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Responsible Research and Innovation (RRI)

Applications of nanomaterials in medicine

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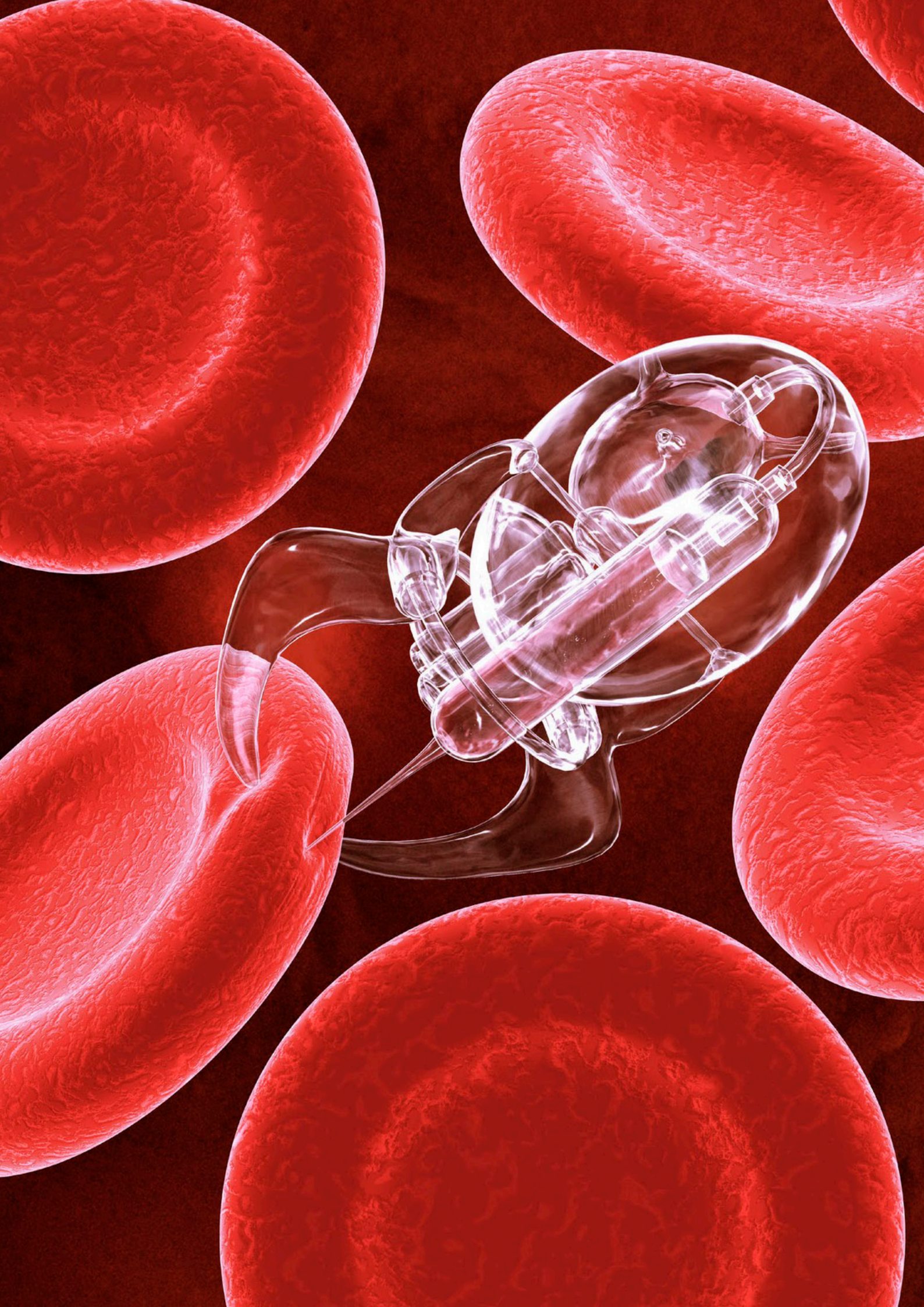
Universitatea Valahia din Targoviste



Applications of nanomaterials in medicine

An educational module for sciences lessons for primary and secondary school levels, developed by a Professor from Târgovişte, Romania.

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

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1

Overview

Applications of nanomaterials in medicine

The activities proposed to be carried out enable the students to learn general knowledge about nanomaterials and their applications in medicine. The activities in this module aim the formation of a conscious and responsible attitude towards the importance of using properties of nanomaterials either natural or synthesized in the medical laboratory.

This involves the development of experimental activities to highlight the structural and functional characteristics of natural nanomaterials and their involvement in various medical applications (accessible to the public with secondary).

Overview

Grade/Educational level		primary and secondary education
Domain		Sciences/Biology
Theme / themes of non-formal activity:		**Nanomedicine**
Educational objectives		1. Definition and classification of nanomaterials; 2. Characteristics identification of nanomaterials; 3. Nanomaterials characterization for adequate medical applications 4. Setting structure-activity correlations for different nanomaterials; 5. Examples of applications of nanomaterials in various medical fields and understanding their importance. 6. Presentation in writing or orally the results of a responsible research approach using terminology specific to nanomaterials; 7. The argumentation of advantages and disadvantages of present and future technologies for the environment and society
Required preconditions		Students hold concepts in some areas as physics, chemistry and biology, on various materials from nature (Lotus effect, ferro-fluid, anatomy / morphology of plant and animal bodies, etc). Students know the properties of the hydrophobic / hydrophilic of different materials / equipment.
Procedural resources (teaching strategy)	Teaching-methods and procedures	Learning by discovery, heuristic conversation, explanation, exposing, questioning, observation, case study exercise, experimentation, demonstration, investigation, brainstorming method, ACS (academic controversy).
	Educational means	computer, videoprojector, flip-chart, texts-support
	Forms of activity organization	Frontal, in groups
Estimated time		3-4 hours

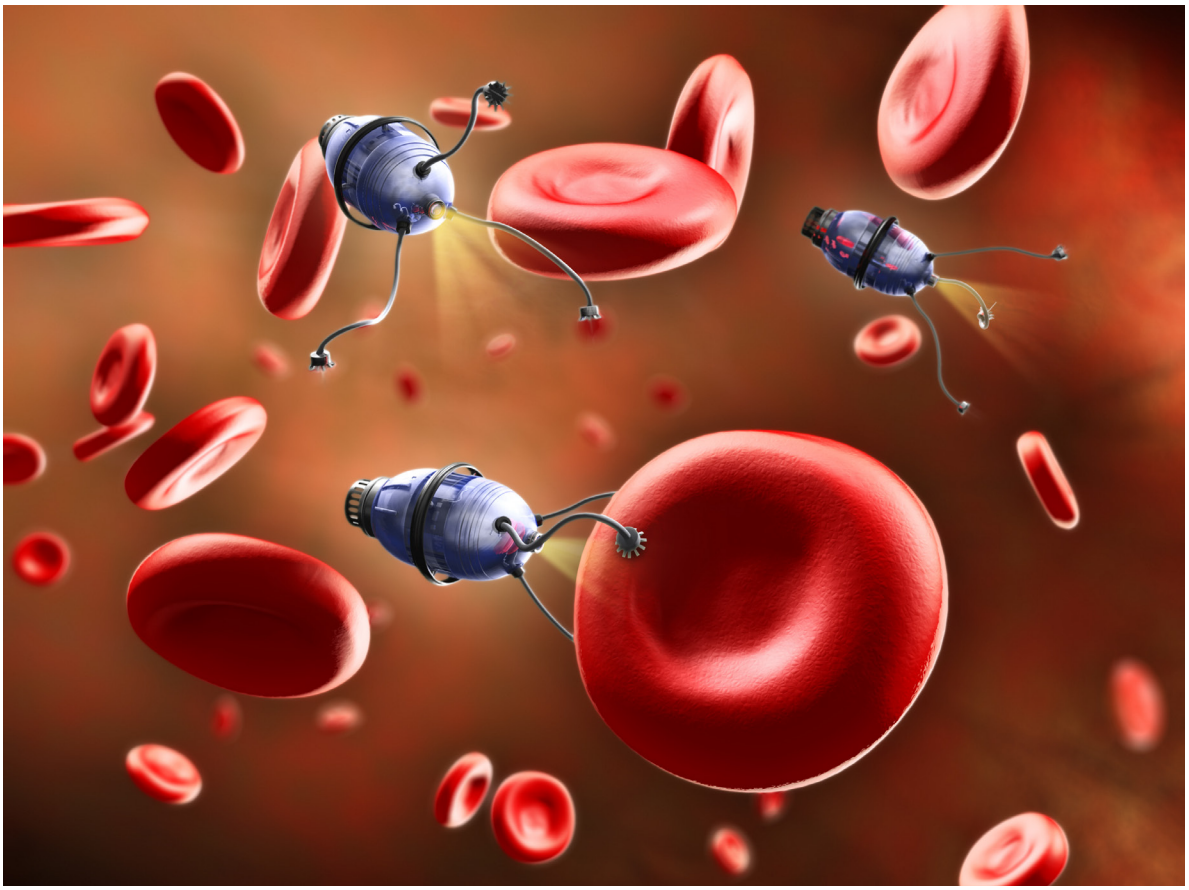


figure 1.1

Image source: https://www.emaze.com/@ACLLOROC/Nanotechnology

Short Theoretical Background

Nanomedicine is the application of nanotechnology in the medical sector by exploiting the physical, chemical and new biological nanoscale materials in order to maintain and / or improve health. Nanomedicine offers efficient and less costly solutions for prevention and diagnosis in the early stage of disease and to optimize treatment methods.

The field is interdisciplinary and complex, involving the simultaneous use of knowledge in several areas and scientific disciplines, such as research in the clinical / medical, biology, chemistry, physics, electronics, mathematics, and robotics. Nanomedicine includes several areas that are intertwined and mutually reinforcing: nanomaterials and nanodevices, molecular nanotechnology, imaging at the nanometer level, innovative drug delivery systems, nanotoxicologie. We all know that nanometric measure a billionth of a meter. Medical Council of the European Science Foundation describe nanomedicine as science and technology of diagnosing, treating and preventing disease and injuries, reduce pain, maintaining and improving human health through the use and knowledge of the human body at the molecular level.

The chronic conditions such as cancer, Parkinson's disease or Alzheimer's disease, cardiovascular diseases, mental / psychiatric creates more problems to modern medicine and nanomedicine comes with new treatment modalities, providing revolutionary tools to diagnose and treat diseases. The nanomedicine applications include a wide range of interventions in specialties such as internal medicine; oncology; emergency medicine, new methods of first aid for physical injuries / accidents, burns and exposure to radiation, surgery, cardiology and cardiovascular surgery, rapid methods of intervention and rehabilitation; neurology and neuro-surgery through new neurographic, regenerating spinal and brain repair interventions; gastroenterology and nutrition diseases to improve nutrition and digestion; sexology field of human reproduction; geriatrics / gerontology - biostasis and control strategies for aging; genetics - growth processes of the human body; gene therapy; reconstruction and cell regeneration; other areas: recreation and leisure; cosmetology, regulatory issues and sociological issues, the future of the medical profession, hospitals and pharmaceutical companies.

Nanomedicine seeks to provide, in the near future, tools and devices research and practice useful medical clinic, which could revolutionize the current way of thinking (preventive and diagnostic) and action (treatments applied) in the medical field, with mainly in the sphere of influence of chronic degenerative diseases. The liposomes were described in 1965, the first polymer nano-particles in 1994, quantum dot nanocrystals in 1998, the first nanosensor in 2001, and the new nanoparticles used as contrast agents in cardiovascular disease at the cellular and molecular level can be the new frontier for combining nano imaging and targeted drug transport in order to develop personalized medical therapies [2].

Shortly, some of the structures and devices used by nanomedicine can be described as follows:

• nanoparticles, created to improve the bioavailability of pharmaceutical, knowing that the bioavailability of various drug forms has been so far a major limitation to the producing of new drugs more effective than those existing today; a good example is the low bioavailability of RNA interference therapy. Due to the very small size, nanoparticles can easily penetrate into the cells and is a vehicle for various drugs, and can at the same time, to be directed to certain target cells; thus it eliminated the danger of toxicity and increase the effectiveness of drug therapy;

• nanotubes, for the physical handling of nanostructures;
• Dendrimers, synthetic nanostructures used in gene therapy or imaging (cardiovascular disease);
• liposomes, currently used in cancer targeted therapy;
• nanocrystal quantum dots used in medicine for diagnostic purposes;
• fullerenes, used as antioxidants in neurodegenerative diseases and cardiovascular;
• nanodevices and nanobots, used in medical imaging and gene therapy for reconstruction of biological molecular structures affected [3].

APPLICATIONS IN HEALTH

Today, modern medicine uses only instruments that can detect anomalies occurring at the macroscopic level, being unable to catch the disease in its early stages. By using nanotechnology might be revolutionized the medical sphere in the future, and current methods of diagnosis and treatment, especially; the possibility diagnosis and treatment of diseases, since their molecular phase, will allow clinicians to treat the cause / origin of the disease and even to replace damaged tissues. By using nano engineering, some artificial tissues can be obtained and used to replace damaged organs (kidney, liver) or regenerate nerves or make implants to restore lost senses, such as sight or hearing. The aim of regenerative medicine is to use their regenerative capacity of the body for the prevention and treatment of chronic debilitating conditions, such as diabetes, osteoarthritis, degenerative diseases of the cardiovascular and central nervous system injuries / accidents [4].

Nanotechnology is essential in developing cost-effective therapies for tissue regeneration in-situ, this involves not only a deep understanding of cell biology, but also to identify effective ways to trigger and control the regenerative process. This strategy "nanobiomimetics" depends on three elements: intelligent biomaterials, bioactive signaling molecules and cells. Biomaterials are designed to react positively to the environment and to stimulating specific regenerative events at the molecular level, conducting proliferation and cell differentiation and extracellular matrix production and organization. Bioactive signaling molecules that trigger regenerative processes at the cellular level are also needed in tissue regeneration. Nanotechnology could enable the sequential release of proteins, peptides and genes mimicking the natural reaction trigger the cascade. As a result of this are produced bioactive materials, which release signaling molecules values / levels controlled, which in turn, activate cells in contact with the stimuli.

Also, some transport drugs systems have been developed to target the cell receptors. Currently, the development of new carriers such therapies derived from the need for "targeted" by the organs affected by the disease, therapies that have increased efficiency, the need to enhance patient acceptability and health care cost savings. On the other hand, requires the identification of new methods of transport for new classes of pharmaceuticals, which can not be achieved by conventional methods, nanotechnology is essential in achieving this goal. Also, these carriers may be used for poorly soluble pharmaceuticals. This targeted transport system is characterized by a high therapeutic efficacy, improved pharmacological properties and therapeutic drugs used in cancer therapy, but also of conditions requiring high potency medication. So, by introducing

nanoparticles pharmaceutical carrier substances, tends to maximize the bioavailability from the point of view of the tissue / organ targeted as well as in terms of time / time period in which dispensing. Nanoparticles can carry drugs or genetic content into the internal environment of the cell without adverse effect whereas nanoparticles are activated only when they reach the final destination. It also prevents overdose phenomena thus avoiding drug intoxication. For the nanoparticles, as in the case of medicinal products, in parallel to the efficacy and safety is assessed. The small size of the nanoparticles is giving them useful applications in oncological imaging. Nanostructures such as "quantum dot" (nanoparticles with quantum properties, such as the ability to change size depending on light emission) used in magnetic resonance imaging, may render exceptional images of tumor localization. Such nanoparticles are brighter, in comparison with the contrast agents and only require a light source to excite the particles. This means that the use of quantum dots fluorescent nanoparticles can lead to a much better image with contrast more powerful and lower cost compared with the methods of magnetic resonance contrast agent used today [6].

The disadvantage is the toxicity of the elements of fluorescent quantum dots. Another property of nanoparticles is the ability to "connect" several substances, thanks to a large area relative to the volume substances that can be transported easily to the tumor and, due to its small size (10 to 100 nanometers) may remain and may accumulate preferentially in the its work facilitated by poor lymphatic drainage in the area. Researchers are investigating the possibility of creating multifunctional nanoparticles by detecting the tumor in the body can do and its treatment which would revolutionize oncology practice, replacing traditional therapeutic methods such as chemo and radiotherapy that affects not only cancer cells, but also those healthy cells too. By using nanotechnology, cancer cells could be destroyed targeted without harming healthy tissue. Some examples of application of nanotechnology in cancer therapy are listed below.

- Kanzius therapy uses gold nanoparticles or carbon that is fixed to the tumor cells and nanoparticles using radio waves as the cells to which they are attached are heated, the tumor is destroyed inside the body. Detecting the early stages of tumor is possible with nanosensors that would detect proteins and other biomarkers of tumor cells in patients' blood.
- Studies at Rice University by Professor Jennifer West have proved effective gold nanoparticle coated with tumor destruction in mice. They are attached to the surface of tumor cells by means of peptides or antibodies, and irradiating the area of the tumor, infrared laser, and the gold nanoparticles will warm enough to cause cancer cell death. The laser used is not heated and not destroy the rest şesuturilor it crosses. In oncology surgery can be used cadmium and selenium nanoparticles, quantum dots, which injected in the body penetrate tumors and exposure to ultraviolet light makes them shiny, thereby highly accurate tumor excision.
- Dendrimers have been used to locate and eliminate cancerous cells without affecting healthy şesuturile (studies at the University of Michigan by James Baker). Dendrimers, through more than a hundred "hooks" can fix a number of substances and / or can attach to body cells perform different functions. Photodynamic therapy using the particles placed in the body and illuminated from the outside of the body, the light is absorbed by the particles, and if they are

made of metal, light metal will heat up and, as a result, the tissue to which it is attached to the particle. Light can be used to produce high-energy oxygen molecules which will chemically react and destroy tumor cells nearby. This method is promising because no toxic adverse reactions, is aimed at the target tissue and is a noninvasive procedure [7].

In the field of oncology, nanomedicine applies to:

1. Prevention and control of disease, developing nano-devices for use in preventing transmission of disease agents and creating multifaceted anticancer vaccines;
2. Early diagnosis and proteomics platforms by developing "smart" mass analysis of tumor markers;
3. oncologic imaging by improving the resolution of images produced using special agents of contrast;
4. Multifunction therapy through treatment devices of the controlled release anti-tumor chemotherapeutic agents [8].

The spectrum of applications of nanomedicine

1. Nanoantibiotherapy

To prevent skin infections due to aggressions to the skin (burns, ulcers, various injuries), it is now investigated the possibility of using so-called "smart bandages" nanocapsules containing antibiotic and a dye sensitive to bacterial toxins. The nanocapsules release only antibiotic in contact with these toxins, and begin to be colored the bandage warning on the local infection. The controlled release of the antibiotic will minimize the risk of antibiotic-resistant bacteria such as, for example, methicillin-resistant Staphylococcus aureus (MRSA - Methicillin-resistant Staphylococcus aureus).

figure 1.2

The aspect of some smart bandages

2. Antitumoral Nanotherapy

Recent researches have regard to the cover (functionalization) of a nanocapsule surface with specific binding sites on the tumor cell surface markers. In this way, after injection, the "targeted" nanocapsule clicks the tumoral tissue and and releases the cytostatic agent.

For the purpose of targeting tumor cells and reduce side effects of chemotherapy, gold nanospheres with subcellular size, were coated with paclitaxel. Studies have highlighted the effectiveness of the drug increased the binding specificity of the active substance of microtubules, blocking the cell division.

For vectorized transport, the antitumoral nanotherapy envisages the use nanoparticles with conjugated systems-aptamers. Aptamers are ligands specific for nucleic acids and peptides, allowing the targeting and controlled release of cytostatics in the tumor mass. The first encouraging results researches have been carried out on cell cultures of prostate cancer.

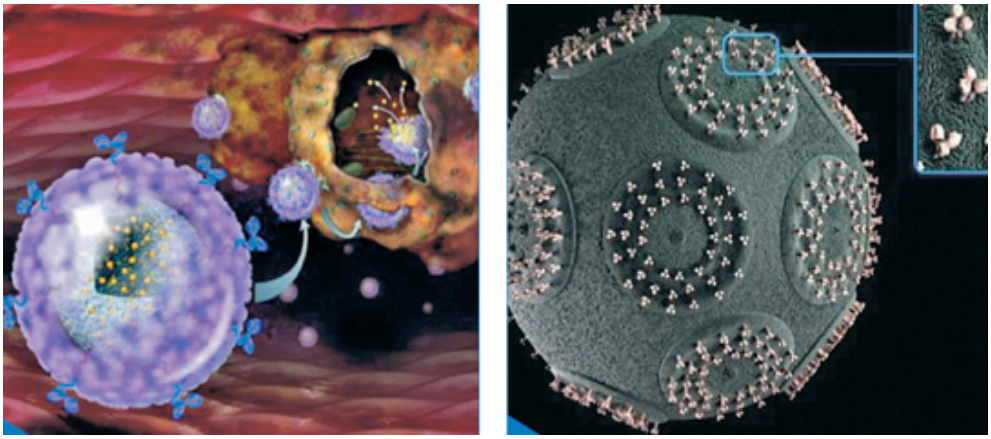


figure 1.3

Left: Biodegradable nanoparticle (Image source: http://medlink-uk.net/wp-content/uploads/pathprojectsnanotechnology2011/LimA&OrrC.pdf)

Right: Programmed nanocapsule (Image source: http://www.nanotech-now.com/news_images/37127.jpg)

3. Neuronal Nano Protection

Neuroprotection is another top area of nanotechnology pharmaceuticals aimed to prevent or slow the disappearance of neurons by drug action vectorized at the cellular and molecular mechanisms involved in neuronal death. For maximum therapeutic benefit, treatment strategies should be applied since the early stages of the condition neurodegenerative (eg in Alzheimer's, Parkinson's, Huntington).

4. Nanosystems transport gene therapy

In the present, the gene therapy is directed to the use of nanoparticles in place of biological vectors (such as viruses). At least theoretically, to viral vectors, nanoparticles are less likely immunological and allow the transfer of large amounts of genetic material to target cells. For this purpose, the animal experiment, have been used macromolecular structures, branched symmetrical type dendrimers. It was found that Dendrimers can transfer DNA into the nucleus

of the target cell without triggering immune responses in nature.

5. Nanovaccines

Compounds that induce immune response both humoral and cell-mediated, are more effective than conventional vaccines. Furthermore, compliance is much greater in the former case, since nanovaccines can be applied in the form of nasal drops. The new preparation technologies, still in the experimental stage, aim to shorten the growing viral strains from 60 to 28 days, extremely important if we take into account pandemics.

In Canada, the preclinical research leading to a nanovaccine against diabetes mellitus type 1 laboratory mice, the nanovaccine restored normal blood sugar level by removing the hyper-reactive T cells responsible for the autoimmune destruction of pancreatic beta cells. Vaccines based on nanoemulsions intranasal proved non-toxic and effective against influenza viruses, hepatitis B, HIV, smallpox. The advantages of nano-drugs: better protection at biological-induced degradation; increased biodisponibility; specific tissue target; intracellular penetration. By nano-pharmaceutical application, increase the efficacity, specificity, tolerance and therapeutic index of active substances.

6. Molecular Nanodiagnosis

The emergence of new contrast agents, markers for tumor diagnosis which type formulations based nanoparticles led to increased sensitivity and specificity in vivo detection of carcinomas, contributing to improved medical imaging techniques High resolution, non-invasive cellular and molecular: ultrasound (US - Ultrasonography), computed tomography (CT - Computed Tomography), nuclear magnetic resonance imaging (MRI - Magnetic Resonance Imaging), optical imaging (OI - Optical Imaging), positron emission tomography (PET - Positron Emission Tomography). Nano imaging has an important contribution to the early detection of tumors. This technology is the future in cancer diagnosis. Currently, imaging techniques have a maximum resolution of 1 mm; using nanoparticles, the resolution can be increased at least 10 times. The nanoparticles are capable of crossing the blood-brain barrier and to accumulate in brain tumors without causing local damage. By injecting the fluorescent nanoparticles vinto ascular fluid was achieved "enlightenment" of some brain tumors in mice. For "targeting" of tumor cells was used clorotoxine, a low molecular weight peptide isolated from the venom of the scorpion. The method has therapeutic applications, based on the finding that in combination with nanoparticles clorotoxina drastically limited tumor spread. Brain tumors are highly invasive and harm the surrounding tissues without a clear demarcation between normal and damaged brain tissue. Thus, by improving contrast, nanoparticles allow surgeons better visualize tumor boundaries [9-11].

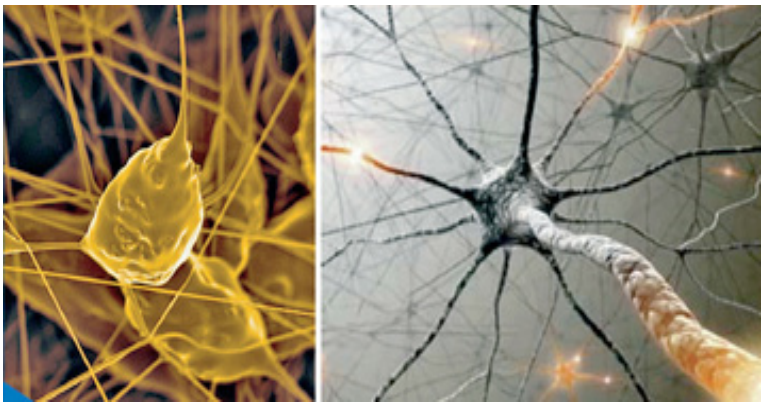


figure 1.4

The aspect of...

Left: cerebral implant (Image source: http://cdn.physorg.com/newman/gfx/news/hires/2009/1-neural.jpg)

Right: artificial neuron (Image source: http://www.theatlantic.com/health/archive/2012/06/the-neural-rhythms-that-move-your-body/258094/)

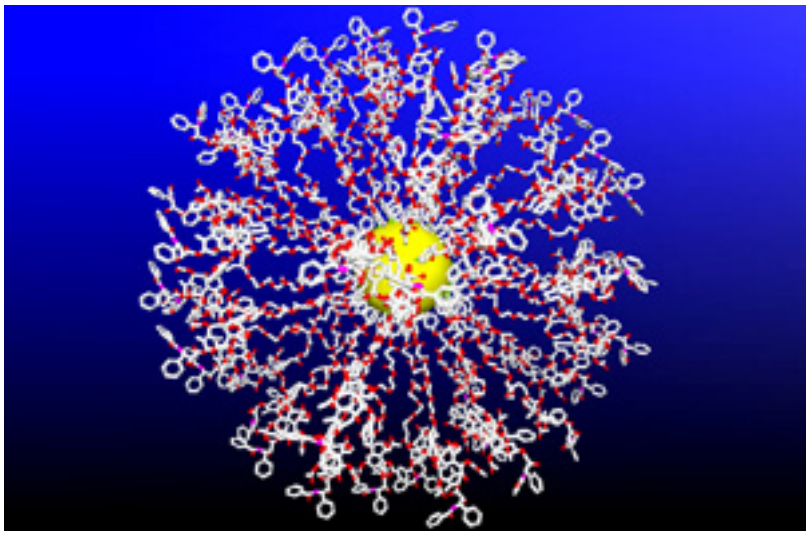


figure 1.5

The aspect of the system paclitaxel-gold nanoparticle (Image source: https://pubs.acs.org/cen/_img/85/i36/rdsciconline.jpg)

7. "Intracellular surgery " and "nanodoctors"

Still fantastic, the concept of "intracellular surgery" is entirely based on nanotechnology. Thus, "nanodoctors" (nanobots) can identify intracellular structures and molecular signaling pathways, their intervention having an extremely high degree of specificity: preventing the degradation and repair of DNA, denatured proteins elimination, stimulation of lysosomal treating cerebral aneurysms, etc.

Conclusion

Nanotechnology, namely construction and applications at the cellular and molecular systems or devices, is an interdisciplinary field that has experienced extraordinary growth in recent years. In this regard, nanomedicine is undoubtedly one of the high value applications of nanotechnology. If you remember only therapy to target pharmaceutical nanotechnology aim was to obtain the most effective drugs with minimal side effects and how to benefit from a better compliance. Also, in the past 20 years, nanosystems have increased sensitivity, speed, and flexibility of the medical diagnosis. Detection of early stage increases the chances of curing serious illnesses, such as cancer.

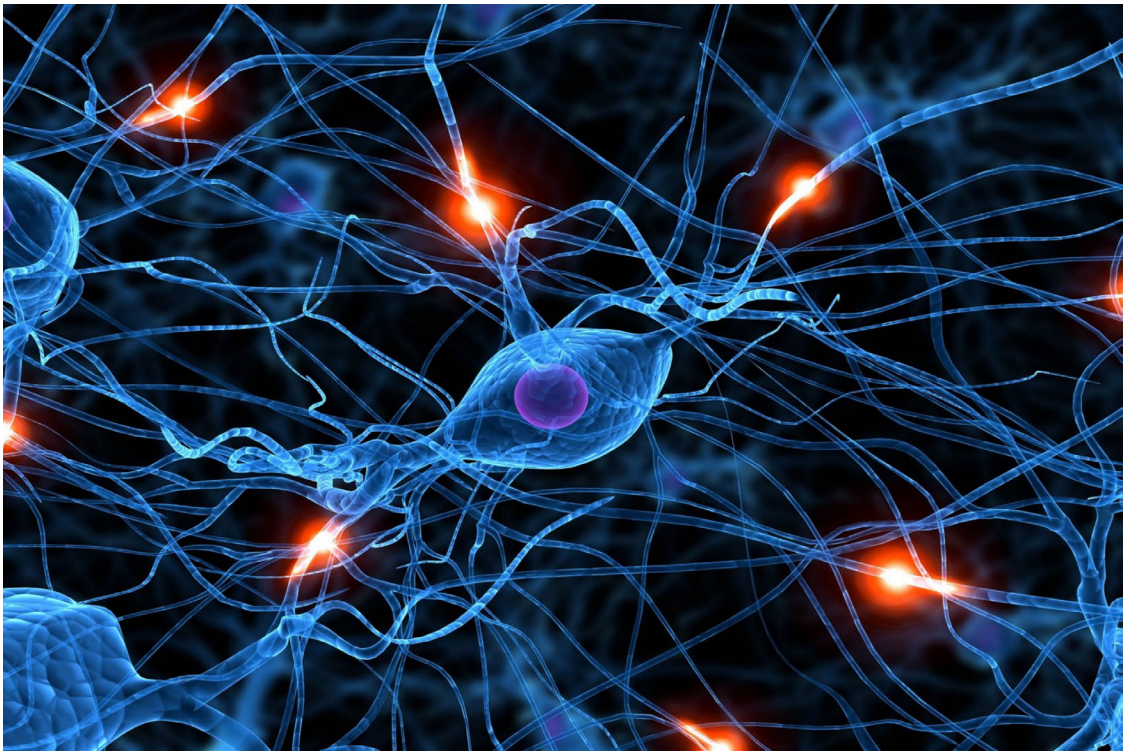


figure 1.6

Neural network (Image source: http://www.extremetech.com/wp-content/uploads/2013/09/340.jpg)

Educational scenario

Steps of non-formal activity/ time management	Educational objectives	Proposed activities	Non-formal Learning activities
1. Engage 25 min	OE 1, OE3, OE5	It presents informative materials on digital media to students, where are shown the current results of the research in nanomedicine.	Students create short presentations about applications on scale medical of nanomaterials. Create an account on Facebook - Nanomed- where their opinions about nanomedicine, promote new breakthroughs in the field.
2. Explore 35 min	OE2, OE4	Provides students the material needed to perform the microscopic observations and experiments, monitors and guides students during the development of the experiments.	It argues the importance of nanomaterials in medicine; Explain What is the healing ability of nanomaterials in medical disorders. Experience how the healing of various nanomaterials with different texture and structure, the behavior of nanomaterials in various natural medical systems (special dressings); Differentiate, the SEM images, the structures involved in various applications
3. Explain 30 min	OE6	It gives students with additional explanations on medical nanomaterials. Provides students worksheets and questionnaires; explains how to complete them.	Students role asks for information clarifying the aspects above. Make assumptions, theories check, complete worksheets and questionnaires
4. Elaborate 25 min	OE6, OE7	Answer questions from students.	Student activity focuses on issues specific Responsible Research and Innovation. They will ask questions of researchers, scientific experts on the advantages and disadvantages of nanomaterials. Express personal views in relation to respect for the environment through the use of nanomaterials.
5. Disseminate / Share / Present / Expose 45 min	OE5, OE6	Listen to student responses, requests additional information or supplemented, if necessary	Presentation by students in the group, their own opinions on the use of nanomaterials as well as the importance of research in nanomedicine. Develop a poster to be presented in plenary.
6. Evaluate 20 min	OE1, OE2, OE3, OE4, OE5, OE6, OE7	Check the extent to which students have achieved sustainable purchasing, the finality of default. Share feedback form	Fill in the feedback form

The results of non-formal learning	Non-formal activity strategy			Evaluation
	Teaching methods and procedures	Means of education	Forms of organisation	
PPTs, Facebook account, active account. News of knowledge in the field of nanomedicine; Habits of use, handling digital tools.	conversation, explication, exercise, practical works	PC, videoprojector	in groups, frontal, individual	Oral assessment
Extended -knowledges about nanomaterials, - Skills of observation and experimentation - Handling skills laboratory instrumentation.	experiment, observation, explanation, questioning, discovery learning	- kitchen towels, 100% polyester textile fragment, piece of pine wood, pine wood fragment treated with protective varnish, natural wax fine film, aluminum foil (E1) - Textile material 100% cotton, polyester fabric (at least 80%) nanotex material, vegetable oil.	in groups, frontal	Oral assessment
- completed questionnaires	conversation, explanation, problem solving, cooperative learning	records, questionnaires, evaluation grids	frontal, in groups	Oral evaluation and written evaluation
Informations posted on the account facebook-Nanomed	Conversation, questioning	Videoprojector, PC, internet	Frontal, individual, in groups	Oral assessment
Posters	Conversation	Sheets of cardboard, markers, sheets of paper	Frontal discussions	Oral evaluation and written evaluation
Answers to of the activity feedback form. Post feedback on the platform.	Survey based on questionnaires, conversation, explanation, personal reflection	Printed questionnaire	Individual	Written evaluation

3

Teacher guide

Teacher guide

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

1. The definition and classification of nanomaterials;
2. The identification of nanomaterials characteristics;
3. The nanomaterials characterization appropriate for medical applications;
4. The structure-activity relationship for different nanomaterials;
5. Exemplifying applications of nanomaterials in various medical fields and understand their importance;
6. Presentation in writing or orally of the research results of a responsible research, by using terminology specific to nanomaterials;
7. The rationale advantages and disadvantages of current and future technologies for the environment and society.

The results of non-formal learning will be:

- Knowledge of news in the field of nanomaterials and nanomedicine;
- Habits of use and manipulation of digital tools.
- Presentations PPTs,
- Facebook- Account Nanomed, actively maintained;
- Skills of observation and experimentation
- Handling skills of laboratory instrumentation.

1. Engage

The activities proposed in this module are based on a scenario that launches a question (which involves solving a problem), which tries to find an answer.

The proposed scenario - Octavian is passionate about gardening. He likes to help his parents when working in the greenhouse. However, he has a problem: after working in the greenhouse, he gets scratched or cut into twigs that cut in the greenhouse. Therefore, every night his mother is obliged to apply a wound dressing that incorporate nanomaterials for wound healing and skin protection.

The work is based on students' prior knowledges in biology, physics, chemistry and aims that by the used strategies to lead to the acquisition of exploration and investigation skills of the environment, development of the capacity for analysis and synthesis, the acquisition /development of personal skills for communication and relationship.

In this activity, students become familiar with some terms relating to the behavior of different nanomaterials. The strategies suggested in this first phase are: discovery learning, heuristic conversation, explanation, exposure, problem solving, case study, experimentation.

Also, students create a mini-exhibition that promotes nanopathes on the facebook account - Nanomed - in oder to express their views about the benefits of using nanotechnology in medicine, to promote a responsible attitude towards the environment by using the nanotechnologies.

2. Explore

The proposer provides students the material needed to perform microscopic observations and experiments, monitors and guides students during the course of the experiments. Students argue the importance of nanomaterials in medicine, explains the healing ability of nanomaterials in medical conditions; healing experience with different nanomaterials with different texture and structure, explain the difference from the wild behavior of nanomaterials in medical systems (special dressings); it differentiate by SEM images, the structures involved in various applications.

3. Explain

The proposer helps students with additional explanations on medical nanomaterials.

Available for student records, questionnaires and tables; explains how to complete them.

4. Elaborate

Student activity focuses on specific issues Responsible Research and Innovation. They will ask questions from researchers, scientific experts on the advantages and disadvantages of nanomaterials. Express personal views in relation to respect for the environment through the use of nanomaterials.

5. Expose

Presentation by the students in the group, expressing their own opinions on the use of nano-

materials as well as the importance of research in nanomedicine. Develop a poster to be presented in plenary.

6. Evaluate

The teacher verifies the extent to which students have achieved sustainable procurement, the finality of default. Share feedback form.

Aimed educational objectives

Aimed educational objectives	Non-formal learning activities
1. Definition and classifgication of nanomaterials	Presenting and describing the characteristics of nanomaterials
2. Identifying the characteristics of nanomaterials	Presentation of materials used in the medical field that are based on technologies like nano
3. Characterization of nanomaterials the appropriate medical applications	Presentation of the two driving mechanisms of the nanoparticles
4. Making structure-activity correlations for different nanomaterials	Differentiation of microscopic preparations / SEM images of the structures involved in hydrophobicity characteristics that determine the self-cleaning property
5. Exemplifying applications of nanomaterials in various medical fields and understand their importance	Listing areas of activity in which nanomaterials are used
6. Written or oral presentation as a result of a responsible research approach, using the terminology of nanomaterials	Presentation of the advantages of using these materials
7. Rationale advantages and disadvantages of current and future technologies for the environment and society	Expressing a personal view to respect for the environment through the use of nanomaterials.

For learning activities proposed under formal activity, it is assumed that students know: Background about nanosciences; minimal notions about nanomaterials: lotus effect, getting nanomaterials in suspensions of plant extracts, what is the internal composition of a leaf, general properties materials and their behavior towards water. The students are instrumented with techniques for handling laboratory instruments and techniques PC user.

Evaluation

Formative assessment of students' concerns (mentioned objectives of this approach):
a) Training of communication skills, networking
b) Formation of skills to use laboratory instruments
c) Acquisition of knowledge about nanomaterials
d) Formation of a responsible attitude towards research in the field and to scientific research in general.

Evaluation strategy:

1. Predictive Evaluation will be done at the beginning of the work, targeting student's knowledge and skills as prerequisites to acquire new knowledge and the formation of new capacity.
2. Formative assessment will be found throughout non-formal activities as follows:

- Oral questionnaires,
- Through systematic observation of activities of students (measurements, notations manipulation of instruments, proposed sequencing protocol compliance, measurements etc), by check of the data collected through systematic observations of student behavior during the proposed activities and progress during the students' personal activities through investigation.
- The formal work products (power-point presentation, Facebook account).

3. Summative assessment - is present formal end of the activity, self-assessment, peer and written questionnaires.

Assessment tools

Instruments used for evaluation are:

G1 – Grid (self-) evaluation of the experiment

No.	Evaluation criterion	Grades		
		Satisfactory	Good	Very good
1.	The arrangement of the materials used	- materials needed to run the experiment are incomplete and randomly arranged	- materials needed to run the experiment are present on the working table, but they are randomly arranged	- all materials are present on the working table and are properly arranged
2.	Compliance with the labour protocol	Steps of experiment does not follow the order of protocol	The steps of experiment are undergone hesitantly, in late, but correctly	Experiment steps are followed and manipulation instruments is made without hesitation
3.	Filling tables / grids / Worksheets	The data contain errors	The data are correct but incomplete	The data are complete and correct.
4.	Establish the conclusions (data interpretation)	No conclusions after the completion of the experiment	Not all the conclusions of the ongoing experiment are present	The conclusions are clear and comprehensive
5.	Cooperation within the group	Very low	Relatively good, sometimes unproductive	Very good, productive

G2 - Teamwork observation

4	3	2	1
Personal contribution			
He presents useful ideas during team work or in class discussions, stimulating the participation of colleagues. He contributes significantly to the success of his work.	He presents useful ideas during team work or class discussions. He tries his best for what he has to do	Shows some useful ideas during team work or class discussions. Never refuse to work	Rarely shows useful ideas during team work or class discussions. He may refuse to work
Kind of verbal interaction			
Listen and speaks balanced	Listen but sometimes talks too much.	He talks all the time and rarely allows someone else to speak	Talk all the time and do not allows anyone to speak
Conflicts			
He never has conflicts with colleagues and contribute actively to prevent or solve them.	Never has conflicts with colleagues.	Rarely has conflicts with colleagues	He has frequent conflicts with colleagues
Problems solving			
Active search and propose solutions to the problems in question	Upgrade solutions presented by colleagues.	He doesn't suggest any solutions but he is willing to experiment solutions proposed by colleagues	Doesn't solve problems nor help their peers to solve
Time management			
Manage time well and draw conclusions in the available time limits	He tends to delay conclusions but manages to fit in the time available. The group should not postpone handing results	He tends to delay conclusions but manages to fit in the time available but the quality of work is affected by his behaviour	No end in the time available and group limits must postpone handing results

G3 – Grid (self-) evaluation on PowerPoint Presentations

No.	Activity	Evaluation criterion	Grades		
			Satisfactory	Good	Very good
1.	Making power-point presentations	Ability to comply with the proposed plan	Meets 20% of the plan	Meets 70% of the plan	Meets the plan
2.	Conclusive data	Proper use of the data.	Data errors in 50% of slides	20% of slides with redundant data	Presents conclusive data to over 80% of slides
		Using relevant data	50% of slides have data less relevant	20% of slides have data less relevant	Relevant data
3.	Scientific reasoning used in interpreting data	The use of logical reasoning	Data present, but no interpretation	Interpret data correctly in 50% of cases	Interpret data correctly in 80% of cases
		Rationale reasoning	Presentation of ambiguous reasoning	Presentation reasoning, but hesitant argument	80% argumentation with evidence of the use of reasoning
		Correct interpretation of the data	Inaccurate or misinterpreted data in 40% of cases	Accurate, but misinterpreted in 20% of cases	Correct interpretation of the data requested statements
4.	Conclusions set-up	The existence of clear conclusions and suggestions	There are opinions, but not shown in the end	The conclusions are present, but are rendered in an unsafe way	Conclusions clear, obvious, logical

G4 - Grid for assessing group products (essay / poster)

Performance criterion	**4**	**3**	**2**	**1**
Content (coherence, consistency, fairness, logic)				
Originality / creativity				
Design				
The oral presentation of the product				

Feed-back questionnaire

Dear students!

Thank you for your participation, we invite you to answer a few questions about the impact this activity had on your.

1. Do you consider that the specific steps of research and responsible innovation should be included explicitly in the context of Science lessons (Chemistry, Physics, Biology)?

To a very great extend	To great extend	To a moderate extend	To a small extent	In a very small extent

2. Do you ppreciate the activity that you attended today as interesting for you?

To a very great extend	To great extend	To a moderate extend	To a small extent	In a very small extent

3. Do you consider that the experiments were interesting for you?

To a very great extend	To great extend	To a moderate extend	To a small extent	In a very small extent

4. Do you wish to attend to this kind of activities again?

To a very great extend	To great extend	To a moderate extend	To a small extent	In a very small extent

5. Today I learned about.....

.....

6. I like it more when .....

.....

7. I would like to know more about .....

.....

.....

8. In today's activities were discussed related items:

RRI principles	Yes	No
Involvement - highlighting the role of all social actors (researchers, teachers, students etc.) in research and responsible innovation process		
Gender equality – ensure optimal representativeness of women (students, researchers and teachers) in research and innovation.		
Science education – handling students with a set of knowledge and skills necessary for responsible participation in the research and innovation.		
Accessibility - ensuring transparency and open access to research results and innovation in order to boost their capitalization and adequate social level.		
Ethics - respecting and valuing ethical principles in research and innovation process.		
Governance - students must realise the role that policymakers have in terms of prevention / combating of research and innovation efforts that disregard ethical principles and bring social harm.		

4 Sources

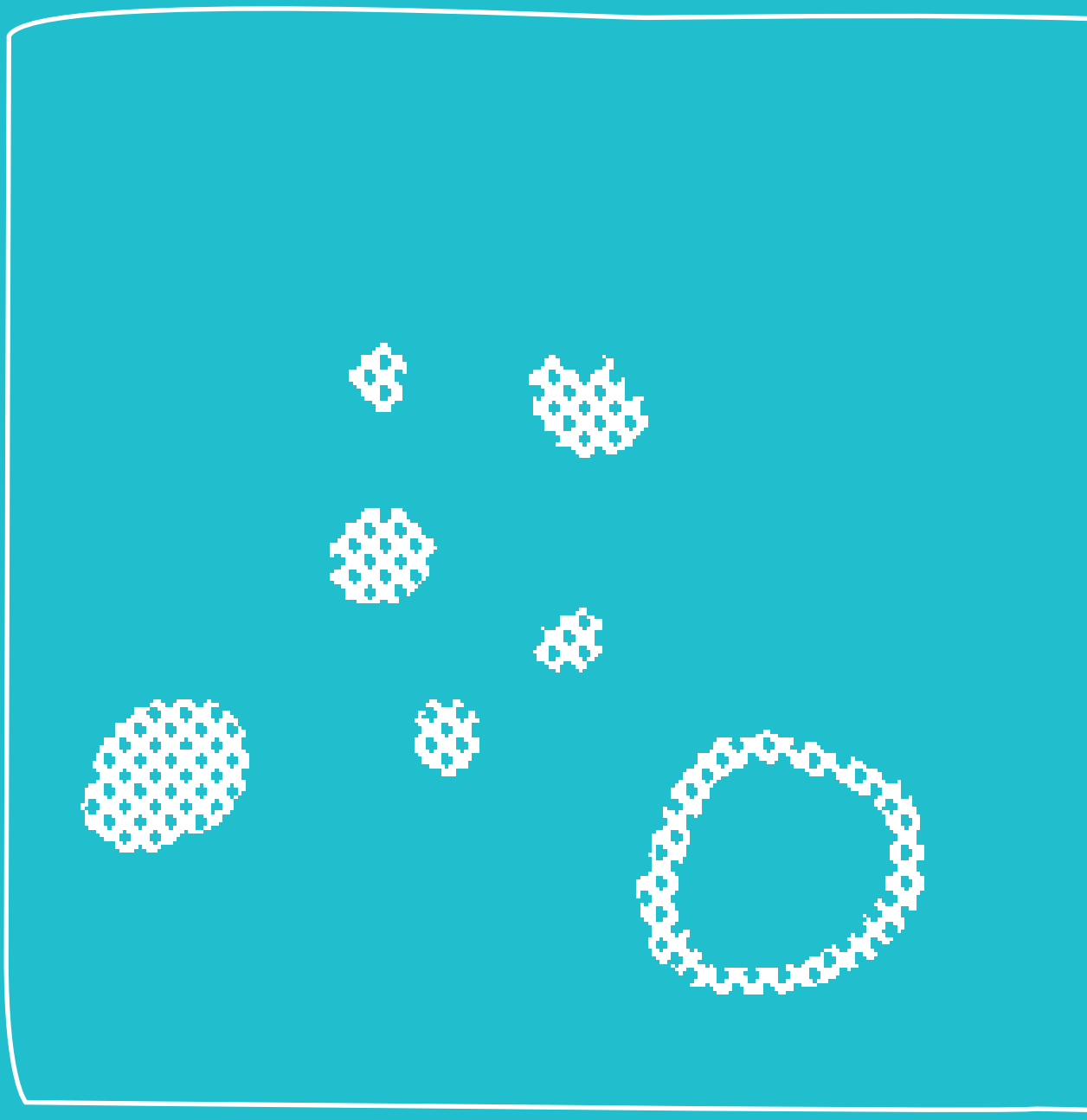
Sources

1. Internal imaging of human body (pag. 2) - Image source: http://nanotechnology4today.blogspot.ro/2010/10/internal-imaging-of-human-body.html
2. R.M.Ion, R.C. Fierascu, and I. Dumitriu, Photonic metallic nanostructures in photodynamic therapy, Advanced Topics in Optoelectronics, Microelectronics, and Nanotechnologies IV, Proceedings of the SPIE, 7297, pp.72970H-729723 (2009)
3. R.M. Ion, New trends in photodynamic therapy-review, in "Aspects of Photodynamic medicine" Biomedicine Engineering Acta, 3/2008, pp.123-159, H.Podbielska, A.Sieron, W.Strek, (Eds.), Wroclaw, Poland, 2008
4. R.M.Ion, L. Maresca, D. