irresistible

Responsible Research and Innovation (RRI)

Biomimicry / Nanobiomimicry

10

SAPIENTIA ET VIRTUS
UNIVERSITATEA VALAHIA DIN TÂRGOVIȘTE
1992

Universitatea Valahia din Targoviste

Biomimicry / Nanobiomimicry

An educational module for sciences lessons for secondary education, developed by a physics teacher from Târgoviște, România.

Developed within the framework of the European project -IRRESISTIBLE – Engaging the Young with Responsible -Research and Innovation – www.irresistible–project.eu

Developers

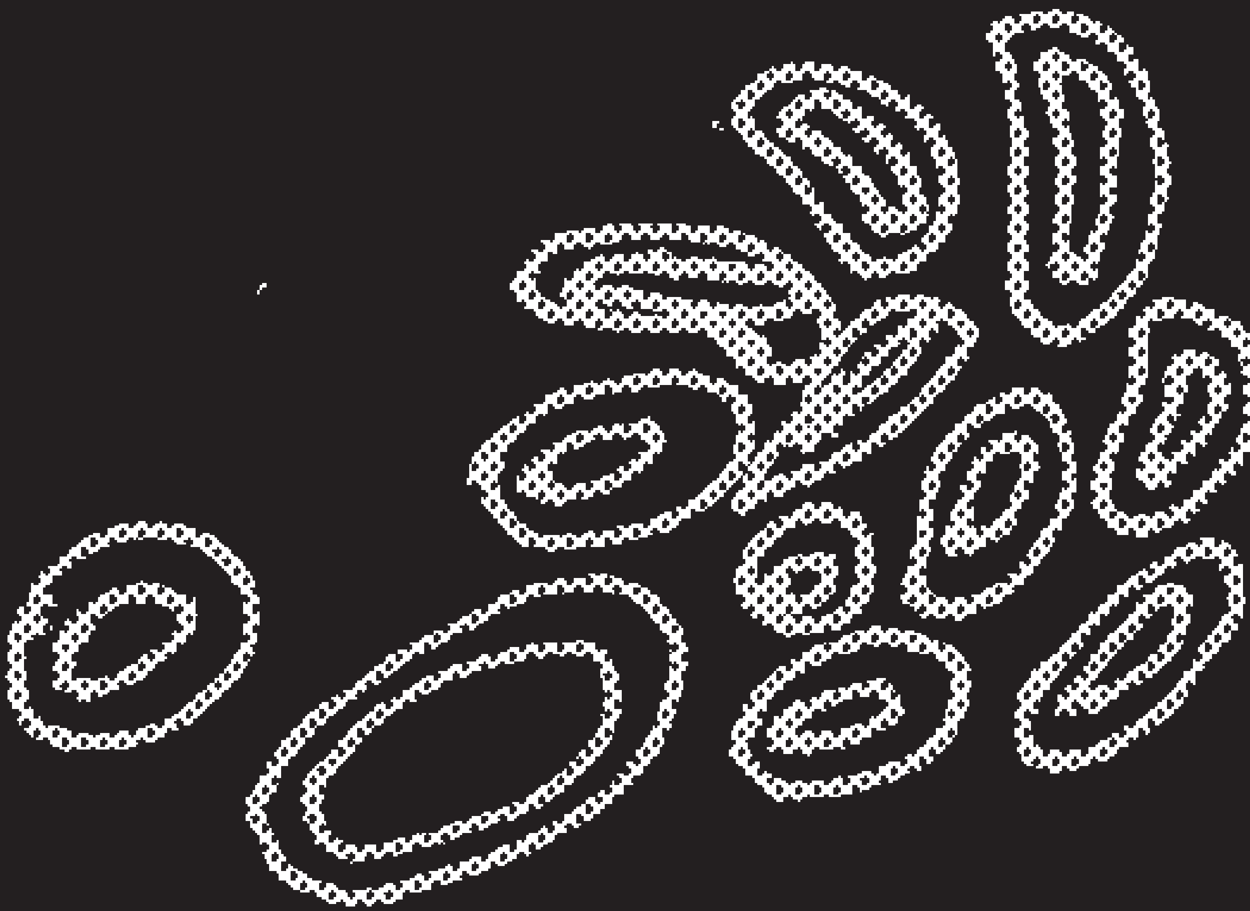
Proposed by:

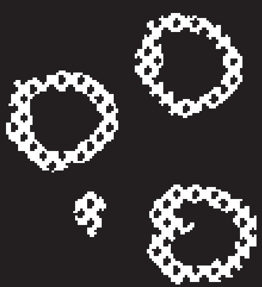
- **Prof. Carmen ANTONESCU** („Bălaşa Doamna" Art College, Târgoviște, Romania)

Revised by:

- Assoc.Prof.PhD. Luminița Mihaela DRĂGHICESCU
- Lect.PhD. Gabriela Alina ANGHEL
- Lect.PhD. Ana Maria Aurelia PETRESCU (Valahia University of Targoviste)
- Romanian Community of Learners (IRRESISTIBLE Project)

www.irresistible–project.eu





1

Overview

Biomimicry / Nanobiomimicry

This activity intends to offer, to students, sufficient arguments for understanding the nano world and how the biomimicry and nanobiomimicry works.

Overview

Grade/Educational level		Secondary education
Domain		Science
Theme / themes of non-formal activity:		**Biomimmicry/Nanobiomimicry**
Educational objectives		1. identifying the significance of concepts: nanotechnology / biomimicry / nanobiomimicry 2. filling the observation sheet with the aspects mentioned after watching the video; 3. completion / development of the knowledge about (nano) biomimicry; 4. identifying personal experiences where they have observed (nano)biomimicry situations; 5. creating a poster or a structured essay based on questions asked by the proponent. 6. identifying the ethical, social and scientific implications of the nonotechnology use, needed to act as responsible citizens in relation to research and innovation;
Required preconditions		**Botany and Zoology concepts**
Procedural resources (teaching strategy)	Teaching-methods and procedures	**Exposure, conversation, explanation, demonstration, brainstroming, collective discussion**
	Educational means	Projector, computer, worksheets, assessment questionnaires
	Forms of non-formal work	Frontal activity, by groups and individual
Estimated time		3-4 hours / 150 -200 min.

Summary

Nanotechnology, shortened as "nanotech", includes the study of controlling matter on the molecular and atomic scale. In general, Nanotechnology is concerned about structures with the size of 100 nanometers or less and involves materials or devices that operate with such dimensions. Nanotechnology have a wide variety, from new extensions of conventional physics to approaches based on molecular self-assembly in order to develop new materials, which represent nano-scale dimensions.

Biomimicry represents the examination of nature, its models, systems, processes and elements in order to emulate or get inspiration from them and solve human problems. The term “biomimicry” comes from the Greek words bios, meaning life, and mimesis, meaning "to imitate". A similar term is bionics.

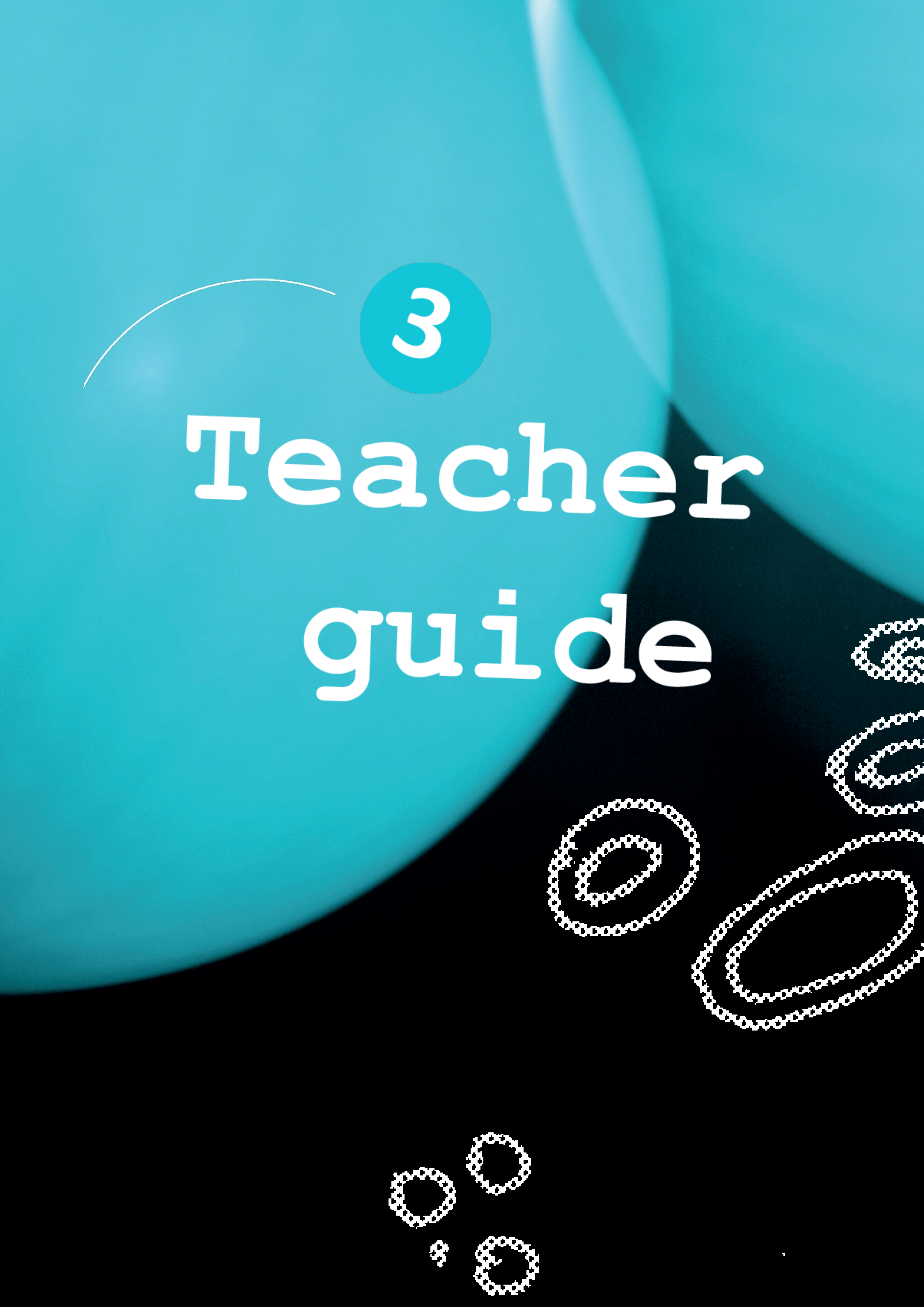
In the past 3,600,000,000 years, nature has undergone a refining process of living organisms, processes and materials on the planet. The emerging field of biomimicry has given rise to new engineering technologies, inspired by biology, both at macro and nanoscale. Biomimicry is not a new idea. People have looked at the outside world to find answers to simple and complex problems and nature has provided solutions to many of the current problems, such as hydrophobicity or solar energy capitalization by progressive mechanisms.

The concept of biomimicry is around since 1982, being promoted by Janine Benyus in 1997 in the Innovation Inspired by Nature paper. Biomimicry is defined in the book as "a new science that studies nature models and then imitates or is inspired by these designs and processes in order to solve humanity’s problems." Benyus suggests that we regard nature as "Model, Measure and Mentor" and emphasizes sustainability as a goal of biomimicry.

Educational scenario

Steps of non-formal activity/ time management	Educational objectives	Proposed activities	Non-formal Learning activities
1. Engage 20 min. - 30 min.	OE1	Students are asked to identify the significance of nanotechnology / biomimicry / Nano biomimicry concepts. Together with the students, the term biomimicry is defined.	Students complete a brainstorming exercise through which they identify the associated terms to biomimicry.
2. Explore 50 min.	OE2	A video about Nanobiomimicry is projected. Students receive observation sheets in which they will note the essential aspects of the material viewed.	Students watch the video about nanobiomimicry and completed the observation form.
3. Explain 20 min. – 30 min.	OE3, OE6	The unknown terms are explained to students. Complementary information is provided besides the exposed material.	Students request clarifying information regarding the issues observed.
4. Elaborate 30 min. - 50 min.	OE4	Various relevant examples from nature to nanotechnology / biomimicry / Nano biomimicry are presented.	Students ask their questions to the proponent and present their experiences which imply situations about (nano)biomimicry
5. Disseminate / Share / Present / Expose 30 min.	OE5, OE6	Students are asked to reflect on the implications of new nanotechnology use and create a poster or essay based on structured questions from the proponent.	Create a poster or structured essay based on the proponent's questions.
6. Evaluate 20 min. - 30 min.	OE1 OE2 OE3 OE4 OE5 OE6	The evaluation grid of the groups' product and the evaluation questionnaire are distributed of the activity. The results of the activity are discussed.	Teams assess their peers'posters. The activity's assessment questionnaire is completed. Feedback is posted on the social platform of the project, in the related work location.

The results of non-formal learning	Non-formal activity strategy			Evaluation
	Teaching methods and procedures	Means of education	Forms of organisation	
Defining the concept of biomimicry	Brainstorming	Flipchart	Frontal	Oral
Observation sheets completed.	Systematic observation	Observation sheets, computer, projector	Frontal, individual	Oral
Clarifying the unknown terms.	Explanation, collective discussion	-	Frontal	Oral
Enriching students' knowledge about nanotechnology / biomimicry / nanobiomimicry	Explanation, collective discussion	PowerPoint presentation, images, computer, projector	Frontal, individual	Oral
Poster or essay	Practical works	Sheets of cardboard, markers, paper sheets, scorecards	Groups	Oral, written
Answers to the activity's evaluation questionnaire. Post feedback on the platform.	Investigation based on questionnaires	Evaluation grid of the groups' product. Questionnaire regarding the activity's assessment. Feedback on the platform.	Groups, Individual	Written, peer feedback



3

Teacher guide

Teacher guide

This non-formal activity allows students to acquire / to develop knowledge, skills, attitudes etc. seeking:

a) Nanotechnology, biomimicry and nanobiomimicry;

b) Situations / examples from nature relevant to nanotechnology, biomimicry and nanobiomimicry

c) Involving students as responsible citizens in relation to research and innovation

The results of non-formal learning will be:

- Definition / understanding of the concept of biomimicry;
- The completed observation sheets based on watching a video about nanobiomimicry;
- Clarification of some unknown / least known terms by the students;
- Enrichment of students' knowledge about nanotechnology, biomimicry and nanobiomimicry;
- Creation of a poster or a structured essay;
- Completion of the evaluation questionnaire of the activity.

Recommended training arrangements

Activity no. 1 - ENGAGE / INVOLVEMENT

Students are asked to identify the significance of the notions: nanotechnology / biomimicry / nanobiomimicry. It is recommended to use the brainstorming method and text no.1.

Activity no. 2 - EXPLORE

A movie about nanobiomimicry is projected. It is recommended to watch the video and complete an observation sheet centered on the following aspects: specific situations for identified nanabiomimicry, positive/ negative effects, implications for science and technology, implications in social life / community / family, personal assessments etc.

Activity no. 3 - EXPLAIN

The three concepts: nanotechnology / biomimicry / nanobiomimicry are explaned. It is recommended to use the conversation method and text no. 2.

Activity no. 4 - ELABORATE

Examples from nature are widely provided. Students are asked to identify and describe their experiences in which they have seen situations regarding (nano)biomimicry. It is recommended to use the conversation method and Text no. 3.

