irresistible

Responsible Research and Innovation (RRI)

The World Of Nanomaterials

9

Universitatea Valahia din Targoviste

The World Of Nanomaterials

An educational module for sciences lessons for secondary education, developed by Prof. Dr. Agnes Terezia ERICH and Lecturer Dr. Mihai BÎZOI, Valahia University of Târgoviște, România.

Developed within the framework of the European project -IRRESISTIBLE – Engaging the Young with Responsible -Research and Innovation – [www.irresistible–project.eu](http://www.irresistible-project.eu)

Developers

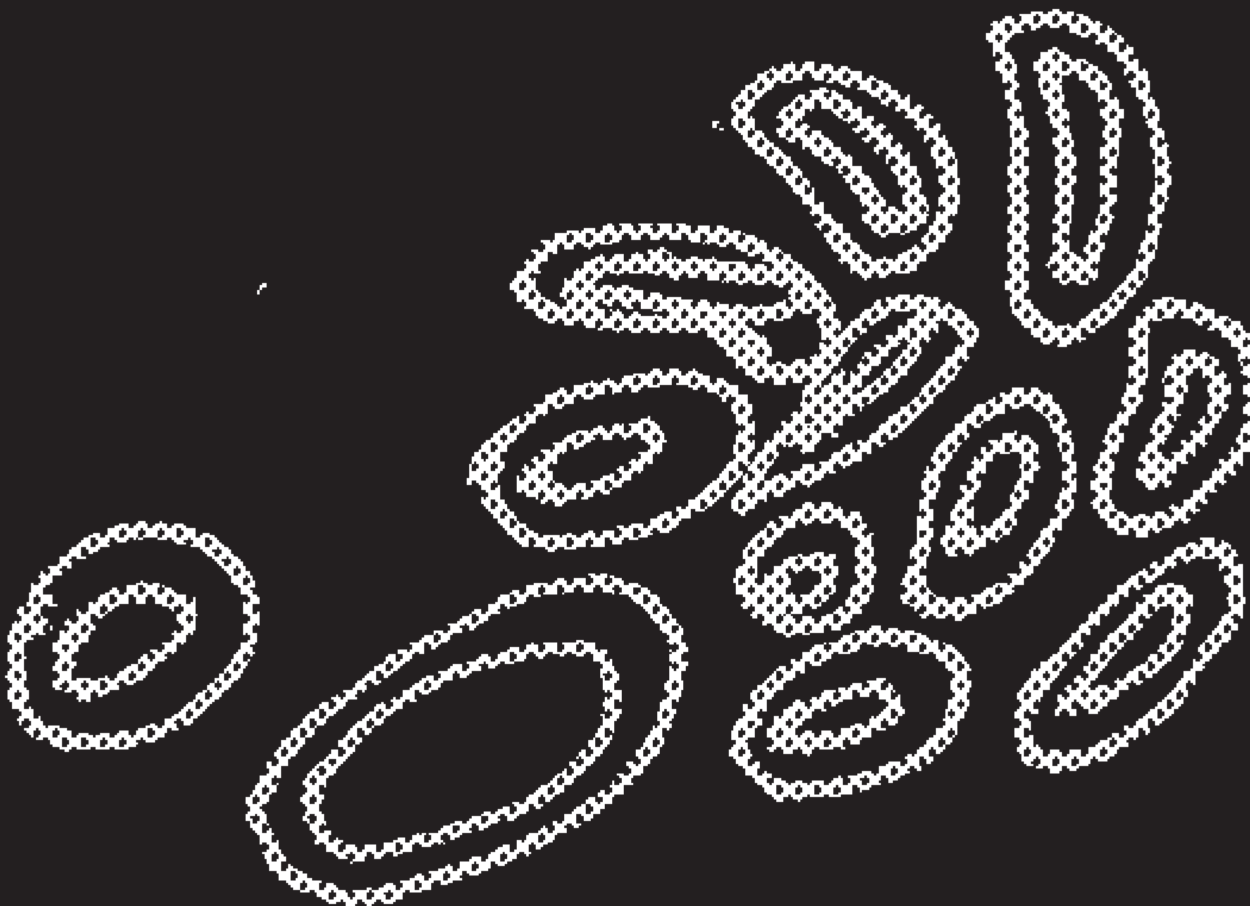
Proposed by:

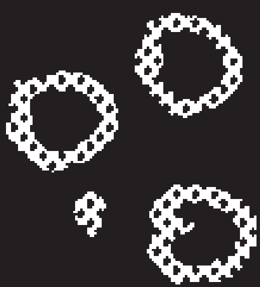
- **Prof. Dr. Agnes Terezia ERICH**
- **Lecturer Dr. Mihai BÎZOI** (Valahia University of Târgovişte, România)

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

The World Of Nanomaterials

The present activity approaches students through a trip into the world of nanomaterials. Using multimedia elements (visual) students get to know a number of nanomaterials' applications, many of them having its origins, or being found in the world around us.

Overview

Grade/Educational level	Primary and Secondary education
Domain	Science
Theme / themes of non-formal activity:	**The world of nanomaterials**
Educational objectives	Objectives: O1. – identifying the significance of the following concepts: nanoscience, nanotechnology and nanomaterials; O2. – watching the movie about The world of nanomaterials; O3. - identifying significant events in the history of nanomaterials and nanotechnology; O4. – formulating questions in order to clarify / complete/ develop the scientific knowledge regarding nanomaterials; O5. - detecting situations in which nature inspires human progress; O6. - recognizing significant studies published in various papers on the topic of nanomaterials and nanotechnology, over time; O7 - developing a poster in electronic format in which to capitalize the information obtained; O 8 - completing the evaluation questionnaire. Educational objectives: - Increasing students' interest on topics like nanomaterials and nanotechnology; - Facilitating students' acquisition of specific skills needed to act as responsible citizens in relation to research and innovation in the field of nanomaterials / nanotechnology; - Stimulating students' interest in relation to the understanding of contemporary issues, science and technology;
Required preconditions	**Basic knowledge in the fields of: biology, physics, chemistry, technology, ICT.**

Procedural resources (teaching strategy)	Teaching-methods and procedures	**Exposure, conversation, explanation, demonstration, brainstorming, collective discussion, teamwork, gallery tour.**
	Educational means	Projector, computer, worksheets, evaluation questionnaires
	Forms of non-formal work	Frontal activity, by groups and individual
Estimated time		2-4 hours / 100 -200 min.

Summary

Nanomaterials are chemicals at a very low scale, their structures ranging from 1 to100 nanometers in at least one dimension. Some nanomaterials such as smoke, soot, dust or sand are natural. Others have been in use for a long time: black carbon and silica are used since the late nineteenth century. Among other engineered nanomaterials, some are specially designed for their size and properties. They have more pronounced and unique characteristics compared with the same material in its ordinary normal form. Therefore, the physico-chemical properties and (eco)toxicity of nanomaterials may be different from those of the bulk substance or the particles of larger size. Due to their particularities, nanomaterials offer technical and commercial opportunities but may pose risks to the environment and raise questions of safety and health for humans and animals.

Nanotechnology implies studying nanomaterials. This domain is expanding rapidly, with more and more nanomaterials being fabricated every day. The European market containing nanomaterials already exists (eg. batteries, coatings, antibacterial clothing, cosmetics and food).

The present activity approaches students through a trip into the world of nanomaterials. Using multimedia elements (visual) students get to know a number of nanomaterials' applications, many of them having its origins, or being found in the world around us.

Educational scenario

Steps of non-formal activity/ time management	Educational objectives	Proposed activities	Non-formal Learning activities
1. Engage 10min. - 15 min.	O1	Students are asked to identify the significance of the concepts: nanoscience, nanotechnology and nanomaterials. Together with the students, the two concepts are defined and the RRI paradigm is presented	Students complete a brainstorming exercise by identifying words related to nanoscience, nanotechnology and nanomaterials
2. Explore 50 min.	O1, O3	Project the movie about the world of nanomaterials.	Students watch the movie about nanomaterials' world.
3. Explain 20 min. – 30 min.	O4, O5	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.	O6	Various relevant examples from nature to nanotechnology / nanoscience / nanomaterials are presented	Students ask their questions to the proponent and present their experiences which imply situations about nanotechnology / nanoscience / nanomaterials
5. Disseminate / Share / Present / Expose 30 min. - 50 min.	O7	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. - 35 min.	O8	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 concepts: nanoscience, nanotechnology and nanomaterials	Brainstorming	Flipchart	Frontal	Oral
Enriching the students' knowledge about nanoscience, nanomaterials and nanotechnology.	Systematic observation	Observation sheets, computer, projector	Frontal, individual	Oral
Clarifying the unknown terms	Explanation, collective discussion	-	Explanation, collective discussion	Oral
Enriching students' knowledge about nanotechnology / nanoscience / nanomaterials	Explanation, collective discussion	PowerPoint presentation, images, computer, projector	Frontal, individual	Oral
Poster or essay	Practical works	Sheets of cardboard, markers, paper sheets, scorecards	In groups	Oral
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.	In groups, Individual	Written, inter-evaluation

3

Teacher guide

Teacher guide

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

a) Nanotechnology, nanoscience and nanomaterials;

b) Situations / examples from nature relevant to nanotechnology, nanoscience and nanomaterials;

c) Involving students as responsible citizens in relation to nanomaterials' use in everyday life.

