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Responsible Research and Innovation (RRI)

Industrial applications of nanomaterials

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Universitatea Valahia din Targoviste

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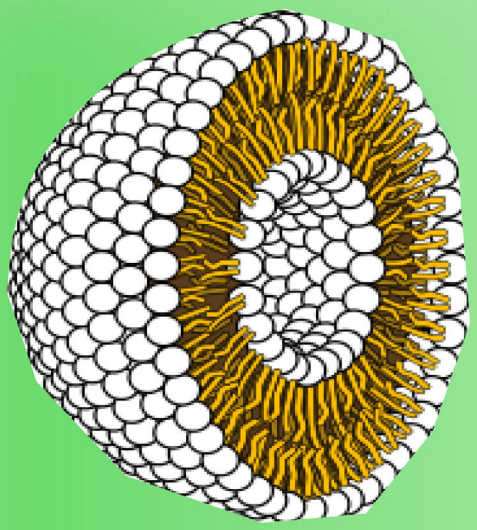
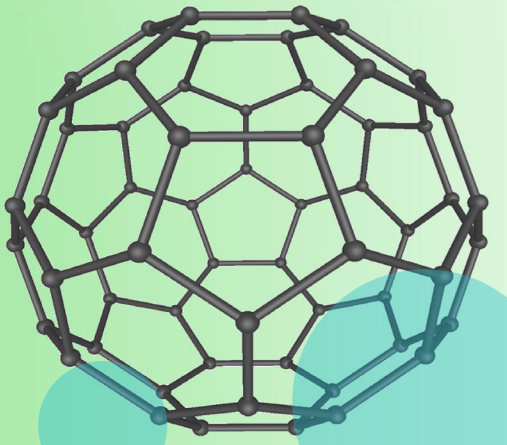
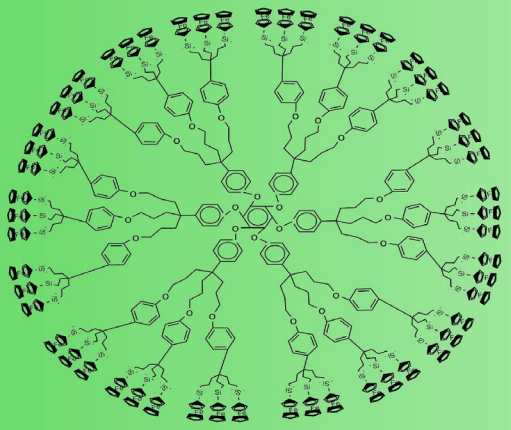
Nanomaterials (1-100 nm)



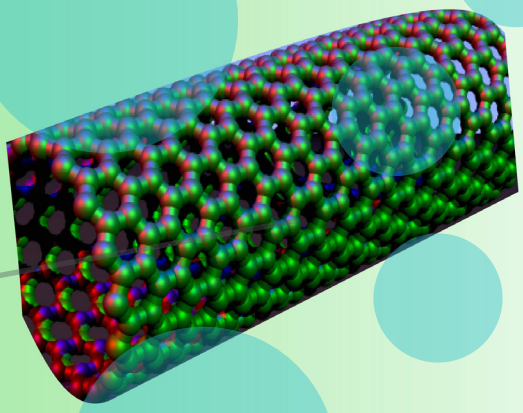
Liposome



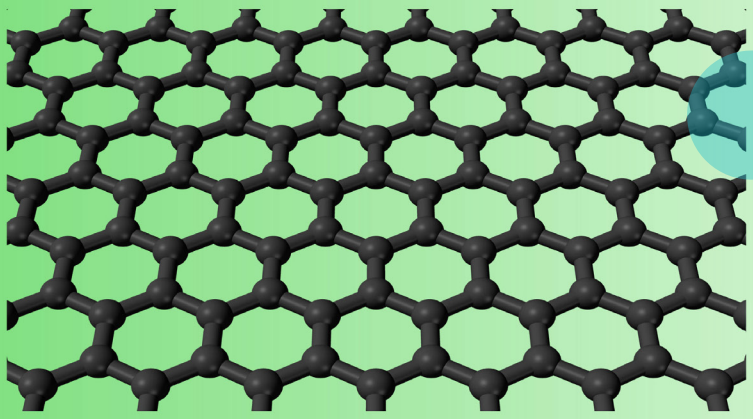
Fullerene



Dendrimer



Carbon nanotube



Graphene

Industrial applications of nanomaterials

An educational module for sciences lessons for lower and upper secondary school levels, developed by a Romanian teacher from Târgovişte.

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

Developers

Proposed by:

- Asist. drd. Radu OLTEANU (Valahia University of Târgovişte)

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)

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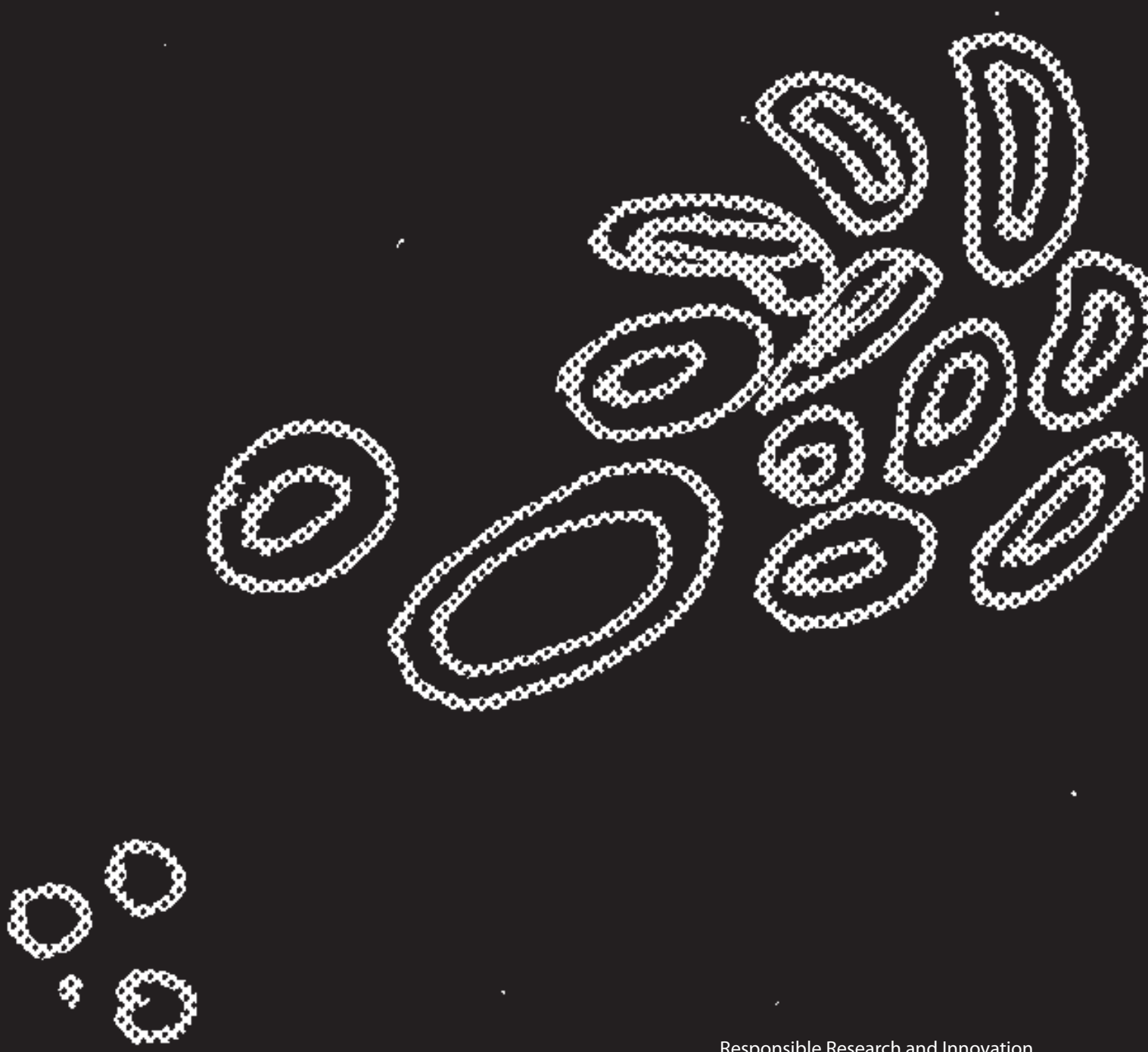

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Overview

Industrial applications of nanomaterials

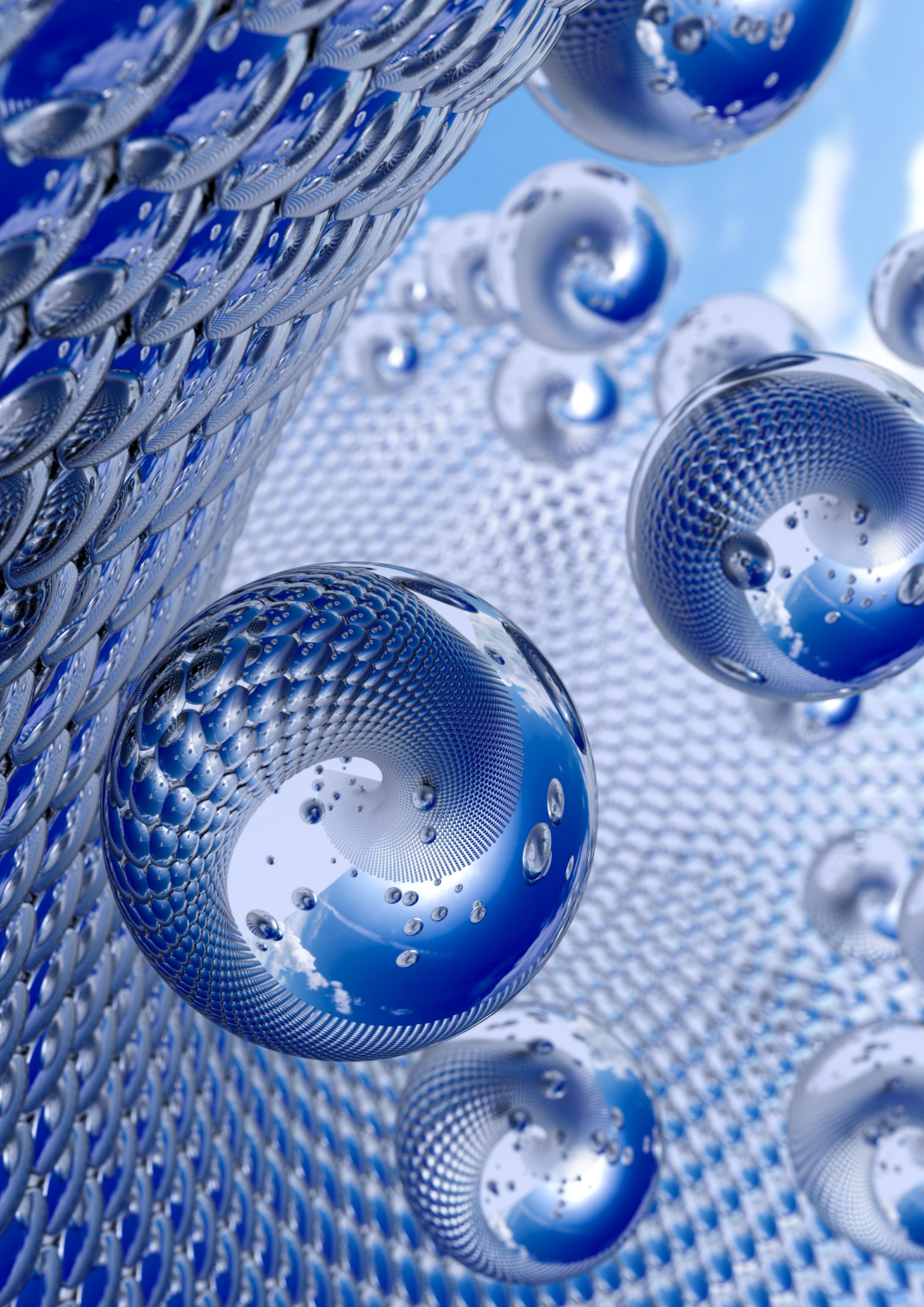
It is anticipated that nanotechnologies will play an important role in the technological development in this century, introducing higher performance materials, intelligent systems and new methods of production, with significant impact for all aspects of the society. What is happening in the present can be considered as the beginning of a revolution based on the human ability to work on the same scale as nature. In recent years, there have been developed numerous new applications of nanomaterials. They include a range of consumer products such as UV filters in sunscreen cream and fabrics which prevent the formation of odours. However, there are also many medical and technical applications, such as antitumor therapies, lithium-ion batteries that can deliver electric energy to the cars or solar panels. These applications have the potential to generate significant technological advancements and, therefore, nanomaterials were identified as a generic essential technology.

Benefits of nanomaterials range from applications in saving lives in medicine, to applications generating simple innovations and improvements in consumer products. Also, risks and exposure of workers, consumers and the environment differ greatly from their total absence, until the potential risks that need to be addressed. On the basis of current knowledge, nanomaterials are similar to common products / chemicals, meaning that some may be toxic, while others do not. Possible risks are linked to nanomaterials and their specific uses. Therefore, nanomaterials require a risk assessment that must be carried out on a case by case basis,

using the relevant information. The current risk assessment methods are applicable, even though the clarification of some specific aspects of risk assessment is still needed.

The activities proposed to be carried out by the students can get to know general notions about nanomaterials and their applications in industry. It is important that the activities to be organized by the method of discovery so that the students to participate actively in the debate, bringing arguments on their claims. The groups of students can get toward solving or investigating a problem in the community that can be resolved through nanotechnologies. Problems are resolved through group discussion, with proposals for alternative solutions and with motivating the choice of final solution.

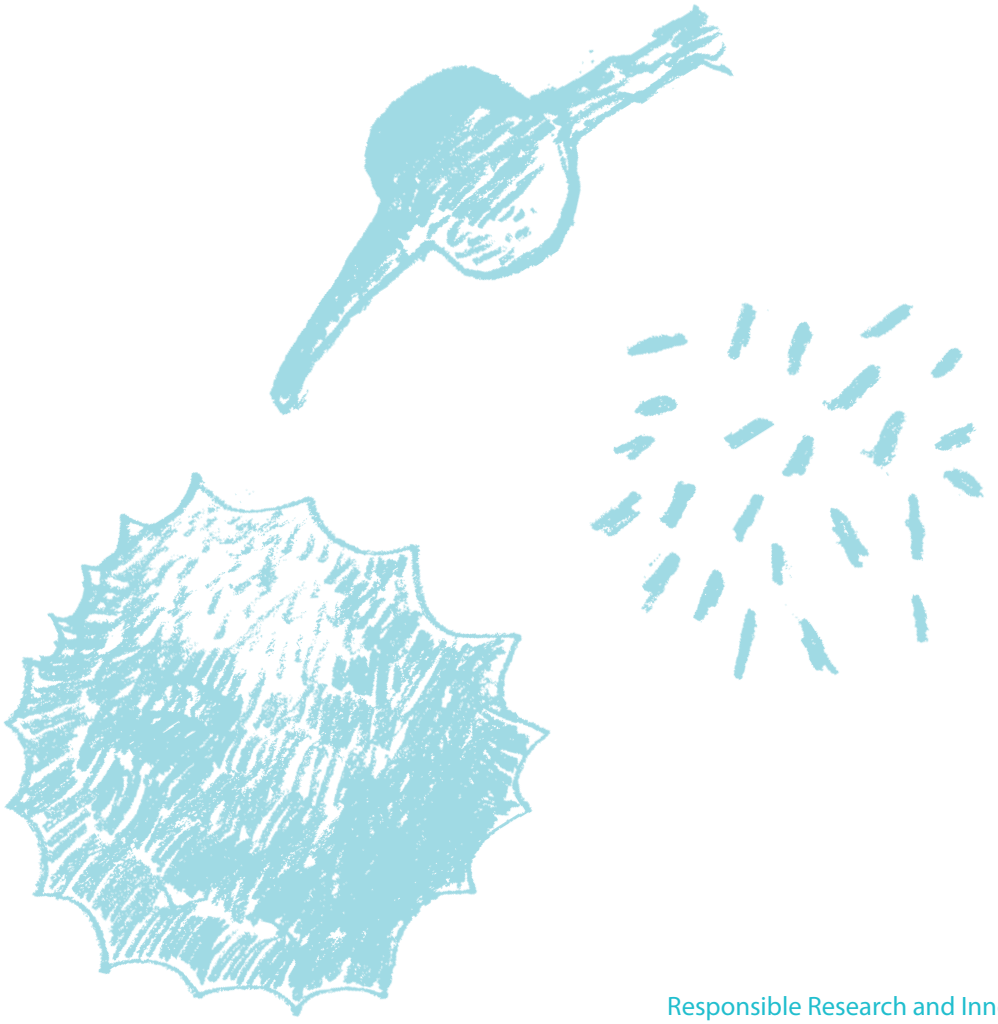
The purpose of the activity is to make known to the pupils a range of relevant issues from the scientific point of view: the notion of nanoparticle, the properties of nanoparticles and the areas of applicability. The activities carried out under this module aim at the same time the formation of conscious and responsible attitudes toward the importance of using certain properties of nanomaterials in various industrial applications.



Overview

Grade/Educational level	V-VIII – lower secondary, IX-XII –upper secondary
School subject	Sciences
Theme / themes of non-formal activity:	**Industrial applications of nanomaterials**
Educational objectives	1. Definition, classification and identification characteristics of nanomaterials; 2. To identify the types of nanomaterials suitable for industrial applications; 3. Establishing the correlation between structure and activity for different nanomaterials; 4. Exemplifying the use of nanomaterials in various industrial fields; 5. Explaining the importance of the applications of nanomaterials in industrial areas; 6. Presentation, in written form or orally, of the results of investigation using specific nanomaterials terminology; 7. The argumentation of the advantages and drawbacks of the current and future technologies for the environment as well as the analysis of the consequences of the use of nanotechnologies for society and environmental quality; 8. Expressing personal opinion, coupled with responsible attitudes with regard to industrial applications of nanomaterials; 9. Taking optimal decisions about the use of nanotechnologies.

Required preconditions		Knowledge, skills and habits concerning: different materials natural or synthetic (properties, reaction under certain environmental factors or deluded), nanoparticles, nanomaterials and nanotechnologies.
Procedural resources (teaching strategy)	Teaching-methods and procedures	Structured academic controversy, reflection, conversation, explanation, observation, case study, exercise, learning through discovery, the investigation, brainstorming.
	Educational means	Computer, projector, flipchart, text support, worksheets.
	Forms of activity organization	Frontal, by groups, individual.
Estimated time		120 minutes



Short Theoretical Background

Industrial applications of nanomaterials are based on the following categories of nanoparticles / nanomaterials:

- Metal oxides, particularly silica (SiO_2), alumina (Al_2O_3), titanium oxide (TiO_2), iron oxide (Fe_3O_4, Fe_2O_3) currently occupy top spots in terms of importance, from the economic point of view, in the case of inorganic nanoparticles. The table below lists the current and emerging applications of nanoparticles:

The current and emerging applications of nanoparticles

Electronics, optoelectronics and magnetic	Biomedicine, pharmaceuticals and cosmetics	Energy, catalysis, structural applications
Chemical-mechanical polishing	Antimicrobial agents	Catalysts for cars
Electroconductive coatings	Biodetection and labeling	Membranes
Magnetic fluids and recording media	Biomagnetic separation	Fuel cells
Multilayer capacitors	Drugs delivery	Photocatalysts
Optical fibers	Contrast agents in medical imaging	Coating agents resistant to abrasion
Optical quantum devices	Implants	Structured ceramic
Phosphorescent devices	Protective screens	Solar cells

- Nanocarbon is present in industrial applications, in particular in the form of carbon black (made up of chains of nanoparticles size ranging from a few nanometers), used in the manufacture of rubber tires and as a pigment for photocopiers, as well as nanotubes and fullerenes.

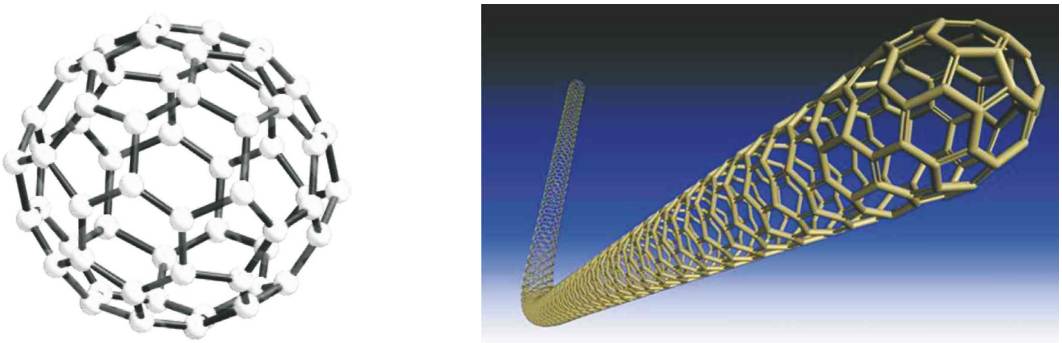
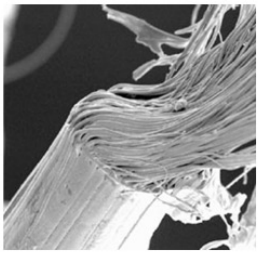
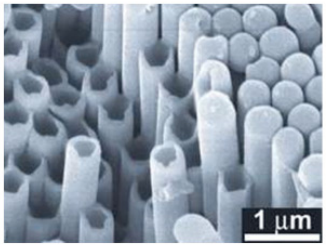


figure 1

Left: Computer generated model of a fullerene molecule (C_{60})
Right: Computer generated model of a nanotube

- Nanoclays (nanosilicates multilayer organic change) are used as fillers for polymers, for improved performance in terms of mechanical resistance and reaction to fire.
- Organic nanoparticles: polymeric nanoparticles (dispersion), micronized drugs and chemicals (vitamins, pigments, pharmaceuticals), macromolecules (dendrimers), the mycelia, liposoms.





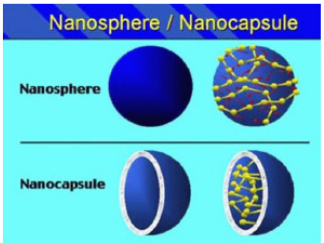


figure 2

Left: Nanofibers (polyethylene)
Center: Polymeric nanotubes (polystyrene)
Right: Nanocapsule

- Nanocomposites: polymer nanocomposites (made up of polymers or copolymers dopped with ceramic, silica, metallic or semiconducting nanoparticles - polymers with nanoclays for improving mechanical strength and heat resistance, epoxy resins flat with nanoparticles for electrical cables isulation, electro-conductive polymers with carbon black or nanotubes for electrostatic protection of electronic devices, polymers with silver nanoparticles with antimicrobial role for applications in medicine), metal matrix composites (obtained by adding metals with ceramic nanofibers in order to improve the thermomechanical characteristics), ceramic nanocomposites (ceramic nanopowders can be used to obtain microelectronic and micromechanical components with a high degree of miniaturization).

In the table below is an overview of the main areas of application of nanomaterials:

The current and emerging applications of nanoparticles

Car industry	Chemical industry	Engineering
- Subassembly with reduced weight - Paints (coatings, transparent surfaces) - Catalysts - Tires (fillings) - Sensors - Coatings for windshields and car body	- Fillers for paints - Coverage systems based on nanocomposites - Paper impregnation - Interchangeable adhesives - Magnetic fluids	- Abrasion protection for machines and tools (antijam coatings, abrasion-resistant coatings for plastic coated parts etc.) - Bearings without lubrication
Electronic industry	**Construction**	**Medicine**
- Memory devices - Display screens - Laser diode - Optical fibers - Optical switches - Conductive, antistatic coatings - Filters (for IR radiation)	- Building materials - Thermal insulation and fire retardant - Functional surfaces (paving, roofing, wood floor etc.) - Facade coatings - Grooves	- Drugs delivery systems - Activ agents - Contrast media - Fast medical tests - Prostheses and implants - Antimicrobial agents and coatings - Cancer therapy
Textiles / Fabrics	**Energy**	**Cosmetics**
- Textiles with processed surface - Intelligent clothing	- Fuel cells - Solar cells - Battery - Capacitors	- Solar protection - Lipsticks - Skin creams - Toothpaste
Food products	**Household products**	**Sport**
- Packing materials - Storage sensors - Additives - Fining agents for fruit juices	- Ceramic coatings for metal - Odor catalysts - Cleaning agents for glass, ceramic, floor, windows	- Wax for skis -Antifogging glasses - Antiadhesion surfaces for boats - Equipment reinforcement

Video resources:

1) Videos with applications of nanomaterials in consumer goods industry, building materials, textiles, paper.

http://www.youtube.com/watch?v=twr3Dthd4Ao

http://www.youtube.com/watch?v=BvTkefJHfC0

2) Videos with applications of nanomaterials in automotive industry

http://www.youtube.com/watch?v=p2l-pr–qCU

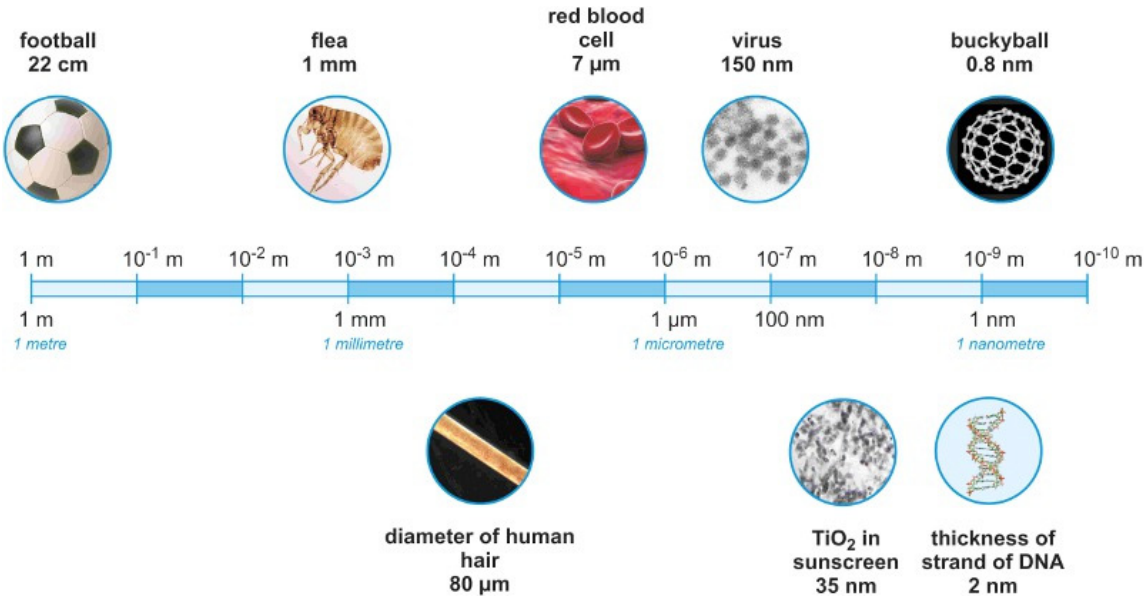


figure 3

Nanoscale

Educational scenario

Steps of teaching approach/time management	Derived competences (codes)	Teacher activity	Non-formal Learning activities
1. Engage 20 minutes	EO 1, EO 2, EO 4, EO 7	- Investigation of a real-life situation; - Formulating hypotheses and planning investigations; - Formation of working teams; - Presentation of informative materials in a digital environment, where are presented the actual results of applications and research relating to nanomaterials in industries.	- Discusses about how nanomaterials / nanotechnologies are valued in current society; - Generates a list of areas of industrial applicability and record them on the board; - Mention positive aspects, as well as the negative aspects of nanotechnologies and record them on the board.
2. Explore 20 minutes	EO 3, EO 5	- Presentation of matters for deliberation; - Presentation of worksheets with information about areas of the industrial applicability of nanomaterials (for each team).	- Thinking of the problems that arise from the point of view of the working group they represent (field / fields of industrial applicability); - The group reflection, centred on defining problems to be investigated and a plan of action; - Students will identify stakeholders, establish the relevant facts, formulate questions, determine the values of each of the parties concerned and propose possible solutions; - It defines the notion of "ethics for students", with an emphasis on the idea of morality; - Students submit shortly, those fundamental rights which may be violated or which may come into conflict with each other.
3. Explain 20 minutes	EO 5, EO 6, EO 7	Explains the elaboration of individual report	Each member of the group will draw up a report that summarizes its own opinion (as expert) regarding the appropriateness of the use of nanotechnologies in the field / fields that group has investigated.

The results of non-formal learning	Educational strategy			Evaluation
	Teaching methods and procedures	Means of education	Forms of organisation	
- interest of students for real-life issues where are capitalized nanomaterials / nanotechnologies; - knowledge regarding the fields of application of nanomaterials (list of areas of industrial applicability).	- conversation - explanation - problem-solving	- computer - videoprojector - magnetic whiteboard, markers.	- groups of 5 students; - frontal.	oral assessment
- cognitive structures based on linking new knowledge with preexisting notions related to nanomaterials (knowledge gained in the lessons of Physics / Chemistry / Biology, regarding the existence of the types of forces that act on the level of nanomaterials, as well as related properties of various nanomaterials); - new information on the current problems of society.	- reflection - conversation - explanation - problem-solving - learning through discovery	- magnetic whiteboard, markers; - worksheets.	- groups of 5 students; - frontal.	oral assessment, systematic observation
- responsible attitude towards various issues of contemporary society; - interest and responsible attitude towards the principles and democratic values; - Individually prepared report, which highlights the capabilities and skills acquired by the students as responsible citizens;	- conversation - explanation - problem-solving	- magnetic whiteboard, markers; - worksheets.	- groups of 5 students; - frontal.	oral assessment, systematic observation

4. Elaborate 25 minutes	EO 2, EO 5, EO 6, EO 7	- It asks students to share individual conclusions and arguments; - Students shall be required to draw up a Group Report in which are presented the decisions taken and the corresponding argument.	- Presenting the arguments identified by each student in the group; - Each group investigates the implications of nanomaterials applications in the domain / domains concerned; - The deliberations of the students by SAC method.
5. Disseminate / Share / Present / Expose 25 minutes	EO 6, EO 7, EO 8	- It asks students to present the final decision concerning the proposed issue; - It asks students to present the final product – the Group Report.	- It sets the final position of the group, supported by the most relevant arguments; - The students draw up a collective report (Group Report), which reflects the position of the working group; - Each group presents to colleagues, through a representative, the final decision.
6. Evaluate 10 minutes	EO 7, EO 8	- It asks students to express personal opinions by answering to the proposed questions; - It calls for answering to the questionnaires (self-assessment grid, feedback questionnaire).	- Students respond to the proponent questions; - Students shall complete the questionnaires (self-assessment grid and feedback questionnaire).

- Individually prepared report;	- Structured Academic Controversy (SERC) - conversation	- sheets of paper, post-it notes, markers; - flipchart.	- groups of 5 students; - frontal; - individual.	oral assessment, written evaluation – drafting Group Report
- Individual report prepared and submitted	- conversation - explanation - exposing	- sheets of paper, post-it notes, markers; - flipchart.	- groups of 5 students; - frontal.	oral assessment, systematic observation
completed self-assessment grid and feedback questionnaire	- conversation - explanation	- sheets of paper, post-it notes, markers; - flipchart.	- individual.	Oral evaluation Written evaluation – completing the self-assessment grid and the feedback questionnaire.

3

Teacher guide

Teacher guide

The expected non-formal activity allows students to acquire / to form new knowledge, skills, attitudes, etc. aming:

1. The definition, classification and characteristics of nanomaterials;

2. To identify the appropriate types of nanomaterials for industrial applications;

3. Realization of structure-activity correlation for different nanomaterials;

4. Exemplification and understanding the importance of nanomaterials applications in various industries;

5. Presentation, in written form or orally, of the results of investigation using specific nanomaterials terminology;

6. Reasoning for the advantages and drawbacks of the current and future technologies for the environment.

Non-formal learning results

At the end of non-formal activity the students will be capable to:

- argue the importance of nanomaterials in industrial applications, based on their characteristics and correlation structure-activity of different nanomaterials;
- present the advantages of using these materials;
- express a personal view on the impact of nanomaterials use on the environment;
- present the products of their activity in the form of PowerPoint presentations / posters or miniexhibition in which to render the current concerns and perspective in the field of industrial applications of nanomaterials;
- be aware of some of the problems facing the society currently;
- express and argue their own opinion;
- demonstrate abilities and skills specific to a responsible citizen;
- to get involved actively in debating issues of civic nature.

Recommend teaching and learning strategies

The activities subsumed under this theme are based on a scenario that begins with a question (which involves solving a problem), while students try to find an answer.

Proposed scenario – Two school mates, Andrei and Radu were playing. They are advised that they must discontinue play because Andrei is called to help his father to wash the car. Radu looks a little annoyed, because he finds that Andrei family's car should be washed more often than the car of his parents and tells him that his car "it wash oneself". On what was based when he made that statement?

The proposed project is based on prior knowledge that students gained at Biology, Physics, Chemistry, and aims, through strategies, acquiring skills for the exploration and investigation of environment, development of analysis capacity and synthesis, acquisition / development of personal skills, communication and relationship.
In this activity, students are familiar with a number of notions related to the behaviour of various nanomaterials and their applications in various fields of interest.
The suggested strategies are based on:

- methods and processes: structured academic controversy, reflection, conversation, explanation, observation, case study, exercise, learning through discovery, the investigation, brainstorm;
- forms of organisation: groups, frontal, individual.
- material resources: computer, videoprojector, flipchart, texts support.

Through these promotes strategies, in particular those inductive, deductive and heuristic, pupils will form / develop skills / capabilities of exploration and investigation, communication and work effectively in groups, analysis and synthesis, evaluation and anticipation, etc. Students will also become aware of the need to respect the principles and ethical values in research-

innovation approach.

1. ENGAGE

It presents materials in a digital environment in which are presented the actual results of applications and research relating to nanomaterials in industrial areas. It is proposed to students to investigate a real-life situation.

2. EXPLORE

Distribute worksheets (Annex A.1. – A.4.) with information about areas of industrial applicability of nanomaterials (for each team of students).
Each team is requested to define what problems will be investigated in the field of applications and to develop a plan of action.
It shall ensure the necessary conditions for the realization of the investigation and recording data.

3. EXPLAIN

Explain to students how to elaborate the Individual Report, which will contain data collected under scientific investigation. Each member of the group will draw up a report that summarizes its own opinion (as expert) regarding the appropriateness of the use of nanotechnologies in the field / fields that the working group is assigned.

4. ELABORATE

Students shall be required to submit individual conclusions and arguments, and subsequently, within the working groups to draw up a report in which to mention the decisions taken and their corresponding argument.

5. EXCHANGE

It is proposed to students to submit their final decision, argued, adopted by the working groups whose members are. It is claimed the Group Report.

6. EVALUATE

It presents their own opinions regarding activities. Evaluation activities will be achieved globally and individually, by completing the questionnaires by the students.

Aimed educational objectives

Aimed educational objectives	Non-formal learning activities
1. Definition, classification and identification characteristics of nanomaterials	debates centred on identifying specific aspects and implications of nanomaterials / nanotechnologies in current society;
2. To identify the types of nanomaterials suitable for industrial applications	generate a list of fields of industrial applicability;
3. Establishing the correlation between structure and activity for different nanomaterials	reflection centred on identifying potential problems arising from the utilisation of nanomaterials in various fields;
4. Exemplifying the use of nanomaterials in various industrial fields	presentation and analysis of examples regarding the use of nanomaterials in the industry;
5. Explaining the importance of the applications of nanomaterials in industrial areas	investigating the implications of nanomaterials applications in various fields;
6. Presentation, in written form or orally, of the results of investigation using specific nanomaterials terminology	drawing the Individual Report and subsequently of the Group, including data collected as a result of the investigation carried out and of the debates within the working groups;
7. The argumentation of the advantages and drawbacks of the current and future technologies for the environment as well as the analysis of the consequences of the use of nanotechnologies for society and environmental quality	detecting, presentation and analysis of the advantages and disadvantages of the use of nanotechnologies;
8. Expressing personal opinion, coupled with responsible attitudes with regard to industrial applications of nanomaterials	personal reflections on the promotion / the use of nanomaterials in various industries;
9. Taking optimal decisions about the use of nanotechnologies	personal reflections in decisions regarding promotion / the use of nanotechnologies.

For the learning activities proposed under non-formal activity, it is assumed that students know: notions related to nanoparticles / nanomaterials (lotus effect, natural nanomaterials), properties of materials having embedded nanoparticles.

Evaluation

Evaluation of students, in the framework of non-formal activities cover:
a) understanding of the terms and concepts proposed;
b) quality of information / investigations made;
c) involvement in the different stages of activity;
d) capacity of argumentation;
e) justifying opinions;
f) the quality of final presentation.

Evaluation strategy:

Suggestions for assessing students are as follows:
a) Evaluation will be done individually / on groups;
b) The evaluation will assess the goals targeted;
c) The evaluation will consider the materials made by pupils, but also experiments carried out;
d) In the assessment, there will be analyzed the aspects of personal and social development of students.

1. Predictive evaluation consider the knowledge and skills of students, as prerequisites of the assimilation of new knowledge and the development of new capabilities.
2. Formative evaluation will be present throughout, as follows:
– through oral questionnaires, systematic observations;
– through systematic observations of activities of students (measurements, ratings, instrumentation, compliance with the handling stages proposed in the protocol, determination, etc.), by checking the correctness of data gathered, through systematic observations on the behaviour of pupils;

Table A - Assessment rating grid of the work group

Criteria	1	2	3	4
The student accepts its responsibilities or roles within the group	The student does not meet any of the tasks associated with the roles. They are made by his colleagues.	The student performs rarely any of the tasks associated with the roles. Often he needs others to remind his duties.	The student carries out frequently his tasks/roles. The student has rarely needed the others to remind his duties.	The student performs the tasks/roles for which it is responsible. The student does not require others to remind his tasks.
Type of personal intervention	The pupil presents rarely useful ideas while working in a group and do not keep pace with the evolution of the working group.	The student contributes promptly to the working group, although sometimes gets distracted.	The student contributes to its working group and is responsible for his tasks.	The student contributes to the group work and boosts his colleagues to participate. His contribution is crucial for the success of the group work.
Relationship with group fellows	The student show indifference or exercising a leadership with a negative impact on the functioning of the working group.	The student looks interested, though it does not interfere with group dynamics work.	The student shows an interest in the dynamics of the working group and make a positive contribution in this regard.	The student interacts positively with others or has adequate leadership skills, with a positive impact on the functioning of working group.
Decision making	The student does not try to solve problems or to help his colleagues.	The student does not pose a solution but is willing to try the solutions presented by others.	The student brings important contributions, in order to improve the solutions presented by other colleagues.	The student tries, actively, solutions and presents solutions for the problem.
Time management	The student does not finish tasks on time and as a result, the group cannot meet deadlines.	The student did't finish his tasks on time. Although the group may still meet the deadlines, the quality of group work is affected by such behaviour.	The student not adequately manage working time, but completes the tasks undertaken, allowing the group to achive the deadlines proposed.	The student can manage his time properly, in order to achieve prompt the tasks.
Oral participation	The student does not participate or always speaks; don't allow others to speak.	The student participates in a conversation/debate quite often, preventing oral participation of others.	The student may hear his colleagues, but sometimes talks too much, don't allow others to speak.	The student can hear and speak in a balanced way.

Table B - Self assessment

Criteria	1	2	3	4
Responsibility for tasks or roles within the group	I have not performed any of the roles/tasks for which I was responsible. They were carried out by colleagues from my group.	I performed rarely any of tasks/roles for which I was responsible. Often, I need others to remind me of my tasks.	I carried frequent tasks/roles for which I was responsible. I need rarely for others to remind me of my tasks.	I realized the tasks/roles for which I was responsible. There is no need as a colleague reminded me of my duties.
Type of personal intervention	I presented rarely useful ideas while working in a group. I have not kept pace with the evolution of the working group.	I have contributed promptly to the work in the group, though; sometimes I get distracted from the task.	I have contributed to the working group and I was responsible for my tasks.	I have contributed to the working group and have stimulated the participation of my fellows. My contribution has been important to the success of the work in group.
The relationship with my colleagues	I forgot whatever or I exerted a negative impact on the functioning of my group.	I have not interfered with the dynamics of the working group.	I had a positive contribution to group dynamics.	I interacted positively with others or I harnessed the leadership skills, with a positive impact on the work group.
Decision making	I have not tried to solve any problem or I was helped by my teammates.	I don't have any kind of solution, but I was willing to try the solutions presented by others.	I've made important contributions, in order to improve the solutions presented by others.	I actively sought solutions to resolve the problem.
Time management	I didn't finish my tasks at the time and, as a result, my group could not meet deadlines.	I didn't finish my tasks at the time. Although the group could still receive the deadlines, the quality work group has been affected by my behaviour.	I have not managed properly the time, but I completed tasks and the group was able to meet deadlines.	I was able to manage the time properly and I have completed my tasks on time.
Oral participation	I have not attended or I was always talkative, by preventing the participation of other colleagues.	I participated quite often in conversation/debate, preventing always others to participate.	I listened, but sometimes I've talked too much, by preventing others to speak.	I listened and talked in a balanced way.

Annex A.1.

In the field of consumer goods most applications are based on the property of self cleaning or to facilitate the cleaning of the surfaces of ceramic or glass as well as ensuring a high level of protection against the aggressive agents in the environment.
Use of nanofibers in textile enabled already getting some waterproof clothing, impurities and crease resistant.

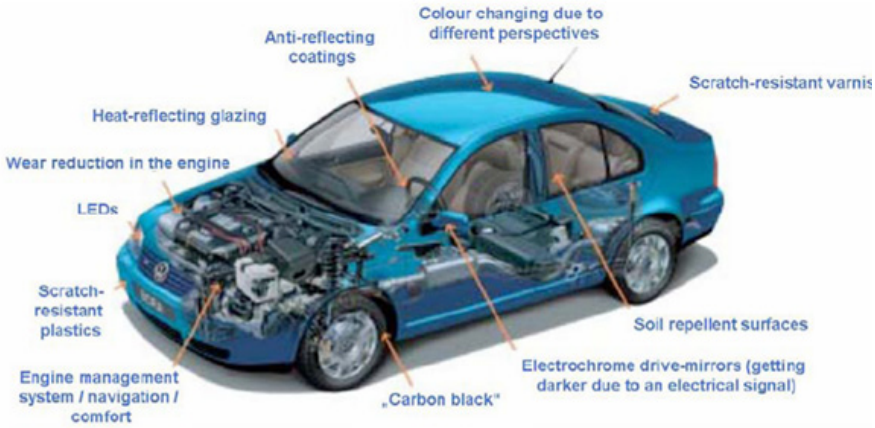


figure 4
Nanotechnology

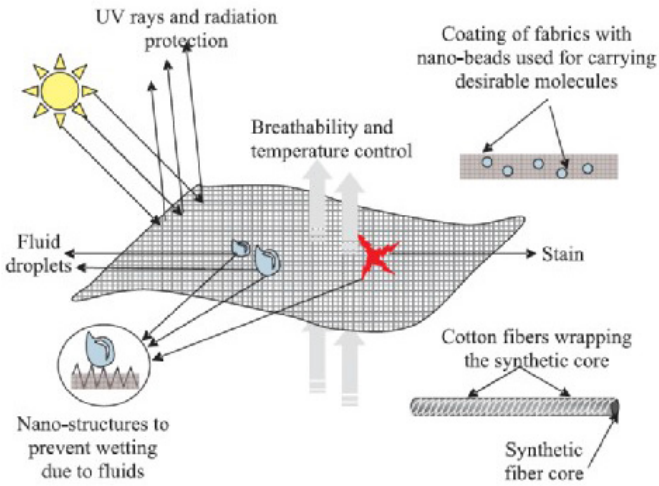


figure 5
Self- cleaning textile

Fabrics with self cleaning characteristics are based on photocatalytic property of titanium dioxide, a compound used also in nano-technologies involved in solar cell development. The fabric is coated with a very thin layer of titanium dioxide nanoparticles (20 nanometers in diameter).
In the field of cosmetic products one of the directions of applicability investigated is the use of nanoparticles (such as those on the basis of titanium oxide) in sunscreens. Nanotechnologies have already been introduced into the sport by allowing obtaining equipment enhancement: athletic shoes with lightweight, canes baseball incorporating carbon nanotubes for increasing resilience and reducing weight, textile equipment including nanotechnologies for prevention of infections, antimicrobial, etc.

figure 6
Waterproof shoes

1. Do you consider ethical the creation of new materials and rearrange matter?

2. Listed a series of applications of nanomaterials that you consider important in the consumer goods industry.

3. Put yourself in the position of a businessman: what business opportunities can you identify in connection with the use of nanotechnologies in the field of consumer goods?

4. Indicate a series of advantages and disadvantages related to the use of nanotechnologies in the field of consumer goods.

5. What I could do if I were a person with responsibilities in relation to:

- Legal aspects of the use of nanotechnologies

- The development opportunities created by the development of nanotechnologies

- The possible funding of research in the field

Annex A.2.

Military applications of nanotechnologies involve several directions of which can be listed:

- Getting some nanosenzori that allow the detection of biological agents (these systems are already in an advanced stage of development and will be one of the first forms in which nanotechnology will be applied in the military);
- Integration of nano-technologies in creating uniform with outstanding properties. Incorporating nanoparticles in the material are made not only to increase uniforms durability but offer high resistance to temperature, impact and chemical agents (these features are based on the property of nanoparticle incorporated into the material to group together when an external factor - mechanical impact - is acting on the material, thus increasing significantly resistance in the area of impact).
- Pigment mobile nanoparticles mobile entered into the material that are made the uniforms can lead to achieving superior camouflage characteristics (nanoparticles may be able to change their color depending on the color of the environment in which it is located).
- Nanotechnology can occur in the thermal camouflage (military uniforms, vehicles) by reducing the infrared radiation emitted by these surfaces, reducing their detection risk by thermal sensors.
- Nanotechnologies can also contribute to the development of a medical surveillance system of health and level of stress (such systems could react by releasing drugs or wound compression if necessary - for example, if the system detects a wound which bleeds, you will be able to comprime area surrounding the lesion until it can be applied a subsequent medical treatment). The system will be able to administer medication to the soldier (such as painkillers against pain) and to send data on the health status. The energy required to maintain such communication could be provided through soldier body movements.

1. Do you consider ethical the creation of new materials and rearrange matter?

2. Listed a series of applications of nanomaterials that you consider important in the military domain.

3. Put yourself in the position of a businessman: what business opportunities can you identify in connection with the use of nanotechnologies in the military field?

4. Indicate a series of advantages and disadvantages related to the use of nanotechnologies in the military field.

5. What I could do if I were a person with responsibilities in relation to:

- Legal aspects of the use of nanotechnologies

- The development opportunities created by the development of nanotechnologies

- The possible funding of research in the field

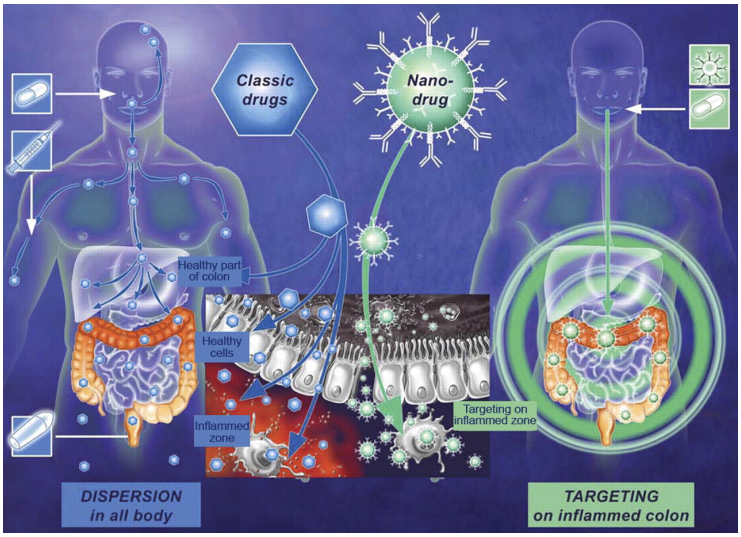
Annex A.3.

Nanotechnologies can be applied in the production, processing, packaging and food safety improvement. Packing films incorporating nanocomposite may allow placement of some antimicrobial agents directly on the surface of the film; nanocomposites can increase or decreases permeability to gases of different fillers as needed for different products, can improve the mechanical and thermal properties and can subtract the degree of oxygen transmission. Research are made also to apply nanotechnology in the detection of chemical and biological substances present in foodstuffs.

Nanomedicine represents the application of nanotechnology in the medical sector, by exploiting the physical, chemical and biological properties of materials at the nano-scale, with the aim of maintaining and / or improve health. The field is interdisciplinary and complex, involving the simultaneous use of several knowledge areas and scientific disciplines, such as in the area of clinical research / medical, biology, chemistry, physics, mathematics, electronics, robotics. Nanomedicine includes several areas that are interwoven and mutually reinforcing: nanomaterials and nanotechnology, nanodevices, molecular imaging at microscale level, innovative systems of administer drugs, nanotoxicology.

In the framework of structures and devices used by the nanomedicine may be included:

- nanoparticles designed to improve bioavailability in pharmacy (due to very small sizes nanoparticles can penetrate easily into cells representing one vehicle for different drugs and at the same time to be directed to specific target cells; such is diminished or removed the danger of toxicity and increase the effectiveness of medical therapy);
- nanotubes, for physical handling of some nanostructures;
- dendrimers, synthetic nanostructures used in gene therapy or imaging (cardio-vascular diseases);
- liposomes, currently in use in cancer therapy;
- nanocrystals quantum dots, used in medicine for diagnosis;
- fullerenes, used as antioxidants in neuro-degenerative and cardiovascular diseases;
- nanodevices like nanorobots, use in medical imaging or in gene therapy for reconstruction of biological molecular structures affected.



1. Do you consider ethical the creation of new materials and rearrange matter?

2. Listed a series of applications of nanomaterials that you consider important in food and medicine areas.

3. Put yourself in the position of a businessman: what business opportunities can you identify in connection with the use of nanotechnologies in the food industry?

4. Indicate a series of advantages and disadvantages related to the use of nanotechnologies in the medicine area.

5. What I could do if I were a person with responsibilities in relation to:

- **Legal aspects of the use of nanotechnologies**
- **The development opportunities created by the development of nanotechnologies**
- **The possible funding of research in the field**

Annex A.4.

Nanotechnology has the potential to intervene in the construction industry in terms of: speed, cost, safety, variety. In the future it is expected that nanotechnologies will allow for example detection of cracks from the foundation and sending nanobots to fix it.

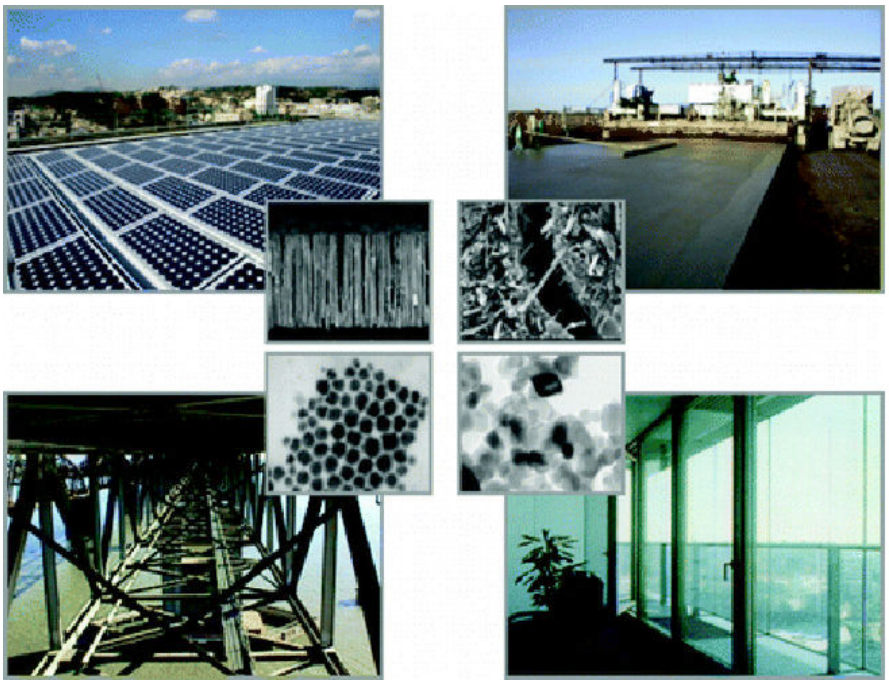
Nanotechnologies in construction involve the use of nanoparticles such as those of alumina and silica. Manufacturers also are investigating methods of obtaining nano-cement; if the cement with nanoparticles could be obtained and processed it could open a wide range of opportunities in the field of ceramics, high strength composites and electronic applications.

The additivating of steel used in construction reinforcement with copper nanoparticles results in an increase of mechanical resistance. Steel cables (used for example at suspended bridges) flat with carbon nanotubes exhibit also superior features (mechanical resistance and corrosion resistance, elasticity) compared with classical materials.

Timber industry constitutes a major opportunity in applying nanotechnologies for developing new products. The wood is composed from the nanotubes or "nanofibers" based on lignincellulose elements which have a comparable or even superior strength compared with steel.

Glass, a material used in construction, is an area of interest for the application of nanotechnologies. Nanoparticles of titanium dioxide (TiO2) can be used to provide a disinfecting and antifouling effect to the surface. Nanotechnology has been used also at the base of a glass with protection against fire by introducing a intermediate - layer sandwich - between two panes of glass, the layer of silica nanoparticles which when heated turns into a rigid, opaque, with particular resistance to light and thermal radiation.

Building coating agents are widely used to cover / "painting" walls, doors, windows, to provide a protective layer or with a particular functionality of basic material. These products should have repair properties through a process of so-called "self-assembling". Nanoparticles-based systems can provide a better adhesion and transparency.



1. Do you consider ethical the creation of new materials and rearrange matter?

2. Listed a series of applications of nanomaterials that you consider important in construction / building materials areas.

3. Put yourself in the position of a businessman: what business opportunities can you identify in connection with the use of nanotechnologies in building materials / construction?

4. Indicate a series of advantages and disadvantages related to the use of nanotechnologies in construction / building materials.

5. What I could do if I were a person with responsibilities in relation to:

- **Legal aspects of the use of nanotechnologies**

- **The development opportunities created by the development of nanotechnologies**

- **The possible funding of research in the field**

Annex B.1.

In the field of consumer goods, most applications are based on the property of self-cleaning or facilitated cleaning of ceramic or glass surfaces, as well as ensuring a high level of protection against the aggressive agents in the environment. Ceramic nanoparticles can improve surface roughness and thermal resistance of the equipment. Extremely thin films of polymers incorporating nanoparticles, are already used as cover in case of sun glasses, giving the antireflective properties and outstanding protection. Nanocompozitele are also applied with success in the field of optics, allowing obtaining coverage areas extremely resistant to mechanical stresses.

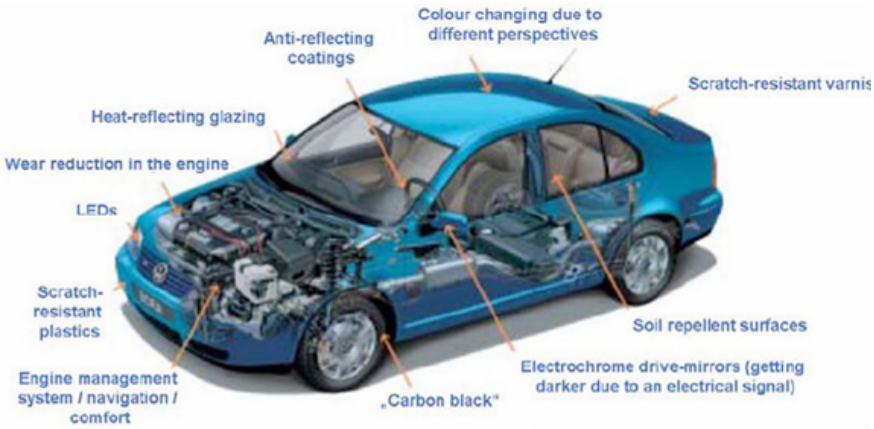


figure 7
Nanotechnology

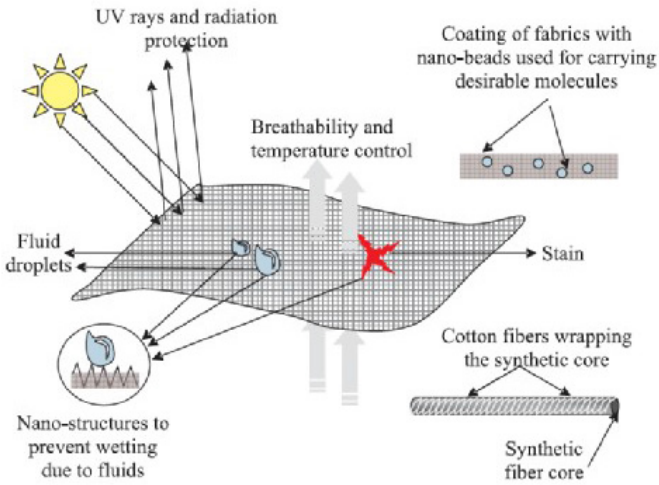


figure 8
Self- cleaning textile

Use of nanofibers in textiles enabled already getting some waterproof clothing, impurities and crease resistant. Incorporating nanotechnology textiles can be washed less frequently and at lower temperatures. Also, the use of membranes composed of carbon nanoparticles offers an effective protection against electrostatic charging.

Zinc oxide, in the form of hexagonal prisms sub-micron covering a fabric can lead to drastic alteration of its watering. It's an effect that was observed for the first time at the lotus leaves and which has as a consequence the obtaining of a material having properties of self cleaning. In this case, the method of preparation is the so-called method of electroless deposition, known

for more than 150 years, which was originally applied to metal deposition on nonconductive surfaces for mirrors (silver) or for protective or decorative coatings (chromium, nickel, copper). Here's how, applied for a new material on a substrate non-classic, the results are spectacular. More than changing the property of watering, cover with microscopic prisms of zinc oxide improves also optical properties of textile material in question.

Fabrics with self cleaning characteristics are based on photocatalytic property of titanium dioxide, a compound used also in nanotechnologies involved in solar cell development. The fabric is coated with a very thin layer of titanium dioxide nanoparticles (20 nanometers in diameter). When this layer semiconductiv is exposed to light, the photon with energy equal to or greater than the electrons of free band of titanium dioxide excite these electrons, passing in the conduction band; the excited electrons from crystalline structure react with oxygen atoms, forming oxygen free radicals - they are strong oxidizing agents that can break down the majority of organic compounds through oxidoreduction reactions. In these reactions, organic compounds (contaminants, pollutants, microorganisms) are broken down by simple substances like carbon dioxide and water, which can be easily removed. Because titanium dioxide plays the role of catalyst not consuming, it can resume the cleanup cycle.

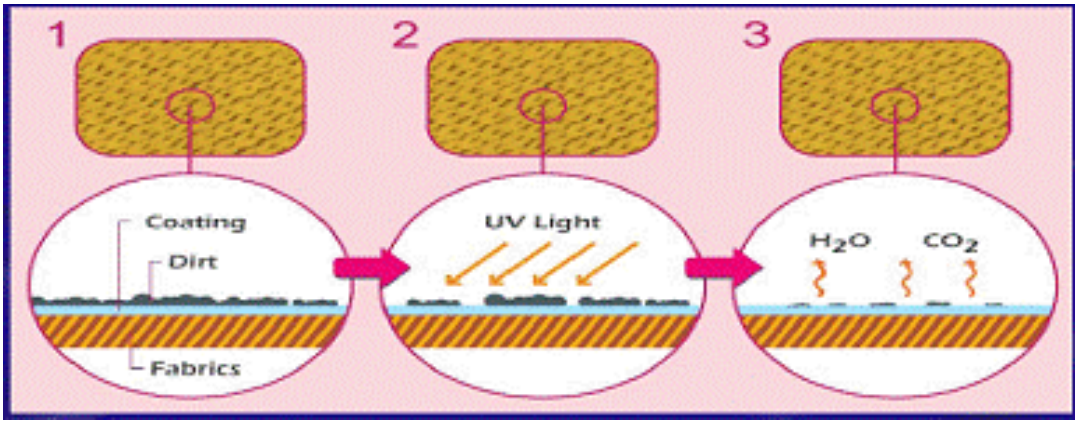
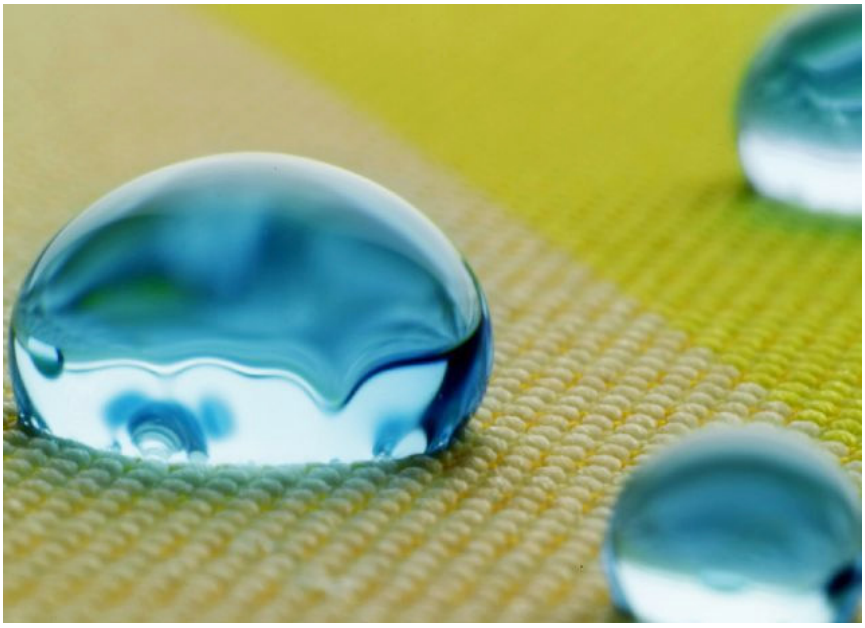


figure 9

Self- cleaning mechanism of the textile incorporating nanoparticles of titanium dioxide



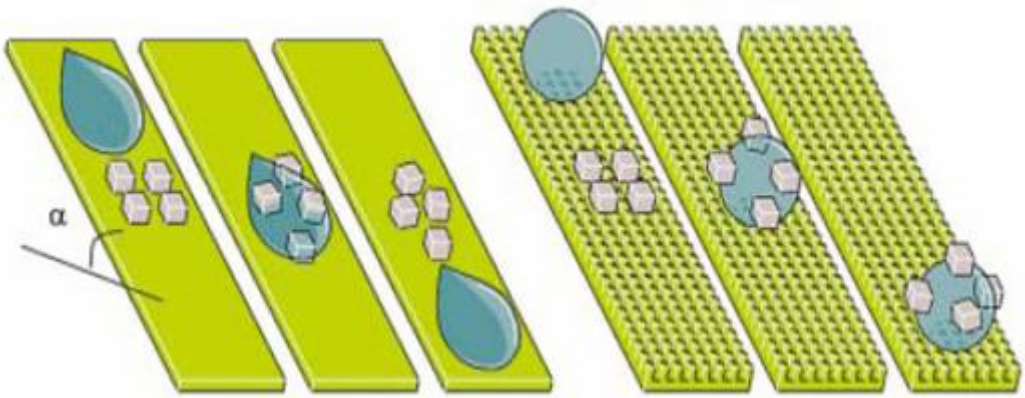


figure 10
Left: Fabric with untreated surface
Right: Fabric surface treated with silver nanoparticles

In the field of cosmetics, one of the directions of applicability investigated is using nanoparticles (such as those on the basis of titanium oxide) in sunscreens.
Nanotechnologies have already been introduced in the field of sport, allowing obtaining equipment enhancement: athletic shoes with lightweight, canes baseball incorporating carbon nanotubes for increasing resilience and reducing weight, textile equipment including nanotechnologies for prevention of antimicrobial resistance etc.
For example, gold nanoparticles can be incorporated into the pressure sensors: gold nanoparticles were dispersed in a solution until it has a blue color and with this solution has been treated an extremely thin and elastic polymer film. When a compulsion is made over the polymer film (by pressing or tapping), nanoparticles in that area begin to separate, and at the same time changing the color, depending on how strong the force was exerted on them. In other words,

this type of sensors can indicate not only the place where the solicitation occurs, but also how strong it was. This reaction can be highlighted in the figure below:

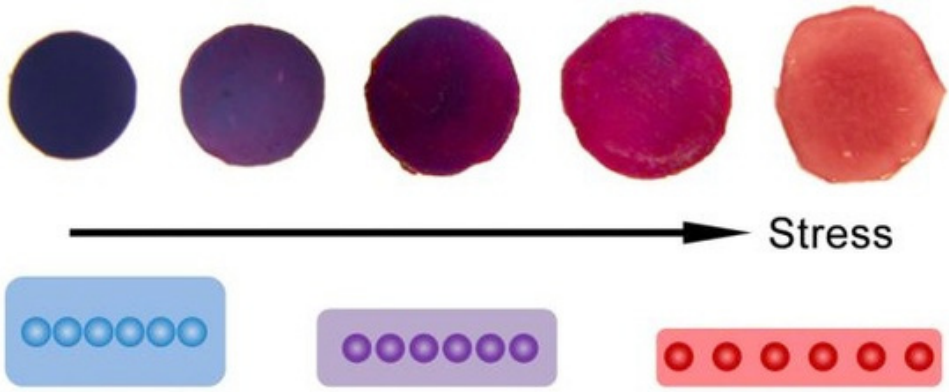


figure 11

Reaction to stress of a polymer film in pressure sensors

Nanomaterial	Sport	Benefits
Carbon nanotubes	Tennis/ Badminton	Increase stiffness, consistency, durability, resiliency, impact, repulsion power and vibration control of racquets
	Golf	Reduce weight, lower torque/spin of clubs
	Kayaking	Enhance abrasion/crack resistance and easy paddling in kayaks
	Archery	Better vibration control in arrows
Silica nanoparticles	Tennis/ Badminton	Increase stability, power & durability of racquets
	Skiing	Decrease torsion index & facilitate transition in skis
	Fly-fishing	Enhance hoop & flex strength of rods
Fullerenes	Tennis/ Badminton	Reduce weight and twisting of racquet frames
	Golf	Facilitate flexible club whipping
	Bowling	Reduce chipping & cracking of balls
Carbon nanofibers	Cycling	Reduce weight and increase stiffness of bicycles
Nanoclay	Tennis/Golf	Increase resiliency and bounce of balls
	Watercraft	Reduce weight and enhance speed of water-boats
Nano-titanium	Tennis/ Badminton	Resist deformation and increase strength & durability of racquets, transmit more power to shuttlecock/ball, more accurate shots
Carbon nanoparticles	Road Racing	Decrease rolling resistance, increase grip & mileage in tires
Nano-nickel	Golf	Increase moment of inertia & stability of clubs

figure 12

Nanomaterials in sport

Annex B.2.

Military applications of nanotechnologies has several strands, one of which may be listed:

- Getting some nanosensorsi that allow the detection of biological agents (these systems are already in an advanced stage of development and will be one of the first forms in which nanotechnology will be applied in the military);
- Integration of nanotechnologies in creating uniform with outstanding properties. Incorporating nanoparticles in the material are made not only to lead on increasing uniforms durability, but offer high resistance to temperature, impact and chemical agents (these features are based on the property of nanoparticles from material to group together when an external factor - mechanical impact - is acting on the material, thus increasing significantly in the area of impact resistance). Mobile pigment nanoparticles entered into the material from which are made uniforms can lead to achieving superior camouflage characteristics (nanoparticles may be able to change their color depending on the color of the environment in which it is located). Nanotechnology can occur in the thermal camouflage of surfaces (military uniforms, vehicles), by reducing the infrared radiation emitted by these surfaces, thereby reducing the risk of detection by thermal sensors.
- In addition, nanotechnologies can contribute to the development of a medical surveillance system of health and level of stress (such systems could react by releasing medicated or wound compression if necessary - if, for example, the system detects a wound which bleeds, you will be able to comprime area surrounding the lesion until it can be applied to a subsequent medical treatment). The system will be able to administer medicines to the soldier (such as painkillers against pain) and informed health care professionals on the health status of it. The energy required to maintain such communication could be provided through the soldier's body movements.

figure 13
Military applications of nanotechnologies

Annex B.3.

Nanotechnologies can be applied in the production, processing, packaging and food safety improvement. Packing films incorporating nanocomposite may allow placement of some antimicrobial agents directly on the surface of the film; nanocomposites can increase or decreases permeability to gases of different fillings, as needed for different products, can improve the mechanical and thermal properties and can subtract the degree of oxygen transmission. Research work are made also to apply nanotechnology in the detection of chemical and biological substances present in foodstuffs.

Nanomedicine represents the application of nanotechnology in the medical sector, by exploiting the properties of physical, chemical and biological properties of nanoscale materials, with the aim of maintaining and / or improving health. The field is interdisciplinary and complex, involving the simultaneous use of several knowledge areas and scientific disciplines, such as in the area of clinical / medical research, biology, chemistry, physics, mathematics, electronics, robotics. Nanomedicine includes several areas that are interwoven and mutually reinforcing: nanomaterials and nanotechnology, nanodevices, molecular imaging at micro scale level, innovative systems of administer drugs, nanotoxicology.

In the framework of structures and devices used by the nanomedicine may be included:

- nanoparticules, created in order to improve bioavailability in pharmacy (due to very small sizes nanoparticles can penetrate easily into cells, representing a different vehicle for drugs and, at the same time, to be directed to specific target cells; thus, it can be removed the danger of toxicity and increase the effectiveness of medicinal therapy);
- nanotubes, for physical handling of some nanostructures;
- dendrimers, synthetic nanostructures used in gene therapy or imaging (cardiovascular diseases);
- liposomes, currently in use in cancer therapy;
- nanocrystals quantum dots, used in medicine for diagnosis;
- fullerenes, used as antioxidants in neuro-degenerative and cardiovascular diseases;
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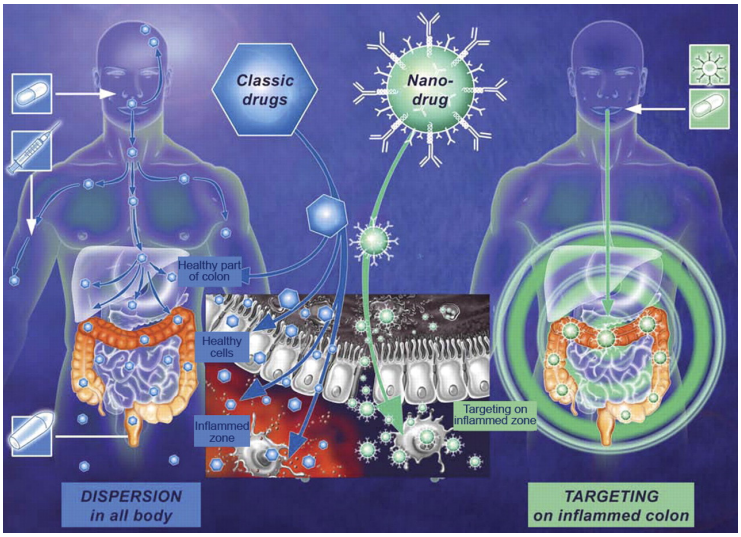


Currently, modern medicine uses instruments that can detect anomalies arising from the macroscopic level, being unable to capture the disease in its early stages. The use of nanotechnology in the medical sphere provides the ability to diagnose and treat diseases since their molecular phase and may allow doctors to treat the cause / origin of the disease and even to replace the affected tissue. By using nanoengineering you can obtain and use artificial tissues to replace the affected organs (kidney, liver) or to regenerate nerves or to produce implants that render the senses, such as sight or lost hearing.

Nanotechnology is essential in the development of therapies for the regeneration of tissue in-situ, this involving not only a profound understanding of cell biology, as well as identifying effective ways to trigger and control regenerative process. This strategy, "nanobiomimetics", depends on three basic elements: smart biomaterials, bioactive signaling molecules and cells.

Nanoparticles can carry drugs or genetic content in the internal environment cell without producing side effects, since it can become active only after they reach final destination.

The small size of nanoparticles offers useful properties in case of oncological diseases, particularly cancer imaging (nanostructures such as quantum dot - nanoparticles with quantum properties such as the ability to change size depending on the light emission, used in magnetic resonance imaging - can render images of tumor location); this type of nanoparticles are much brighter compared to contrast substances and require only a light source for excitation of particles.

Another property of nanoparticles is the ability to "bind" numerous substances, thanks to a large areas in comparison with the volume, which can be transported so easily at the level of tumor and, due to the small sizes (from 10 to 100 nanometers), may remain and may accumulate preferentially at the tumor level. With the help of nanotechnologies, cancer cells could be destroyed being targeted, without harming healthy tissue.

For prevention of skin infections, it is currently investigated the possibility of using so-called "smart bandages" which contain nanocapsule-containing antibiotic and a dye sensitive to bacterial toxins. So, nanocapsule just frees the antibiotic into contact with these toxins, and bandage begins to be coloured warning over local infection.

Annex B.4.

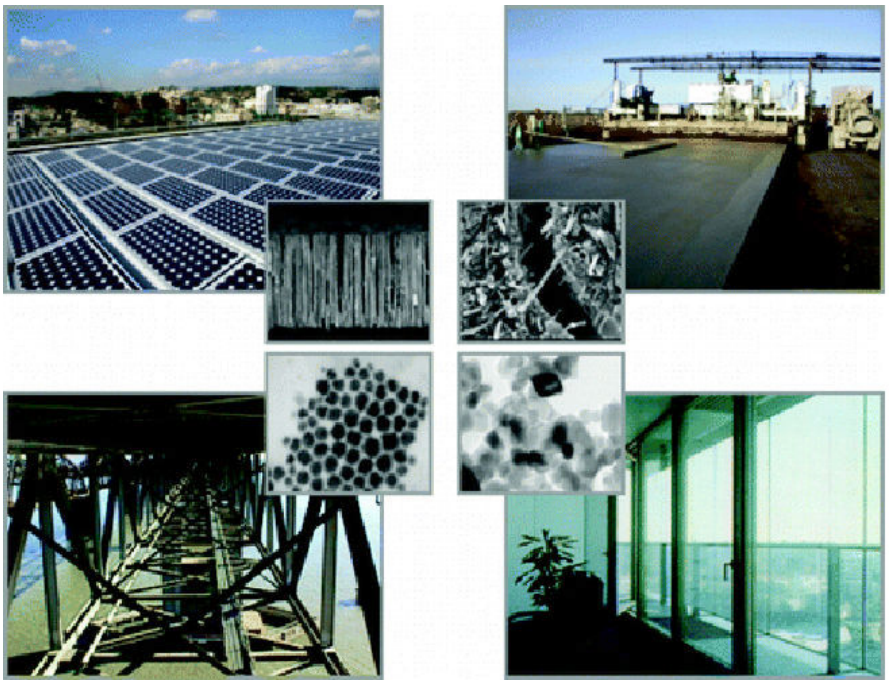
Nanotechnology has the potential to intervene in the construction industry in terms of: speed, cost, safety, variety. In the future it is expected that nanoyechnologies will allow, for example, cracks detection from the foundation and sending nanobots to fix it.

Nanotechnologies in construction involve the use of nanoparticles, such as those of alumina and silica. Manufacturers are also investigating methods for obtaining nano-cement; if the cement with nanoparticles could be obtained and processed it could open a wide range of opportunities in the field of ceramics, high strength composites and electronic applications. Nanomaterials still have a high price compared with conventional building materials, which makes them currently impracticable for building materials with high volume.

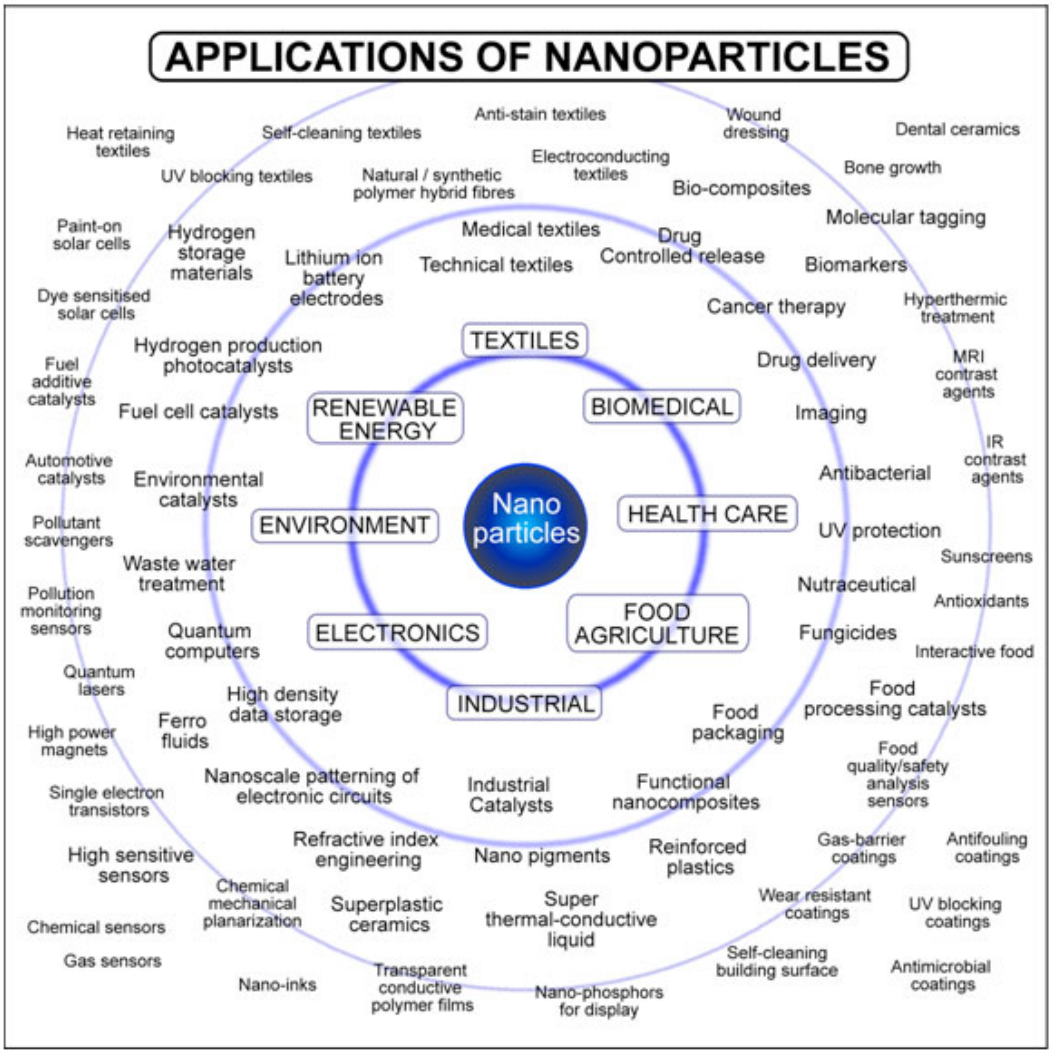
Nano-level analysis of cement has a particular relevance in understanding its structure. Silica (silicon dioxide SiO2) present in conventional cement as part of their usual mixture when it is in the form of nanoparticles result in micro and nano-densification of cement, translated through an improvement of the mechanical properties.

Steel reinforcement used in construction with copper nanoparticles results in an increased mechanical strength of it. Steel cables (used, for example, at suspended bridges) flat with carbon nanotubes exhibit also superior features (mechanical resistance and corrosion resistance, elasticity) compared with classical materials.

Timber industry constitutes a major opportunity in applying nanotechnologies for developing new products. The wood is composed from the nanotubes or "nanofibers" based on lignin-cellulose elements which have a comparable or even superior strength compared with steel. Incorporation of silica and alumina nanoparticles and hydrophobic polymers in wood structure has led to the achievement of structures with particularly reject water effect (based on the structural model of lotus leaf).



Glass, a material used in construction, is an area of interest for the application of nanotechnologies. Nanoparticles of titanium dioxide (TiO2) can be used to provide sterile and antifoulling effect to the surface (nanoparticles can catalyze reactions that destroy organic pollutants, volatile organic compounds and bacterial membranes; titanium dioxide has hydrophilic properties which make it possible to attract water droplets that can remove particles of impurities, thus ensuring a self cleaning effect of the surface in which are incorporated). Nanotechnology is at the base of a glass with protection against fire, by introducing a intermediate layer - sandwich type - between two panes of glass, the layer of silica nanoparticles which, when heated, turns into a rigid, opaque layer, with particular resistance to light and thermal radiation.
Building coating agents are widely used to cover / "painting" walls, doors, windows, to provide a protective layer or with a specific functionality of the basic material. These products should have remedial properties through a process of so-called "self-assembling". Nanoparticles-based systems can provide a better adhesion and transparency.
Nanoroofs provides an efficient insulation, corrosion, UV protection and are resistant to water. Some of these roofs are considered "healing" that removes pollutants from the atmosphere and the vicinity of the building.



4 Sources

Sources

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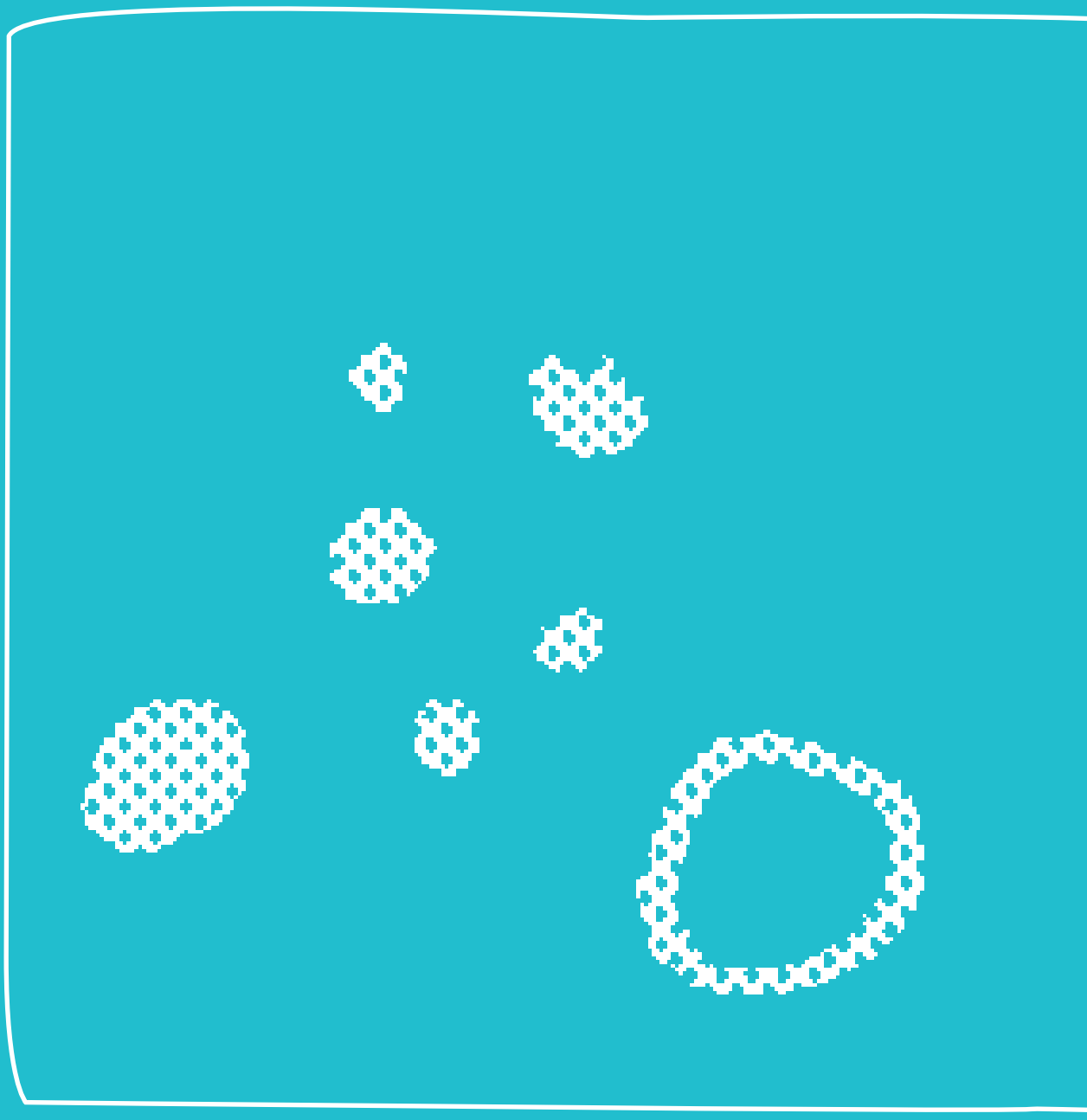
5 Colophon

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

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Coordinator: j.h.apotheker@rug.nl