secret to survival. (BENYUS 1997, REED 2004, BAR-COHEN 2006). The biomimicry practice follows a well-organized but flexible transdisciplinary team-based design process applicable to any kind of tangible or intangible design challenge (ROWLAND 2017). The first level of biomimicry is the mimicking of natural form. Deeper biomimicry adds a second level, which is the mimicking of natural process, or how a thing is made. At the third level is the mimicking of natural ecosystems (BAUMEISTER 2013).

To the expansion of biomimetics, education must play a significant role. It should be included in the education syllabus of architecture and design degrees to make them aware of the potential of the approach (MAHMOUD 2012). For the needs of our intention, the workshop methodology was based on the first level of Biomimicry, i.e. "mimicking of natural form".

EXPERIMANTAL AND THEORETICAL PART

Biomimicry is an approach to innovation that seeks sustainable solutions to human challenges by emulating nature's time-tested patterns and strategies. The goal is to create products, processes, and policies—new ways of living—that are well-adapted to life on earth over the long haul.

When an interior designer says that a design is influenced by nature, he or she is most likely talking about its appearance: it has an organic shape. Nature is a good teacher in this regard, but imitating or being inspired by natural-looking forms, textures and colors alone is not biomimetics. To quote Dr. Julian Vincent 'biomimetics has to have some biology in it.' By which he means that a design should in some way be informed by nature's science, not just its look to be truly biomimetic. However, perhaps the key to understanding the role of biomimicry in interior architecture is the fact that the reason for the success of any design is not that it can trace its roots back to a natural principle but that it is an example of good design! Biomimicry is a philosophical approach that can lead to novel ideas and innovative solutions that have many potential advantages, for example, from functional or sustainability perspectives (MAHMOUD 2012).

Workshop Methodology

The first workshop stage covered complex mapping of the state of the art of geometric principles found in the nature, as well as mapping the most significant examples of applying the nature inspired principles in art, architecture and design.

The second project stage comprised the individual scientific and artistic experimental research. The task of each participating student was to present three products of nature, which they brought to the studio. The presentation was grounded not only on observing the product of nature; moreover, it covered also geometrical and mathematical analysis of the element focused on identifying the aforementioned geometric principles and drawing the specific product of nature in identified geometric condensation. Design students were subsequently divided into groups, based on the same or similar elements they analyzed.

The creative experiment itself comprised the application of the knowledge into an object design in the form of conceptual solitaires inspired by the forms, patterns and geometrical relations derived from the natural principles. The project outputs were the scale models, sketches, geometrical analyzes and photos of scale prototypes.

As an example of good practice were students familiarized with examples of the current similar bio-inspired project such as biomimetic research project based on the biological principles of conifer cones. They presented some designs inspired by the method that cones protect the seeds inside; the spines close up to protect the seeds inside in the rainy weather and open up to improve the chances of the seeds escaping at the dry weather, see Fig. 2. One of these designs is the FAZ Pavilion which located in the city centre of Frankfurt; the summer pavilion provides an interior extension of this popular public space.

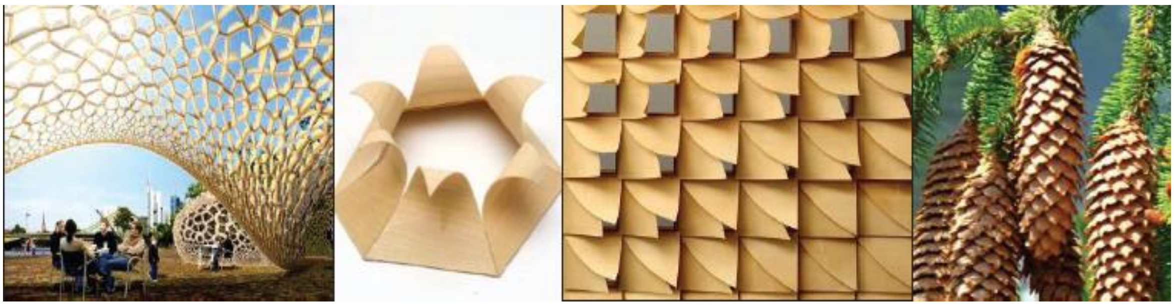


Fig. 2 FAZ Pavilion project (MAHMOUD 2012).

Bio-inspired furniture as an example for design studies

Mantis Table (Fig. 3) designed by Alvaro Uribe. Inspired by insect body parts and adding a light and elegant touch, the table's base is structured to mimic the small and delicate legs of a praying mantis which are uniquely angled to support the insect's disproportionately long and heavy body. The design uses bio-inspired concepts adding to the structure's lightness while still encompassing high-strength properties to support the heavy glass surface. The table uses the least amount of aluminium still being able to hold six times its own weight. Its shape is dynamic and natural.

Fig. 3 Alvaro Uribe - Mantis table (http://arthitectural.com).

Biomimicry chair- 3D Printed Soft Seat (Fig.4) designed by Lilian Van Daal that uses plant cell structure. By manipulating the constructions, she has succeeded in realizing not only the base framework but also micro and macro support, ventilation, and the skin of the product using just one substance. It is designed as an alternative to conventional soft seating, which requires several different materials and processes to create the frame, padding, and covers.

Fig. 4 Lilian Van Daal – Biomimicry Chair- 3D Printed Soft Seat (h**ttps://www.lilianvandaal.com).**

Radiolaria - small life-forms were for Lilian van Daal's basic inspiration to create Biomimicry Chair - **Radolaria #1**(Fig.5). The structure of Radiolaria amplified by 3D printing affords various levels of flexibility and comfort without using different types of foam like in common soft seating. The lattice of connections within Bryozoa skeletons inspired Van Daal to create a system of connection points for assembly of the chair without extra materials such as glue.

Fig. 5 Lilian Van Daal – Biomimicry Chair - Radolaria #1 ((h**ttps://www.lilianvandaal.com).**

Visible Patterns in Nature from the Geometrical Perspective

As mentioned above, the natural elements contain certain geometric rules causing that people perceive such object as pretty. When talking about an object which is pretty, i.e. it has artistic qualities; it means that it drew our attention in a certain way, captivated us or pleased us. Regarding the formal aspect, it contains some kind of order that can be expressed as pretty (CRHÁK 2012).

We seek order. The gestalt psychologist Wolfgang Metzger spoke in this connection of a love of order of the sense. Corresponding to love of order of the sense are figures that stand out of against a background and that are as forms clearly recognizable levels and axes of symmetry. This is one reason why we find crystals and certain types of organisms so beautiful, whether they are bilaterally or radially symmetrical.

Geometric rules found in many natural shapes can be characterized as "patterns in nature". According to Stevens, 1976, patterns in nature are visible regularities of form found in the natural world. These patterns recur in different contexts and can sometimes be modelled mathematically. Natural patterns include symmetries, spirals, meanders, waves, trees, tessellations, foams, cracks and stripes. From the viewpoint of using the natural geometry in design, symmetry and curves play the most significant role.

Symmetry

According to Martin, 1996, a geometric object has symmetry if there is an "operation" or "transformation" (such as an isometry or affine map) that maps the figure or object onto itself; i.e. the object has an invariance under the transform. The exact symmetry, however, is strictly limited to mathematics and geometry only. Real object show only approximate symmetry, which is processed by brain into an ideal symmetric shape. Symmetry creates a class of patterns in nature, where the near-repetition of the pattern element is by reflection or rotation.

The main types of symmetries are: point symmetry, linear symmetry and rotational symmetry.

A figure has point symmetry (point reflection) if it is built around a point, called the center, such that for every point on figure there is another point directly opposite and at the same distance from the center.

A set of points has linear symmetry (bilateral symmetry, mirror symmetry) if and only if there is a line "l", such that reflection through "l" of each point in the set is also a point in the set. Certain figures can be mapped onto themselves by a reflection in their lines of symmetry. It is possible for a figure to have more than one line of symmetry.

Let's show for example of real function to illustrate the symmetry of its graphs.

Let $f(x)$ be a real-valued function of a real variable. Then f is even if the following equation holds for all x and $-x$ in the domain of f.

$$f(x) = f(-x)$$

Geometrically speaking, the graph face of an even function is symmetric with respect to the y-axis, meaning that its graph remains unchanged after reflection about the y-axis.

A geometrical figure has rotational symmetry if the figure appears unchanged after a rotation around a point by an angle whose measure is strictly between 0º and 360º. The angles of 0º and 360º are excluded since they represent the original position (nothing new happens). The angles of rotational symmetry will be factors of 360.

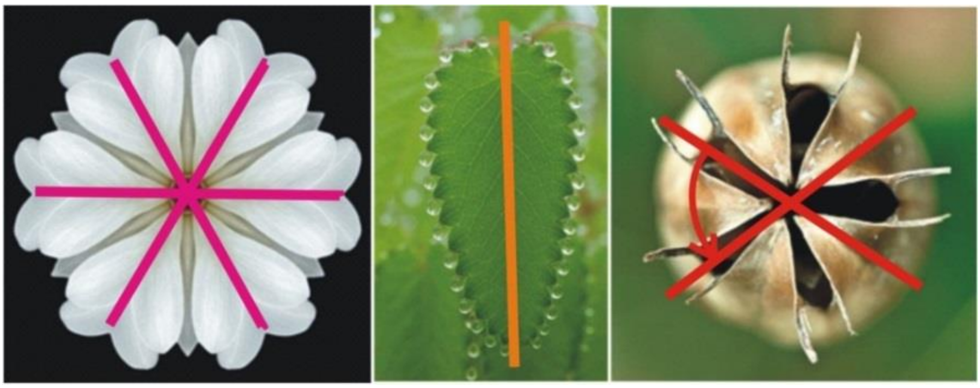


Fig. 5 Natural object's symmetry.

Curves and Spirals

The straight line can be found rarely in the nature. The growth and changes of the environment modelled the living organisms into rounded shapes based on curves. Many natural curves are excellent real models of mathematical curves. Mathematical curves most often found in the nature are e.g. circle, spiral, helix or regular sinuous curve - meander.

Spiral is a plane curve described by the point *P* on a line *p* turning around a fixed point *O*, while the distance *OP* does not change. The most famous spirals are:

Archimedean spiral $r = a + b\theta$
logarithmic spiral $r = a.\, e^{b\theta}$
(approximations of this are found in nature as Fibonnaci and golden spiral)
Fermat's spiral $r = \theta^{1/2}$
hyperbolic spiral $r = a/\theta$

Spirals are common in plants and in some animals, notably mollusks. For example, in the nautilus, a cephalopod mollusk, each chamber of its shell is an approximate copy of the next one, scaled by a constant factor and arranged in a logarithmic spiral. Other plant spirals can be seen in phyllotaxis, the arrangement of leaves on a stem, and in the arrangement of other parts as in composite flower heads and seed heads like the sunflower or fruit structures like the pineapple, as well as in the pattern of scales in pine cones, where multiple spirals run both clockwise and anticlockwise.

A model for the pattern of florets in the head of a sunflower was proposed by H. Vogel. This has the form:

$\theta = n\ .\ 137{,}5°,\ r = c\,\sqrt{n}$

where *n* is the index number of the floret and *c* is a constant scaling factor, and is a form of Fermat's spiral. The angle 137.5° is the golden angle which is related to the golden ratio and gives a close packing of florets.

These phyllotaxis spirals can be generated mathematically from Fibonacci sequence which approximates the golden section (golden ratio).

The "golden section" (lat. *sectio aurea*) is a division of an abscissa into two parts so that the longer part divided by the smaller part is also equal to the whole length divided by the longer part" (ŘÍMAN1987). Expressed algebraically, for quantities *a* and *b* with $a > b > 0$,

$a / b = (a+b) / a$

The Golden Ratio describes the perfectly proportional relationship between two proportions. Mathematicians since Euclid have studied the properties of the golden ratio, including its appearance in the dimensions of a regular pentagon and in a golden rectangle, which may be cut into a square and a smaller rectangle with the same aspect ratio. The golden ratio appears in some patterns in nature.

Helix is a solid curve, which can be defined as a line on a rotary plane created by a point that is moving while the ratio between the axial shift and corresponding angle rotation is constant.

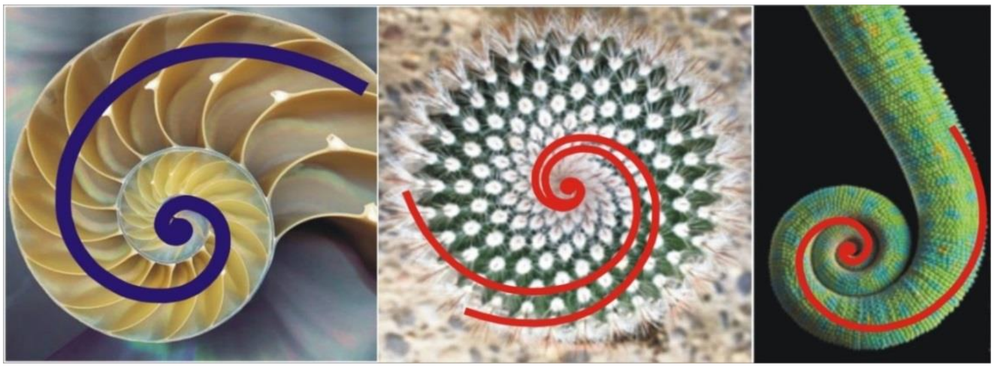


Fig. 6 Natural curves and spirals.

Natural Forms and Principles in Architecture and Design of the 20th and 21st Century

The most significant style of the 20th century playing and important role in creating our current perception of what we call inspiration by the natural motives, is the Art Nouveau.

The tendency of architecture with natural shapes with its smooth flowing volumes, consistency with the natural environment and use of natural materials was established by the architect of Modern style A. Gaudi. (Fig: a) Asymmetry and irregularity of architectural shapes have become a feature of the work of F. Hundertwasser. (Fig. b) In his Vienna house architect realizes his ideals of beauty: the absence of straight lines, rich polychromatic facades (colored majolica tiles and plaster), diversity of vegetation, different configuration of window and door openings (KAZANTSEVA, MYHAL 2014).

The style which applied geometrically stylized motives in a similar way is Art Deco. This movement connected various styles of the early 20th century including Constructivism, Cubism, Modernism, Bauhaus, Art Nouveau and Futurism. Art Deco follows the early Neoclassicism with the elements of exotic motives, stylized animals, leaves and sunrays.

Organic design was initiated by Frank Lloyd Wright, who believed in creating harmony between people and nature and considered architecture a medium for creating the perfect equilibrium between the artificial and natural world. This belief was expressed by the use of natural materials and smooth curved forms. His philosophy is clearly mirrored in his most famous buildings like the house over the waterfall “Fallingwater” or Guggenheim museum in New York.

In Scandinavia this trend was overlapping with the “Democratic design” being a way of improving the everyday life of people.

In the 70’s design, the most prominent design personality inspired by the natural forms is the designer Luigi Colani (Fig. c). “Whenever we talk about biodesign we should simply bear in mind just how amazingly superior a spider’s web is to any load-bearing structure man has made – and then derive from this insight that we should look to the superiority of nature for the solutions. If we want to tackle a new task in the studio, then it’s best to go outside first and look at what millennia-old answers there may already be to the problem.” (COLANI 2018) In the case of Colani’s design, the outcome is evidently very successful, but even more is possible, looking at nature as a role model (GRUBER 2008).

4a 4b 4c

Fig. 7 a. A. Gaudi - Cassa Batlo, b. Hundertwasser – Vienna House, c. Luigi Colani - Coal mine Achenbach (https:// sk.pinterest.com/pin/370069294373125298/?1p=true).

The works of his successors like Zaha Hadid, Ron Arad, Mark Newson are strongly marked by the connection to curves inspired by bionic forms found in the nature. Especially significant was the contribution of the designer Ross Lovegrove. Inspired by the logic and beauty of nature his design possess a trinity between technology, materials science and intelligent organic form, creating what many industrial leaders see as the new aesthetic expression for the 21st century. There is always embedded a deeply human and resourceful approach in his designs, which project an optimism, and innovative vitality in everything he touches from cameras to cars to trains, aviation and architecture (LOVEGROVE 2018).

RESULTS AND DISCUSSION

Witin the workshop, the students worked under the expert guidance of the authors of this article with selected natural elements that formed the basis of their design. The first phase of the workshop was aimed at acquaintance the students with the theoretical basics of Biommimicry work and the basic geometric design principles that are contained in nature. Than the selected natural elements were studied from a natural and geometric point of view. The selected natural element was analyzed and its geometrical properties were graphically described There was also a geometric scheme (symmetry, golden rules, spirals,…) that express the specific relationships worked up. Geometric elements and basic natural shape have become the basis for designing of new products. The methodical process was based on Biomimicry procedures representing the most complex designer processes for creating bio-inspired innovations. All the design phases were constantly under the guidance of the authors of the article, and the students were led to correctly apply the theoretical approaches.

The students within the workshop designed unique solitaires with a specific function. The outputs were in the form of sketches, visualizations, photos and models.

False Shamrock – Oxalis triangularis (authors: Dobešová Daniela, Froncová Martina, consutants: Lizoňová Denisa, Tončíková Zuzana, Melicherčíková Iveta)
The inspiration for this design was the plant Oxalis triangularis with a distinctive deep-maroon to purple leaves of a triangular shape. At night the leaves resembling butterfly wings close towards the stem. From the geometry aspect, the shape is based on isosceles triangle. The whole object is created on the principle of rotational symmetry with the angle of 120° (Fig. 8).

Fig. 8 Oxalis triangularis.

This geometrically interesting plant inspired the creation of a sun umbrella with additional lighting. The shapes of the umbrella are derived from the plant's organic structure and the folding of the umbrella is inspired by the way of closing the leaves. The surface is made of translucent, water resistant fabric. The sun umbrella is supplemented by LED lighting.

African Violet (authors: Borbélyová Jozefína, Hlavatá Miriam, consutants: Lizoňová Denisa, Tončíková Zuzana, Melicherčíková Iveta)
When designing this project, the inspiration was the African violet, specifically the leaf structure and arrangement. From the geometry aspect, the violet leaves are characterized by the axial symmetry. The arrangement of leaf venation supports the symmetry even more. The leaf shape can vary with various cultivars, however, the selected element has a curve similar to the shape of the golden spiral (Fig. 9).

The principle of leaf growth was the inspiration for creating an interior wall lamp. The typical leaf surface was pronounced by the use of soft textile material pleasant to touch. The textile has the function of a lamp shade. Optical fibers were used for the lamp production. The light source is inserted into a paper cover resembling a rock. Two branches of leaves having the function of two lightings at various heights come out of the source.

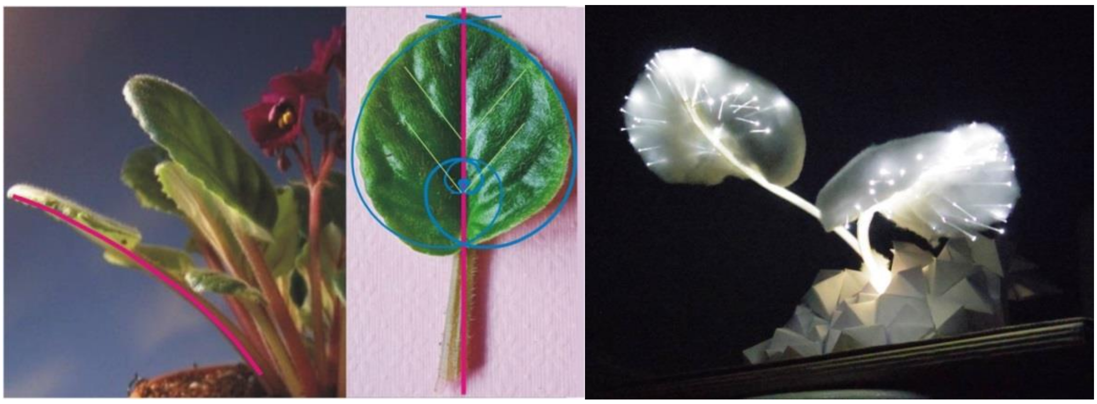


Fig. 9 African Violet.

Grain ear (authors: Horváthová Alexandra, Jack Dominik, Verbovancová Natália, consutants: Lizoňová Denisa, Tončíková Zuzana, Melicherčíková Iveta)
The shape of the following object was inspired by the grain ear, its interesting shape and the

grain arrangement. Considering geometry, the grain ear is typical by its oblique axial symmetry. The composition is dominated by the grain arrangement rhythm (Fig.10).

The shape and internal arrangement of individual grain ear parts were the basis for designing group seating. The supporting aluminum construction is supplemented by wooden elements creating the seat body. Upholstery is designed from natural fabric.

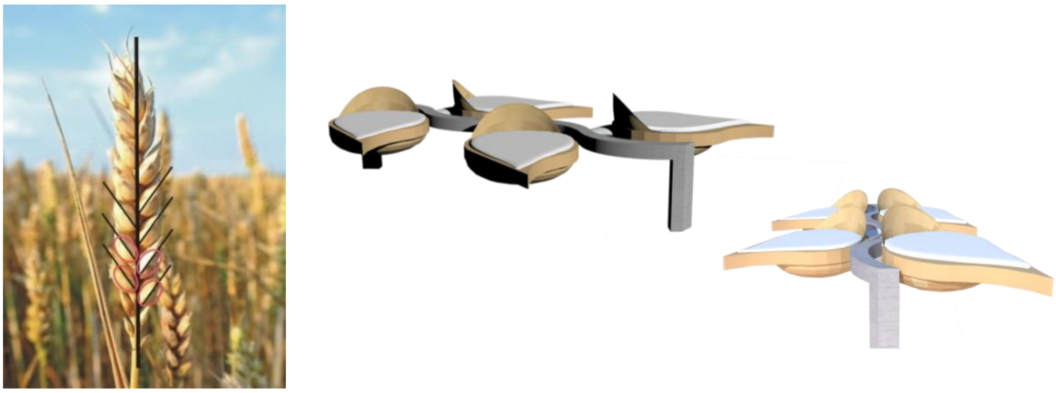


Fig. 10 Grain ear.

Scallop shell (authors: Javorková Veronika, Kováčiková Terézia, Kristof Albert,, consutants: Lizoňová Denisa, Tončíková Zuzana, Melicherčíková Iveta)
Another inspiration from the nature selected by students was the scallop shell. The geometry of the shell profile is characterized by a soft curve resembling the golden spiral in the end part. In addition it features also axial symmetry supported by the regular ribbing pattern creating a king of rhythm (Fig.11).

The design object is a shelf with book stands. Its fan arrangement separates the books. The shelf, to which the book stands are attached, is created by several gradually decreasing parts creating a 3D effect and representing the other half of the closed shell.

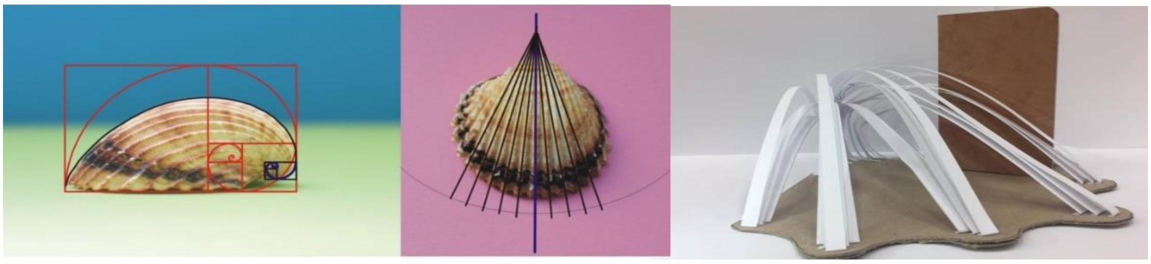


Fig. 11 Scallop shell.

Sea urchin (authors: Bačíková Dominika, Klinovská Kristína, consutants: Lizoňová Denisa, Tončíková Zuzana, Melicherčíková Iveta)
The inspiration in this case was the test of a sea urchin Echinus living on the European seabed. During the life the body of the sea urchins is covered by moving spines. From the geometry aspect, adults are characterized by a distinctive five-fold symmetry. Individual segments with similar color are arranged at the angle of 72°. The cross-section of the shape has the proportions of the golden ratio with a soft shape resembling the golden spiral (Fig. 12).

The designed objects represent massage seating and backrests for a relax zone or a pool inspired by the shape and structure of the test. The designed objects can be used in exterior, too, e.g. in a coral bay. The soft oval shape is supplemented by water massage nozzles.

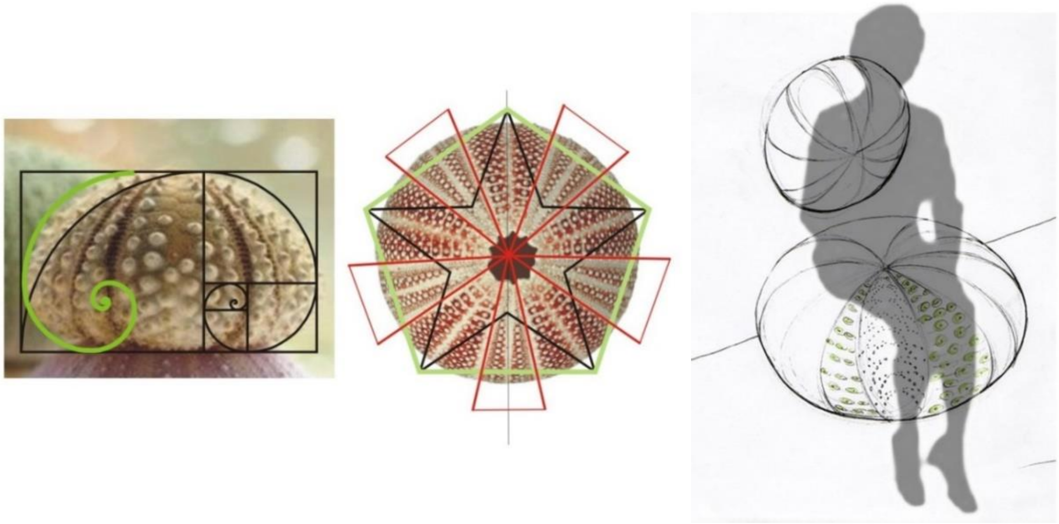


Fig. 12 Sea urchin.

Pine cone (authors: Debnárová Mária, Magerová Júlia, consutants: Lizoňová Denisa, Tončíková Zuzana, Melicherčíková Iveta)
The inspiration from nature was the pine cone and the spiral in its arrangement and the ornament created this way. The female cone has two types of scale: the bract scales, derived from a modified leaf, and the seed scales. The bract scales are spirally arranged around a central axis. The cone geometry is interesting due to several curves visible on its surface. Firstly, it is the arrangement of the bract wood scales in the shape resembling the golden spiral, which can be observed when looking at the cone upside down. Secondly, the bract woody scales are arranged in the shape of a helix (Fig. 13).

The interesting shape created by the nature provided a form suitable for further design inspiration. The spiral curve was preserved and the spaces between individual bract scales were used as storage space for designing a cooking spoon holder.

Fig. 13 Pine cone.

Citrus fruit (authors: Gondová Ivana, Hanesová Simona, consutants: Lizoňová Denisa, Tončíková Zuzana, Melicherčíková Iveta)

The design inspiration was the citrus fruit and its cross-section and regular segment structure. The segments are also called “liths”, and the space inside each lith is a locule filled with juice vesicles. From the aspect of geometry, the cross-section of the citrus fruit features strong radial symmetry. The individual segments create endless rhythm. Various types of citrus fruits are divided into different number of liths, a feature depending on the variety of the fruit.

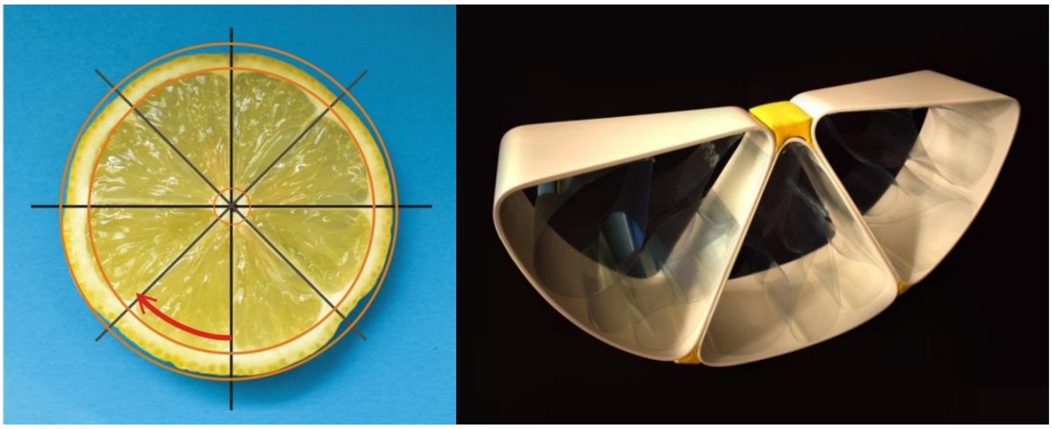


Fig. 14 Citrus fruit.

The designed object is a fruit holder having a shape of citrus fruits. It is created by three main segments that can be separated if required. Inside parts of the segments are further divided by plastic elements in order to enable separate storage of individual fruit types without touching (Fig.14).

Humans are a part of the nature, and therefore, they perceive the arrangement and shapes as something natural and one’s own and such shapes and arrangements are often defined as beautiful. Within education and artistic aims of the project all partial aims were fulfilled: to focus on and map the theory of geometric principles found in the nature and to use the obtained theoretical analyses for creating new design concepts. Within acquiring the information we supplemented the theoretical input of geometric and mathematical analyses of living products of nature with specific examples showing how architects, designers and artists were and still are inspired by the nature and its forms. Most students considered the method “mimicking of natural forms” very inspiring and creative. When comparing this workshop with other workshops focused on artistic geometry and other topics, the students showed more creative potential and were able to create very remarkable concepts.

Within the project evaluation we have realized few deficiencies caused by the time limitation for the instructors’ theoretical inputs. Similarly, the absence of a biologist was considered a negative, since they would be able to immediately answer any questions on the shape and mainly the function of a certain geometric form from the organism evolution point of view. It was encouraging that several students were eager and became absorbed in the topic in order to understand the geometrical shape of the product of nature not only from the formal, but also from the functional aspect. This was partially fulfilled in the case of the false shamrock design, whose lamp shade opening mechanism was inspired by the way how the plant closes its leaves at night. Also the students inspired by the “citrus fruit” used not only the shape of the fruit segment, but also the internal structure reinforcing the bowl construction. The results can be formally compared with similar short-term workshops, when the designers applied the biomimicry procedures, e.g. “Furniture Design” course given to Karadeniz Technical University Interior Architecture 3rd grade students. (TAVSAN, SONMEZ

2015), or findings by (DE PAUW *et al*. 2012). The findings indicate that NIDS inspire the students, encourage out-of-the-box thinking, and provide absolute- instead of relative-design principles to guide the concept development.

Our results indicate a strong potential of the biomimicry procedure for encouraging innovative and creative designer thinking focused on creating furniture and interiors. Since it is them who are the new generation influencing the creation of space that surrounds us in the most intimate sphere – in our homes. Our experience with applying the biomimicry procedures is similar to those of other universities. It shows that universities should make effort to create conditions for availability of similar courses and workshops dealing with the methods suitable for creating new nature inspired innovations.

CONCLUSION

Nature has been a huge laboratory for research, development and design for 3.8 billion years and is still innovating. Since time immemorial people have turned to nature where they have been looking for inspiration, advice or ideas. Almost all aspects of human progress have been associated with observing and studying the natural structures and phenomena.

People, led and inspired by the natural laws, were able to create cathedrals and bridges, brilliant works of arts and inventions. Many of the world's history thinkers like Leonardo da Vinci or Albert Einstein were inspired by natural systems, structures and creations. A framework for understanding one form of biomimicry has been experimentally verified on real student's projects. The case studies emphasize that integrating biomimicry within interior environments requires introducing the approach at the primary stages of the design process, ideally before any preliminary ideas have even been formed. Nature opens the designers, architects, scientists and engineers a completely new world and enables them, through studying the capabilities, structures, shapes and processes developed in plants and animals, to design better, stronger, more ecological and sustainable products for our life and future. Within the short-time workshop with design students we managed to create a compact collection of solitaires inspired by the geometric forms found in living products of nature. At first sight an elementary task showed to be very positive, enlightening and creative experience providing a proof of what a perfect and harmonic world has the evolution created. We believe that such experience will stay in the design students' minds and will help them to look for the answers in the nature also in the future when they face important design challenges.

REFERENCES

ALI, MAHMOUD 2012. Biomimicry as a Problem Solving Methodology in Interior Architecture. Procedia - Social and Behavioral Sciences. 50. 502–512. 10.1016/j.sbspro.2012.08.054.

BAR-COHEN, Y. 2006. Biomimetics—using nature to inspire human innovation. In Bioinspiration & Biomimetics, 2006, 1–12

BAUMEISTER, D, TOCKE, R, DWYER, J, RITTER, S, BENYUS, J. 2013. The Biomimicry Resource Handbook: A Seed Bank of Best Practices. In Biomimicry 3.8: Missoula. 280 p.

BENYUS, J. 1997. Biomimicry: Innovation inspired by nature. New York : William Morrow, 1997, 324p. ISBN 978-0060533229.

CRHÁK, F. 2012. Výtvarná geometrie plus. Brno : VUTIUM, 2012.186 p. ISBN 978-80-214-3767-8

DE PAUW, I. C., KARANA, E., KANDACHAR, P. V. 2012. Nature-inspired design strategies in sustainable product development: A case-study of student projects. In DS 70: Proceedings of DESIGN 2012, the 12th International Design Conference, Dubrovnik, Croatia, 787–796.
ELAM, K. 2011. Geometry of design: Studies in proportion and composition. New York : Princeton Architectural Press, 2011. 143 p. ISBN 978-16-1689-036-0
GRUBER, P. 2008. The signs of life in architecture. In Bioinspiration & biomimetics, 2008, 3(2), p. 023001.
HAECKEL, E. 1998. Atr forms in nature. Munich : Prestel-Verlag, 1998.139 p. ISBN 3-7913-1990.
KAZANTSEVA, T., MYHAL, S. 2014. Aesthetic tendencies in the architectural and landscape design driven by natural shapes. In Przestrzeń i Forma, 22(1): 91–104.
MANDELBROT, B. 1982. The fractal geometry of nature. New York : W. H. Freeman & Co, 1982. 480 p. ISBN 0-7167-1186-9.
METZGER, W. 2006. Laws os Seeing. Cambridge : MIT Press, 2006. 194 p. ISBN 0-262-13467-5.
PLATO. TIMAEUS. 1975. Minneapolis : Wizard's Book-shelf, 1975.
REED, P. A. 2004. A Paradigm shift: Biomimicry. The technology teacher. December/January. 2004. 23–27.
ŘÍMAN, J. 1987. Malá československá encyklopédia. Praha : Academia, 1987. 927 p.
ROWLAND, R. 2017. Biomimicry step-by-step. In Bioinspired, Biomimetic and Nanobiomaterials, 2017, 6(2): 102–112.
STEVENS, P. S. 1976. Patterns in Nature. London : Little, Brown & Co. 1976. 256 p. ISBN 978-01-405-5114-3.
TAVSAN, F., SONMEZ, E. 2015. Biomimicry in furniture design. In Procedia-social and behavioral sciences, 2015, 197: 2285–2292.
VOŘÁČKOVÁ, Š. 2012. Atlas geometrie- Geometrie krásna a užitečná. Praha : Academia, 2012. 252 p. ISBN 978-80-200-1575-4
Available online: www.colani.ch/ (09/2018).
Available online: www.rosslovegrove.com/index.php/about-us/ (09/2018).

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