Activity no. 5 - EXPOSE

Students must reflect on the implications of nanotechnology / (nano)biomimicry and elaborate a poster or structured essay by covering responses to the following questions:

- What aspects of our society are affected by this new nanoscale technology?
- Who is affected by the use of technology?
- What is the role of (nano)biomimicry in nature?

Recommendations are to organize students in groups of 5-6 members, in which each of them will have a predetermined role (eg organizer, timer, reporter, editor, researcher, community representative, etc.)

Activity no. 6 - EVALUATE

The evaluation grid of the group's product and the evaluation questionnaire are completed. General comments are made regarding the conduct of the non-formal activity.

Evaluation

Students' assessment must be based on the following criteria:

• The level of understanding / internalization of proposed concepts;
• The quality of students' responses;
• Clarity in presenting the information, opinions, responses;
• Contribution / involvement of students in various stages of the activity;
• The ability to bring arguments / justify opinions;
• Presentation quality and the originality of the essay or poster.

Evaluation strategies

It is recommended to use three assessment strategies: initial assessment, with a predictive role in identifying students' knowledge, formative assessment, with the purpose of measuring the progress of students, and a final evaluation, summative, to assess the extent to which the objectives set were achieved since the start of the non-formal activity.

Tools used for evaluation

Each group's product is evaluated on a scale from 1 to 5 where 1 represents the lowest and 5 the highest grade. Each group will appreciate the other groups' products. Also, the teacher / proposer can perform in parallel, each group's product evaluating.

Grid for evaluating groups' products (essay / poster)

Criteria	1	**2**	**3**	**4**
Content (coherence, consistency, fairness, logic)				
Originality/ Creativity				
Design				
Oral presentation of the product				

QUESTIONNAIRE ON THE APPLICATION OF NANOTECHNOLOGY

Please be so kind to fill as accurately and honestly as possible this questionnaire, to give us a realistic picture of the effects of the activity. We guarantee anonymity of personal data, these being necessary for statistical processing of provided information.

1. Branch and class profile: ....
2. You are student in the:
IX___ X___ XI___ XII___ VIII___ VII___ VI___ V___ grade.
3. Sex: F___ M___
4. The type of the village of origin:
   - small town, 30-100000 inhabitants
   - very small town, with less than 30,000 inhabitants
   - village / commune center
   - village
5. What impact do you think can the application of nanotechnology have on to human health, the environment and society?
   - Benefic;
   - Harmful;
   - No consequences.
6. Which is the strongest argument IN FAVOR of developing and appliying nanotechnology?
   - Healing of incurable diseases;
   - Improving the quality of life, in general;
   - Improving human physical performance.
7.Which is the strongest argument AGAINST?
   - High costs;
   - Very low funds allocated to research in our country;
   - The probability of negative secondary effects.
8. Why is important, as a priority, the valorisation of nanobiomimicry / biomimicry?
   - To solve the acute problems of the contemporary world (pollution, depletion of natural resources, habitat destruction etc.)
   - For the progress of science and technology;
   - For human adaptation to conditions imposed by a rapidly changing society;
9. Where do you think you can get information about nanotehnology/nanobiomimicry/biomimicry?
   - Science teachers;
   - Parents;
   - Internet
   - Specialized books
   - Specialized magazines
10. Today I learned about ....

....

I would like to find out more information about ....

....

Short Theoretical Background

Text no. 1

Nanotechnology, shortened as "nanotech", includes the study of controlling matter on the molecular and atomic scale. In general, Nanotechnology is concerned about structures with the size of 100 nanometers or less and involves materials or devices that operate with such dimensions. Nanotechnology have a wide variety, from new extensions of conventional physics to approaches based on molecular self-assembly in order to develop new materials, which represent nano-scale dimensions.

Biomimicry represents the examination of nature, its models, systems, processes and elements in order to emulate or get inspiration from them and solve human problems. The term "biomimicry" comes from the Greek words bios, meaning life, and mimesis, meaning "to imitate". A similar term is bionics.

In the past 3,600,000,000 years, nature has undergone a refining process of living organisms, processes and materials on the planet. The emerging field of biomimicry has given rise to new engineering technologies, inspired by biology, both at macro and nanoscale. Biomimicry is not a new idea. People have looked at the outside world to find answers to simple and complex problems and nature has provided solutions to many of the current problems, such as hydrophobicity or solar energy capitalization by progressive mechanisms.

The concept of biomimicry is around since 1982, being promoted by Janine Benyus in 1997 in the Innovation Inspired by Nature paper. Biomimicry is defined in the book as "a new science that studies nature models and then imitates or is inspired by these designs and processes in order to solve humanity's problems." Benyus suggests that we regard nature as "Model, Measure and Mentor" and emphasizes sustainability as a goal of biomimicry.

Text no. 2

a. What is Nanotehnology?

Nanotehnology sums the ability to manipulate atoms at nanometric level in order to understand, create and use structures, materials, devices and systems that have (fundamental) new properties and functions deriving from their particular structure. All biological systems have the most basic properties, but also other defined basic functions at the nanoscale level, starting with their first level of organization. The general objective of nanotechnology in biological systems is to assemble molecules hierarchicaly into objects and vice versa, using structures and techniques that require low power consumption. Nanotehnology provides the tools and platforms for investigating and transforming biological systems and biology serves as source of inspiration to create new devices and nano-scale integrated systems under the above mentioned facets. It is important to note that biological models can not be imitated exactly.

b. What is Biomimicry?

Biomimicry - known in English as the bionics, biognosis, is the use and implementation of concepts and principles on which nature works, creating new materials, devices and systems. Nature provides a rich database in solutions which work ideally, and which serve as inspiration for synthetic paradigm. Biomimicry actually has its origins in the period in which Wright brothers modeled their planes using the structure of birds' wings and when Leonardo da Vinci sketched his aircraft and ships.

c. Nanotechnology and Biomimicry

Most of the applications developed in the past have been created at the macromolecular level. Only recently biomimicry has begun to approach the micro level and the sub-micro molecular level of matter. At the beginning of the century, however, the interests of scientists and researchers has shifted to analyzing materials at the atomic level - therefore resulted a new field: nanobiomimicry - which is the imitation of biological structures and processes at the macro and nano scale. Nature offers a variety of nano-sized materials, which offer potential models. In the last century, the field of nanotechnology has produced a series of new materials and allowed scientists to produce nano-scale replicas. Living organisms and natural phenomena have certain behaviors and properties that allow them to exist in harmony with the environment. By understanding these natural processes, innovative technologies will be developed and applied.

Text no. 3

EXAMPLES

1. Biomorphic mineralization

Biomorphic mineralization is a technique that produces materials with similar morphologies and structures to those of live natural organisms by using templates of bio-structures for mineralization. Compared with other materials' production methods, biomorphic mineralization is easy, safe for the environment and economical. Biomorphic mineralization makes efficient the use of natural and abundant materials such as calcium, iron, carbon, phosphorus, silicon and the ability to convert waste biomass into useful material. The templates derived from organic nanoparticles, such as DNA, viruses, bacteria and peptides can transform disordered inorganic nanoparticles in complex inorganic nanostructures. Derived biological nanostructures are typically manufactured using chemical or physical techniques. Typical chemical manufacturing techniques are plasma spraying, dipping Plasma Ion implantation and deposition, sol-gel, chemical vapor deposition, physical vapor deposition, cold spray and self-assembly. Physical techniques include laser engraving, shot blasting, physical plating, physical evaporation and deposition. Methods for manufacturing with high efficiency, minimal environmental damage, and low cost are highly sought.

2. Biologically inspired engineering

Use of biomineralized structures is vast and derived from the abundance of nature. From the study of the morphology of living organisms many nanoscale applications were developed by a multidisciplinary collaboration between biologists, chemists, bioengineers, nanotechnologists and materials' science specialists.

3. Nanowires, nanotubes and quantum dots

A virus is a non-living particle ranging from 20 to 300 nm, capsules containing genetic material used to infect the host. The outer layers of the viruses are very resistant, being able to withstand temperatures of up to 60° C and remains stable in a wide range of pH values: 2-10. Tubular virus particles, such as thetobacco mosaic virus (TMV) may be used as a template to create nanofibers and nanotubes. From both the inner and outer layers of the virus, surfaces are harvested which may induce nucleation of crystal growth. This was demonstrated in the production of platinum and gold nanotubes using TMV as a template.

4. Display technology

Morpho butterfly's vibrant blue color comes from the structural coloration. Its wings contain microstructures which create structural coloration or coloring effect, rather than pigmentation. Incident light waves are reflected at specific wavelengths to create vibrant colors due to multilayer interference, diffraction, thin-film interference and scattering properties. The same principles trigger the colouring of soap bubbles. Now, companies like Qualcomm are specialized in creating color displays with low power consumption based on these principles.

figure 1
Morpho butterfly
Source: https://en.wikipedia.org/wiki/File:Morpho_didius_Male_Dos_MHNT.jpg

5. Structural colouring

The iridescent brilliant colors of feathers on the male peacock's tail are created by structural coloration, as first noted Isaac Newton and Robert Hooke. Structural coloration represents production of colours on microscopic structured surfaces, called schemochromes, fine enough to interfere with visible light, sometimes in combination with pigments: for example, the peacock's tail feathers are brown pigmented, but their structure makes them appear blue, turquoise, green, and often they appear iridescent.

The geometry is then determining at certain angles the light to reflect from the two surfaces (constructively interfere), while at other angles, the light decreases.

Therefore, various colors appear at different angles.

figure 2
Peacock feathers
Source: https://en.wikipedia.org/wiki/File:Peacock_feathers_closeup.jpg

Structural coloration has great potential for industrial, commercial and military applications, with biomimicry surfaces that could provide brilliant colors, adaptive camouflage, efficient optical switches and low reflection glass.

6. Sheep herd

Holistic planned pasturage using fences and / or pastors, seeks to restore grasslands by carefully planning the movements of large herds of animals. The animals move forward after eating. Fertilizers are applied on the area and the herd returns only after the area has fully recovered.

This method of biomimicry pasturage holds tremendous potential in building soil, increasing biodiversity, reversing desertification and mitigating global warming, similar to what happened in the last 40 million years.

figure 3
Herd of sheep
Source: https://en.wikipedia.org/wiki/File:Herd_of_sheep.JPG

7. Lotus Effect

Lotus effect refers to the strong scattering of water (superhydrophobic) which can be seen on lotus leafs (Nelumbo). Dirt particles are taken up by water droplets due to a complex architecture of the surface (micro and nanoscopic), which reduces the adhesion. This effect can be easily demonstrated in the case of many other plants, for example Tropaeolum (nasturtium), Opuntia (prickly pear), Alchemilla, sugarcane, and in the case of some insect wings.

The phenomenon was first studied by Dettre and Johnson in 1964 using rough hydrophobic surfaces. Their activity has developed a theoretical model based on experiments with glass beads coated with paraffin or PTFE-telomere. Self-cleaning property of superhydrophobic micro-nanostructured surfaces was studied by Barthlott and Ehler in 1977 and some materials were developed by Brown in 1986 for handling chemical and biological fluids.

figure 4
Self-Cleaning Lotus-Effect
Source: https://www.youtube.com/watch?v=TGZVCOnHs3Q&feature=youtu.be

Other biotechnological applications emerged in the 1990s: newly developed treatments, coatings, paints, tiles, fabrics and other surfaces can be kept clean and dry in the same way as the lotus leaf. An example of a product with superhydrophobic self-cleaning properties is Lotusan paint.

8. Biomimicry crystallization and structural analysis

A relevant biomimicry strategy involves the use of organic molecules to modulate the macromolecule's crystal structure, crystallinity, morphology and stability of specific or non-specific interactions which mimic those that occur between the acid macromolecules and the biogenic crystals. They provide a tool to investigate the role of matrix constituents in mineralization and drug interactions with biogenic minerals.

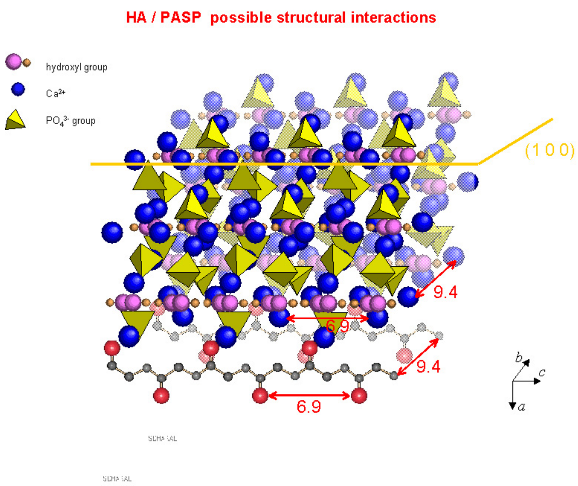
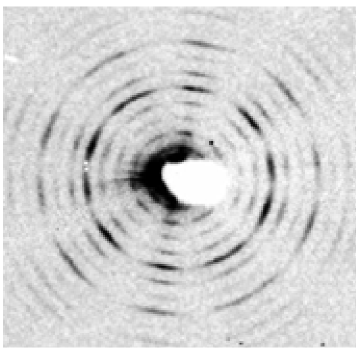
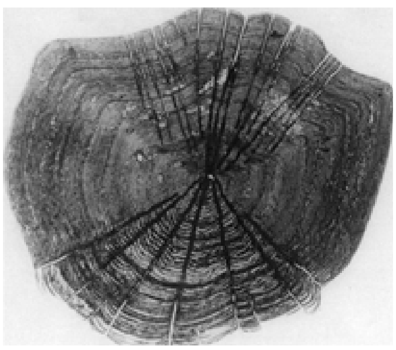


figure 5
HA-PASP structural interactions
Source: http://www.ciam.unibo.it/bio-mimetic/research/biomimetic-materials-chemistry/topics/ha-pasp-structural-interactions

9. The Biomineralization femoral tissue

Biomimicry brings closer the design and synthesis of new functional materials using the strategies adopted by living organisms in order to produce biological ones. Biomineralization of femoral tissues often shows unique and desirable morphological, mechanical and structural properties, and it represents informative models for the development of complex and functional materials. Our research involves studying structural, morphological, chemical and mineral phase macromolecular components of hard tissue.





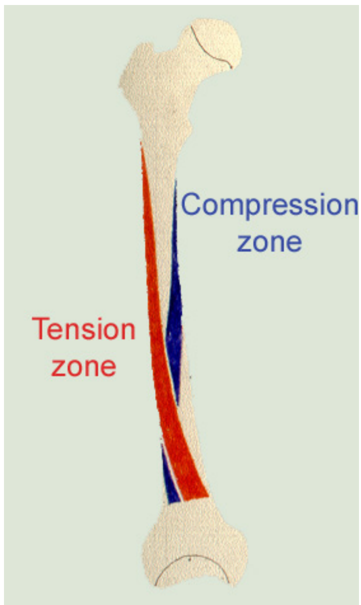


figure 6
X-Rays diffraction pattern (Left)
Teleost scale (centre)
Femur bone (right)

Source: http://www.ciam.unibo.it/biomimetic/research/biomimetic-materials-chemistry/topics/biomineralized-tissues

10. Polymer and inorganic complex architectures

Production of composite materials made of calcium phosphates and polymers is of great interest for the development of appropriate biomaterials used to repair bones. Our research aims at designing and developing inorganic-polymer composites with complex architectures, including microspheres, hollow or porous structures with potential application as bioactive molecules in bone building.

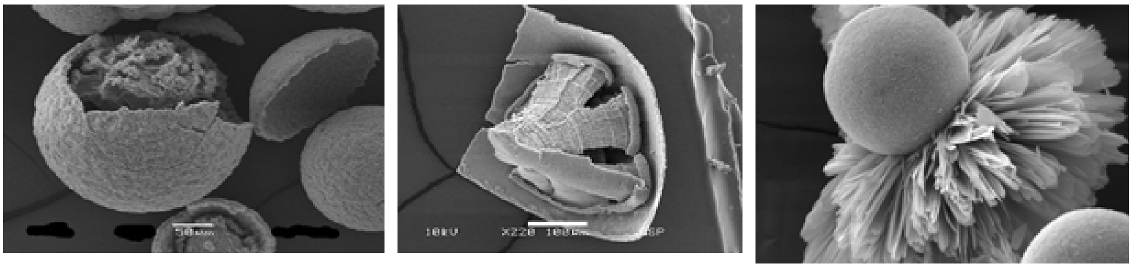


figure 7
OCP-PASP microspheres (left)
OCP-PASP complex architectures (center)
OCP complex architectures (right)
Source: http://www.ciam.unibo.it/biomimetic/research/biomimetic-materials-chemistry/topics/inorganic-polymeric-complex-architectures

11. Porous constructions for regenerative medicine

The medicine exploits regenerative strategies aimed at developing complex materials with hierarchical 3D architecture, with the ability to interact with living cells, and promote tissue repair. The purpose is to obtain identical tissue to the original one, in the case of bone tissue this is based on three-dimensional (3D) scaffold or optionally signal molecules enriched such as growth cells. The research is focused on developing porous scaffolds with an interconnected pore network structure and physical and biochemical properties adapted for growth, revascularization, adequate nutrition and oxygen supply.

For this purpose, biomimicry materials based on calcium phosphates and biodegradable polymer through cement-setting reactions are used, as well as freezing or drying methods.

12. Velcro

Velcro was inspired by small hooks that are on the surface of milling cutters. The researchers have studied the ability of termites to maintain substantially constant temperature and humidity of their African mounds, despite the external temperature, which ranges from 1.5° C

figure 8
Velcro
Source: http://www.mnn.com/earth-matters/wilderness-resources/photos/7-amazing-examples-of-biomimicry/burr-velcro

to 40° C (35° F to 104° F). The researchers scanned a termite mound and created 3-D images of its structure, which revealed a building design which can influence human buildings. In the Eastgate Centre, an office complex in Harare, Zimbabwe, remains cool without air conditioning and uses only 10% of the energy of a conventional building of its size because of such design.

13. Ecolocation modeling

Ecolocation modeling used by bats in darkness led to a cane for the visually impaired. The research done at the University of Leeds in the United Kingdom, resulted in UltraCane, a product previously manufactured, marketed and solded by Foresight Ltd. Janine Benyus refers to her books for silk spiders which create webs as strong as Kevlar used in bulletproof vests. Engineers could use such a material, which pretty much had a low rate of degradation for parachute lines, suspended bridge cables, artificial ligaments for medicine, and for other purposes. Other studies have proposed mussel-like adhesive glue, leaf-shaped solar cells, shark skin emulating material, the collection of water in the mist. The best compilation containing many innovations have been examined and studied by the Institute of biomimicry.

14. Capturing

The Stenocara beetle is a master collector of water. The little black beetle lives in a harsh environment (dry desert) and is able to survive thanks to the unique design of its shell. He is covered with small smooth bumps, which serve as collection points for condensed water from fog. The entire shell is covered with wax and the condensed morning fog water is channeled into the beetle's mouth. It is brilliant in its simplicity.
Researchers at MIT have been able to build on a concept inspired by Stenocara shell. They designed a material that collects water from the air more effectively than existing models. Approximately 22 countries worldwide use nets to collect water from the air, therefore such an increase in efficiency could have a big impact.

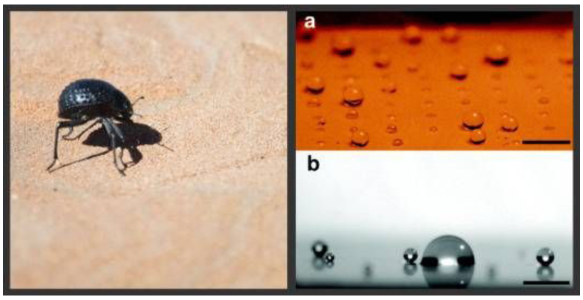
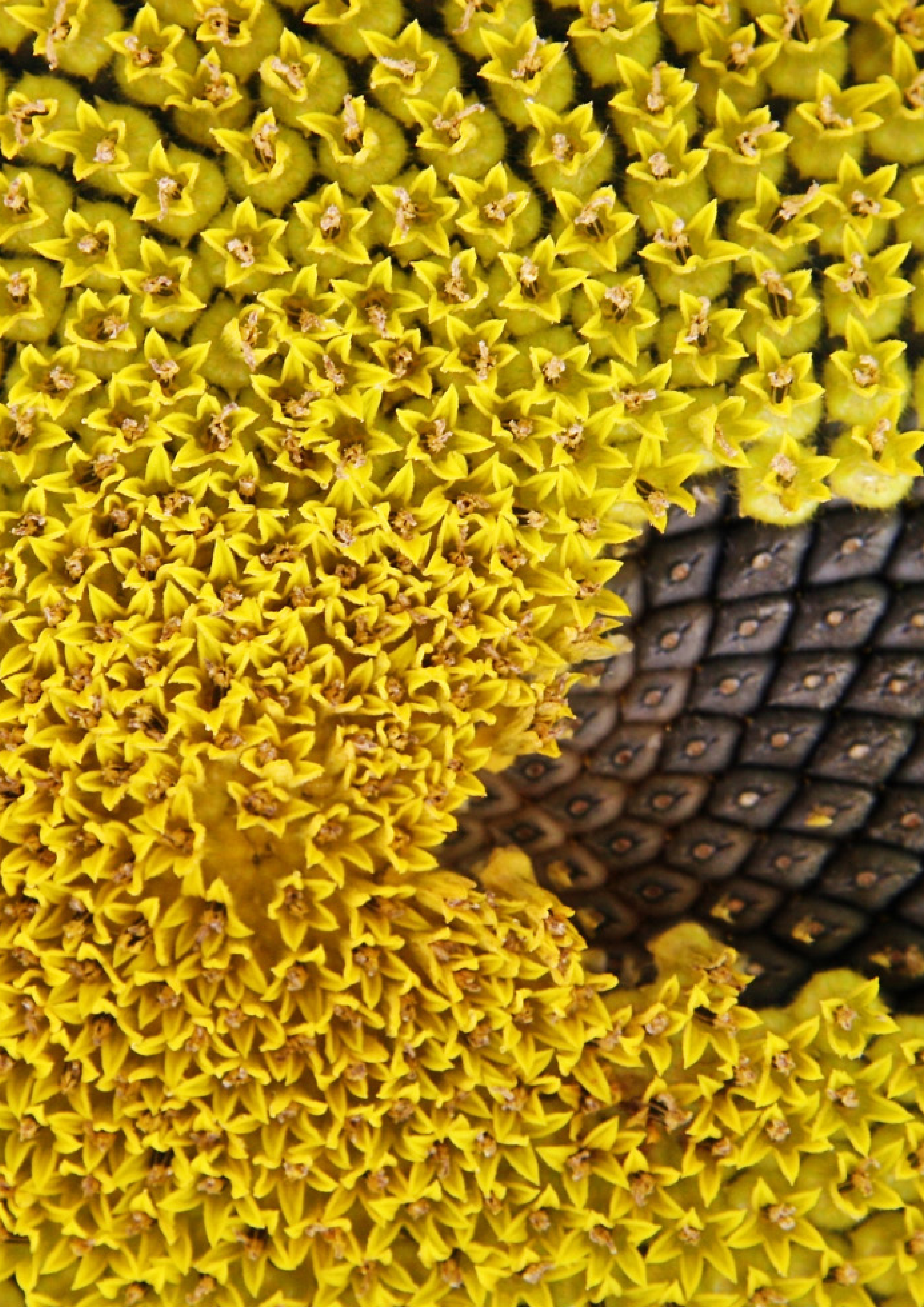


figure 9
Water collection
Source: http://www.mnn.com/earth-matters/wilderness-resources/photos/7-amazing-examples-of-biomimicry/bug-water-collection

15. Swimsuits

The shark skin inspired swimsuit has received great attention from the media during the 2008 Summer Olympics, when it shined onto Michael Phelps. Viewed under an electron microscope, shark skin is composed of many overlapping scales called dermal denticules (or "small skin teeth"). These denticules have grooves running down their length in alignment with the water. These grooves disrupt the formation of turbulent or small vortices, creating a faster passage through water. Their shape also discourages parasitic growth such as algae and shells. Scientists were able to replicate dermal denticules in bathing suits (which are now banned in major competitions) and on the boats' bottom. Scientists aim to apply this technique in hospitals so that surfaces resist the growth of bacteria, because bacteria can not catch on the rough surfaces.



4 Sources

Sources

1. Image sourse (pag.2): https://en.wikipedia.org/wiki/Biomimetics
2. Image sourse (pag.25): https://biomimicry.org/wp-content/uploads/2015/02/seeds_sun-flower_spiral_598360-e1437492940779.jpg
3. http://www.natgeo.ro/stiinta/cercetare-si-tehnologii/8624-biomimetica?start=8
4. http://web.stanford.edu/group/mota/education/Physics%2087N%20Final%20Projects/Group%20Gamma/
5. http://chemeng.adelaide.edu.au/losic-group/research/nanotechnology-diatoms/

5 Colophon

Colophon

IRRESISTIBLE is a project on teacher training, combining formal and informal learning focused on Responsible Research and Innovation. It is a coordination and support action under FP7-SCIENCE-IN-SOCIETY-2013-1, ACTIVITY 5.2.2 Young people and science: Topic SiS.2013.2.2.1-1 Raising youth awareness to Responsible Research and Innovation through Inquiry Based Science Education. The project IRRESISTIBLE is funded by the EU as FP-7 project number 612367

www.irresistible-project.eu

Coordinator: j.h.apotheker@rug.nl