The results of non-formal learning will be:

- Definition / understanding of the concept of nanotechnology, nanoscience and nanomaterials;
- The completed observation sheets based on watching the movie The world of nanomaterials;
- Clarification of some unknown / least known terms by the students;
- Enrichment of students' knowledge about nanotechnology, nanoscience and nanomaterials;
- 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, nanoscience and nanomaterials. It is recommended to use the brainstorming method.

Activity no. 2 - EXPLORE

A movie about the world of nanomaterials is projected. It is recommended to watch the video and students must identify specific situations through which nanotechnology and nanomaterials are capitalized in everyday life, science and technology. At this unit it was used a truncated movie of the original videoclip *NatureTech: The Material World* which can be accessed on youtube at the following links:

Part 1/4: https://www.youtube.com/watch?v=neeP9v_x3os
Part 2/4: https://www.youtube.com/watch?v=IyKILjclGX0
Part 3/4: https://www.youtube.com/watch?v=ECyxDscEjPQ
Part 4/4: https://www.youtube.com/watch?v=THHy7nChqhc

Activity no. 3 - EXPLAIN

Students are asked questions about the content of the viewed material. Unknown terms are explained. Complementary information is provided besides those from the movie, as appropriate. Recommended methods: heuristic conversation, explanation and collective discussion.

Activity no. 4 - ELABORATE

Various examples from nanoscience, nanotechnology and nanomaterials domains are presented, published in various works (books, magazines, periodicals, etc.) or on the Web. Students are encouraged to describe their own experiences / situations in which they learned from various media sources about nanoscience, nanomaterials and nanotechnology.

Activity no. 5 - EXPOSE

Students need to reflect on the implications of nanoscience, nanomaterials and nanotechnology in everyday life, science and technology in relation with RRI principles, and have to create a poster in digital format.

It is recommended for students to form groups of 5-6 members, each of them having a predetermined role (e.g. organizer, timer, reporter, editor, researcher, community representative, etc.)

Activity no. 6 - EVALUATE

Each group presents their product, the Gallery Tour is made and the evaluation grid of the groups' products is applied. Give students the activity's assessment questionnaire. These tools are shown in the Evaluation section. General comments on the conduct of the non-formal activity are made.

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				

Activity evaluation questionnaire

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. Class:........

2. Gender: F___   M___

3. Area of origin:
   - Urban
   - Rural

4. The movie you watched seem:

Very interesting	Interesting	A little interesting	Not interesting	Boring

5. What examples / situations regarding the use of nanomaterials and nanotechnology in everyday life, science and technology have drawn your attention while watching the movie about the world of nanomaterials?

....

....

....

6. You consider that nature:
   - Represents a real inspiration for our scientific and technological progress;
   - May not be copied entirely in the context of contemporary science and technology;
   - Offers humans beneficial solutions for solving daily life problems.

7. What is the message of the movie? ....

....

....

8. About today's activity:

I liked...

....

I didn't like..

....

Short Theoretical Background

Nanomaterials are chemicals at a very low scale, their structures ranging from 1 to100 nanometers in at least one dimension. Some nanomaterials such as smoke, soot, dust or sand are natural. Others have been in use for a long time: black carbon and silica are used since the late nineteenth century. Among other engineered nanomaterials, some are specially designed for their size and properties. They have more pronounced and unique characteristics compared with the same material in its ordinary normal form. Therefore, the physico-chemical properties and (eco)toxicity of nanomaterials may be different from those of the bulk substance or the particles of larger size. Due to their particularities, nanomaterials offer technical and commercial opportunities but may pose risks to the environment and raise questions of safety and health for humans and animals.

Nanotechnology implies studying nanomaterials. This domain is expanding rapidly, with more and more nanomaterials being fabricated every day. Nanotechnology proposes to use and transfer its results into technological applications such as multifunctional very small devices.

The European market containing nanomaterials already exists (e.g., batteries, coatings, antibacterial clothing, cosmetics and food), a lot of them being use in everyday life.

The movie script of the truncated version of the videoclip NatureTech: The Material World

The natural world is full of the most amazing materials: tougher than steel, finer than our best optics. And how nature builds with these materials is even more extraordinary.

In the last few years scientist have begun to look at nature with new eyes and what they're finding promises new materials: warmer, smarter, stronger and more eco-friendly.

Technology – working with nature to build a new and unexpected world.

For thousands of years people have been making use of nature's raw materials. In the early days we relied on them for our homes, our clothes, just about everything. But humans aren't the only creatures using natural building materials.

Here, in northern Namibia, a pair of hornbills have used mud to make their nest secure. The female has been sealed inside the nest hole behind a wall of mud, leaving just a small gap big enough for her mate to pass food to her, but small enough to keep out all predators.

Mud is a really popular choice when it comes to building. Throughout the Tropics colonies of termites use mud to produce complex nests, some standing up to three meters tall, full of intricate tunnels and chambers. To create these incredible structures termites make different types of mud to do different jobs. Mud mixed with saliva and feces dries to create an outer wall as strong as concrete.

People have also been using mud for centuries and have found – like termites – that mud mixed with other substances produces building materials with different properties. It is a versatile materials and it has been used to create some extraordinary things.

The great mosque in Djenne, in Mali – the world's biggest structure made of mud bricks. This impressive building is made of some dry mud bricks held together with a mud mortar then coated with a plaster of smooth mud. The mosque is nearly 100 years old and will last for centuries more if properly maintained. The Malians and termites hit on the same solutions to building by trial and error.

But when biomemetic scientists look at natural materials they are hoping not just to copy nature, but to understand the basic principles behind nature's success and build on that to invent completely new materials. And that's exactly what's happened with wood, an even more versatile material than mud.

Wood is made up of long tough fibers and is used by wasps to make their nests. Chewed to a pal and mixed with saliva, they turn it into a kind of cardboard. It's tuff, its good insulation, in short an excellent building material. And the wasps are surrounded by it.

Wood is everywhere just for the taking, which is why it's been so useful to us: it's been used for everything from stone-age monuments to houses and bridges, to Kats and boats. Is not surprising that wood was the foundation of our world. Unlike mud wood is a complex sophisticated material. It has to be because it supports nature's largest structures.

On the slopes of the Sierra Nevada mountains in California are the biggest organisms ever to have lived. These sequoias tower up to 80 meters above the forest floor though some reach as high as a hundred meters. These massive trees way around 1400 tons and each one contains enough timber to build 120 houses. It's taken them more than two thousand years to get to this

size and that's only possible because wood is such an amazing material.
The fibers that make up wood are long tiny hollow tubes that carry water from the roots to the leaves – the trees plumbing system. Wound around the tubes in a helical pattern tiny fibers of cellulose are embedded in a kind of resin. It's this arrangement that gives wood such amazing properties. In particular this structure makes wood very resistant to cracking, crucial if it loses its branches in a storm.
If the force in a branch is enough to start a crack, the crack just runs around the spiral fibers which absorb its energy and stop it spreading any further. This makes wood very hard to crack, which is why we still use it today as a building material.
But can we do better than nature?
At the University of Reading in the UK scientists are studying wood's performance in detail. Different kinds of wood are tested to destruction. Driven by a high pressure air system, a metal rod is rammed into a block of wood. As the scientists identify which kinds and wood are the strongest. Based on their results they came up with a revolutionary new material, a kind of artificial wood: it's made from resin with fibers running through so it mimics the pattern of wood with many of its tough properties, so much so that is one of the toughest materials ever made. It's yet to be put to practical use but it's strong enough to make bulletproof armor.
But wood is more than just tough, it can also be smart. Like the wooden tree trunks, the woody scales pine cones are made of stiff fibers embedded in a resinous substance. But these fibers line in different directions in the top and bottom layers. When the scales dry out, the bottom line shrinks more than the top, which makes the cone open and release it cedes.
One designer is looking at a clothing fabric that works in the same way. As the fabric starts to get dampened from sweat sections of the fabric lift up to provide ventilation. This is true biomemetic thinking, not merely using natural materials but understanding how they work and applying the principle somewhere else.
But this kind of thinking isn't entirely new. Natural designs inspired some other Victorian age its greatest architecture. In 1849 botanist Joseph Paxton had to build a new and bigger greenhouse for his ever-expanding Victorian lilies. These plants produce enormous leads, up to 2 meters across – hence Paxton's problem. But those same leaves held the solution to his problem. there supported by a complex series of ridges and struts and so he could use the same arrangement to support a large roof span over his new greenhouse.
He showed just how strong these leads where in a most unusual way: they can easily cradle a baby. Paxton was so confident of the leaf strength he entrusted his young daughter to this Victorian equivalent of a water bed and when full-sized these leaves can even support the weight of an adult. He built his greenhouse on these bio-inspired principles and it was so successful that he went on to build even bigger structures like the magnificent Crystal Palace. Built in London for the first World's Fair in 1851, the Crystal Palace was a technological marvel of glass and iron: 33 meters high and covering about seven hectares – all thanks to a plant from the depts. of the Amazon rainforest.
What the lily shows is that it's not just the material used that makes it tough, it's also the details

of how it's constructed and that’s equally true of the materials that make up animals.
When the fall comes to the Rocky Mountains in Northern America nature puts on a dramatic demonstration of one of its remarkable materials. At this time of the year male elk gather up groups of females ready to mate but they have to defend these harems from rivals. For that purpose nature has provided them with tough antlers made of bone.
Despite energetic wrestling broken antlers are very rare. But bone is heavy so nature is as economical as possible. Inside bones are partly hollow but filled with a complex network of archers and spans. This beautiful hidden structure is also elegant engineering.
Even our own skeletons can be a source of inspiration. The human fiber or femur is especially elegant and architects realized they could apply exactly these principles in constructing tall buildings. It's the inspiration behind one of the most famous buildings in the world: the Eiffel Tower. Gustave Eiffel used the structure of the human femur in building his 300-meter tower, the tallest building in the world until 1930. Like the curve in the head at the femur, the famous iron curves in the Eiffel Tower are supported by a latticework of metal struts and girders that transfer the tower’s weight sideways and down into the ground – just as elegantly as the internal struts of bones.
In recent years more and more designers and engineers are looking at the way nature bills bodies and getting inspiration for everything from new bridges and buildings to cars. Cars need to be tough but can't be too heavy or they’ll burn too much fuel. Nature faces the same problem, which is why both animals and plants only lay down material precisely where they need it.
So this car-shaped fish – the box fish – might be a good model for an economic car and when the engineers at Daimler Chrysler designed a chassis using a computer program that, like the box fish, laid down more material wherever loads were greatest, they found that they made their lightest strongest chassis ever.
For vertebrates like fish mammals and birds the skeleton gets its strength from the material of bone and the way it's constructed. Vertebrates are built around the outside of these internal bony struts, a system that works well for the biggest animals like these mowers – giant extinct birds.
But there are other types of skeleton…
Insects are the other way around. Their skeleton is on the outside, an exoskeleton. An insect is hemmed from the inside of a tough protective casing – the optimum engineering solution for small creatures. Bones has strengthened with deposits of heavy calcium phosphate but tiny insects can't afford so much weight. Natural selection has had to come up with a lightweight solution – a structure made of fibers of a substance called chitin embedded in a matrix. Like plywood each layer of fibers runs at a slightly different angle, making the exoskeleton very strong in every direction – tough enough for male stag beetles to use their jaws like the antlers of an elk, wrestling with each other over females. Other insects use their jaws for their original purpose: for eating.
Locusts eat grass, lots of grass. Grass leaves are protected by tiny crystals of silica which ware

away most substances, but the jaws of a locust can cope and before they're in danger of blaring out a young locusts can replace them. Insect cuticle is remarkable stuff so what can we do with it?
First we need more than we can get from tiny insects. But on the East Coast of North America, a huge supply of chitin crawls out of the water onto the beach every spring.
Horseshoe crabs are not insects but neither are they crabs. They're primitive creatures related to spiders swarmed onto beaches to spawn like this for hundreds of millions of years. But like insects their shells are strengthened with chitin in fibers. They were collected for their shells but over collecting has reduced their population – not a good way to work hand in hand with nature.
Fortunately the eastern seaboard of the United States offers us another source of chitin and most of this is going to be thrown away, a much better source.
Crab factories around North America's Chesapeake Bay extract the valuable meat mechanic but the shells themselves could be just as valuable. The shells of crabs also contain lots a chitin but it's bound up with calcium carbonate. However, by treating the shells with acid this can be dissolved, releasing the chitin for use.
By purifying the chitin and chemically altering the fibers a substance called chitosan can be made. In its purest form it's used to make contact lenses, skin creams and wound dressings. But chitosan can also fill many of the purposes of plastic. And even better than plastic, it's biodegradable. But smashing up this amazing substance and converting it into a bio-plastic may not be the best way of exploiting its potential.
An insect's exoskeleton is a marvel of micro engineering and almost endlessly versatile. It can be shaped to resemble a leaf with amazing accuracy, living or dead, even down to the holes chewed by other insects. The level of detail is extraordinary. Hidden in this orchid flower is an orchid mantis. Its body and legs are sculpted and colored to match the petals of the flower exactly. It's virtually invisible to its predators and to its prey.
But look even closer and the insect's body armor is even more astounding: molded and shaped with microscopic precision into a huge variety of shapes. And it's not just there to admire. Each of these microscopic landscapes has a job to do.
These tiny bumps cover the body of a beetle that lives in the Namib Desert. In this parched desert it hardly ever rains yet beetles seem to flourish here. Their only supply of water is the fog that rolls in from the ocean every morning, so the beetles start each day by climbing to the top of a dune where they can intercept the fog blowing in the wind.
Those microscopic bumps help water condense on their bodies. The tips of the bumps attract water while the channels between repel it. This forces the water to form droplets which run down to the beetles' mouth – a desert survival strategy that might help with all too frequent water crises in the human world.
One company is now designing tents for refugees that work in the same way. These tents could condense water from the air each morning even in areas where ground water is in short supply. In this case, understanding how a desert beetle lives could make all the difference between

life and death for these people. And all this comes from the extraordinary design of insects' skeletons. Yet this whole complex structure is shed and replaced every time the insect melts, which seems something of a waist.

Insects can afford to do this because the arrangement of chitin fibers is self-assembled. When the right components come together in the right way the exoskeleton just builds itself and this kind of self-assembly process is very interesting to biomimetic engineers.

Crystals are a simple example of self-assembling structures. The final shape of the crystal is not due to some elegant overall design. It happens because the atoms or molecules naturally come together in a lattice that grows and results in these familiar shapes. More complex molecules can self-assemble into more complex shapes. If we could control the way the component parts of the material interact we could just mix them together, sit back and watch the most complex of design materials build themselves.

Impossible? Nature does it all the time. One impressive example can be seen off the coast of California. Here sea otters seem to live an idyllic life, floating on a gently rolling ocean. And when they're hungry all they need to do is dive down to the ocean floor and pick up a tasty shellfish.

But it's not that easy. Shellfish have tough shells, so tough the sea otters have to resort to a clever trick: they hammer the clam on a stone balanced on their chests and eventually they'll get their reward. As smart as this sea otters' trick looks, it's the discarded shells that are really interesting. Why did it take so much effort for the sea otter to get its meal?

After all, these shells are just made up of calcium carbonate, ordinary chalk, and that's not tough at all. The secret is in how mollusks arrange the crystals of calcium carbonate. Magnifying the shell a thousand times reveals an intricate structure: flat crystals of calcium carbonate sitting in a matrix of protein. If one crystal cracks, the crack simply runs into the protein, which is just stretched, absorbing the energy. Eventually the protein matrix will absorb all the energy and stop it dead. But the protein does more than just stopping the cracks from spreading. It's responsible for the precise way in which the crystals lay down.

As the mollusk grows its shell, it secrets this protein which forms a layer over its body. As calcium carbonate it is secreted into this layer, the proteins make sure it crystallizes in just the right way to form nacre. Nacre is just a kind of ceramic, a tough non-metallic structure made up of tiny crystals.

Humans have been making their own ceramics for thousands of years. Pottery, for example, is also a ceramic. And apart from pots, we now use ceramics as engine parts or even tank armor. But when we make ceramics we have to heat them, to perhaps 400°C.

Nature makes its ceramics at sea temperature. And what it can do is truly spectacular. And this ceramics, made by humble mollusks are twice as strong as anything we can make. Such natural flamboyance gave scientists the idea of isolating the proteins responsible for organizing the way nacre is laid down. Then, by changing them, they hope to be able to grow all kinds of intricate structures. Perhaps, even computer chips more powerful than any that can be made by today' standards.

In the freezing cold of the high arctic it's not strength but warmth that is needed. Polar bears are cozy even in subzero temperatures. Seen with an infrared camera, the brightest areas are those loosing heat, which for the polar bear is mainly its nose. The rest of its body is extremely well insulated apart from the tips of its toes. The polar bear's high arctic survival gear is its fur. Each hair is transparent and hallow and it is used to be thought that this conducted the sun's heat down to the skin. Polar bear's skin is black, which absorbs the heat.

Now scientists are not so sure, but it was a good idea nevertheless, so scientists at the Institute for Textile Technology in Denkendorf Germany, have developed an artificial polar bear fur that does work in this way, by conducting infrared and ultraviolet radiation down to a black base layer. These fibers, on their own, are not as good for insulation as polar bear fur, but a transparent layer on top improves the overall performance by trapping a layer of warm air. Wrapped around a water container, this material can warm the water just by conducting the sun's heat even though it appears this isn't how polar bears do it.

The more we look at the microscopic details of nature's structures, the more we find what they can do. All the plants in a tropical rain forest depend on these torrential downpours for survival. But they can also create problems: the rain washes down dirt which can coat the leaves and block out light. Worse, wet leaves soon grow a layer of mold in this warm, humid environment. Some rain forest plants have drip tips designed for draining water off the leaves. But some just don't seem to get wet at all no matter how much it rains. This is the most spectacular… a lotus leaf.

Slowed down more a hundred times, it's clear that the water just bounces off the leaf. The water can't spread out and wet the leaf, instead it just reforms droplets that bounce across the leaf until they fall off. Again, the secret is in the microscopic detail of the lotus leaf. Its surface is covered in tiny bumps, each of which is kept by a waxy layer. The gaps repel water, forcing its purge on the very tips of the microscopic bumps. Unable to reach the leafs' surface, all the water can do is roll back into a sphere and since it's repelled by the tiny bumps, there is nothing to stop it rolling off the leaf. But even more impressive, the water drop picks up any particles of dirt on the leaf's surface and carry them off as well. So lotus leaves are always immaculately clean, a reason why they are a symbol of purity in eastern religions, and it's too good a trick for science to miss.

This fabric has all the water repelling qualities of a lotus leaf. To make it means first weaving a strong, dense material. The material is then run through a machine that covers it with a substance that's still a closely guarded secret. As it dries this coating produces millions of microscopic bumps over the surface of the material that work in the same way as those on a lotus leaf, making a material that is not only water repellant but it's self-cleaning. And there is already a self-cleaning paint based on the same principle. Ordinary paint soon gets dirty but dirt and water just roll off this new paint called lotusan. And a similar coating over this spoon means simple, pure water will pick up any dirt and leave the spoon totally clean. This surface developed at the University of Bonn in Germany even repels something as sticky as honey which just runs off like water.

Would it be great when the shoes that self-clean will be invented?
Repelling water is the key to water proofing and both people and nature have invented many ways of doing this. We use fabrics coated into repellant oils and many birds do the same, spreading a layer of oil over their feathers, which means the water just runs off like…well… water off a duck's back. So ducks would be the obvious place to look for improvements in water proofing. But in biometics, it's not always the obvious places that are the best. Hidden beneath the surface of South America's streams, a strange spider has a novel way of water proofing itself.
These spiders prey on small fish in mountain streams and underwater they trap a silvery layer of air around their bodies, but when they emerge from water they are completely dry. Researchers at the University of Bonn in Germany have been trying to unlock the spider's secrets. The spiders are covered in bristles and it turns out that the spacing and three-dimensional arrangement of these bristles it's critical in giving the spider its extreme water-proof coat.
Scientists have measured the exact spacing of these hairs as well as looking at the intricate microscopic architecture of the individual hairs. Using these findings researchers have developed an ultra-water-proof fabric. As a test it was submerged in water for four days and still emerged bone-dry.
Staying dry is certainly not a problem faced by the sand fish. This lizard lives in the most inhospitable parts of North African and Middle East desert sandy dunes. It's called a sand-fish because when it feels threatened it can dive into the sand. It's able to swim through the dunes as if they were water, which is surprising since moving through sand should take a lot more energy than moving through water.
So scientists from the Technical University of Berlin decided to take a closer look to this ability. They found the sand-fish's skin had lower fiction than glass or ever polished steel. The sand just rolls off it and it's not at all obvious how it performs this trick. Its shovel shaped head certainly helps but its ability to swim through sand seems to rely mainly on its remarkable skin. Magnified more than 25000 times, a series of tiny spikes appears along the edge of every scale, each just a few millions of a millimeter long. Somehow these structures must reduce the friction between the grains of sand and the skin. But quite how is still not clear…
And even stranger, these tiny structures just don't seem to get warn away by the sand…
One possibility is that these spikes can conduct static electricity stopping the lizard from charging up as it rubs through the sand grains and therefore stopping the sand grains sticking to its skin.
Nature's microstructures might hold the secrets to better waterproofing or nonstick surfaces but they might also hold the secrets to the next generation of computers.
A new information revolution… a story that starts with a spectacular rainforest butterfly…
The bright blue of a Morpho butterfly shines out like a beacon in the rain forest. It can be seen half a kilometer away, exactly what the butterfly wants – to attract a mate. But the wings of these butterflies contain no pigments, they produce color in the same way that soap bubbles do.

These shimmering colors are caused by light being reflected from the outside and inside surface and the bubble and change with the angle a viewing. But the color of a Morpho is far more intense than a soap bubble… and the reason is down to the micro architecture of each and every tiny wing scale. The Morpho uses these colors for display to make itself conspicuous and.. it's certainly been noticed by scientists. At Exeter University in the United Kingdom they've been examining the Morpho's micro architecture down to the finest detail. Each scale is covered in ridges and each ridge is made of layers of cuticle. These layers are separated by a distance that is the same as the wavelength of blue light and so, when some light bounces off each of these layers only the blue light is reflected back and the exact spacing of the layers means successive waves a blue light interfere with each other reinforcing themselves and intensifying the color.
To make it easier to see what's happening the Exeter scientists then built a model of this structure that will work with microwaves that have a much longer wavelength than light. And what they found was that the gaps in the ridges on the wing scales are structured in such a way that no light gets trapped. It's all reflected… which adds to the brilliance of the color.
It's hard to believe that there isn't a single molecule of pigment in these scales…
Japanese manufacturers have incorporated these ideas into fabric, material they call morphotex – made up of nylon and polyester arranged in the same way as the layers of cuticle in a Morpho's wing scale. Morphotex shimmers with interference colors that will never fade and cosmetics companies are already developing lip stick with the same effect. But the Morpho's lesson is even more profound…
Each scale is in fact a photonic crystal, a device that can transmit night – the optical equivalent of a transistor. Transistors revolutionized electronics and power the computer revolution. Photonic crystals could power a new information revolution, of even faster, more energy-efficient optical computing. And nature might well be able to point the way…
With this new way of seeing the world the possibilities are endless… Modern technology has already created a whole range of new materials based on nature's examples but sometimes nature is still one step ahead.
Spider silk is an extraordinary material… size for size stronger than steel but it's also highly elastic; it's made from strands of different proteins and spiders can produce different kinds of silk depending on their need. It's stored as a liquid and solidifies into strands has it's squirted out from tiny nozzles on the spiders' rear end. Yet we've never been able to copy this… Artificial spider silk is still a holy grail for biomimicry.
We'll probably succeed one day but watching the spiders spin these beautiful structures is a good reminder that it'll take some time to catch up with four billion years of evolution. The natural world is built from amazing materials but the structures that nature produces with these materials are just as intriguing and they hold lessons in how to manage energy efficiently and cleanly – lessons that at the start of the 21st century humanity urgently needs to learn.

4 Sources

Sources

1. Stamatin, I. Nanomateriale. Elemente de nanotehnologie: aplicații în biosenzori, surse de energie, medicină, biologie. București: Editura Universității din București, 2008
2. Novoci, A. Nanomateriale şi nanotehnologii. București: Printech, 2010.
3. Aștilean, S. Provocările nanoştiințelor şi nanotehnologiilor. Verso, an 2, nr. 12-13 (feb. - mart.) 2007 şi nr. 14-15 (mart.-apr.) 2007.
4. De la nanoștiință la nanotehnologie [on line]. Accesibil pe web: http://www.imt.ro/Nano-prospect/participanti/prezentari/fundamentala.pdf. Accesat: 20.02.2015.
5. https://echa.europa.eu/
6. The *NatureTech: The Material World* movie:

   Part 1/4: https://www.youtube.com/watch?v=neeP9v_x3os
   Part 2/4: https://www.youtube.com/watch?v=IyKILjclGX0
   Part 3/4: https://www.youtube.com/watch?v=RCvxDscEjPQ
   Part 4/4: https://www.youtube.com/watch?v=THHy7nChqhc

5 Colophon

Colophon

irresistible

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

SEVENTH FRAMEWORK PROGRAMME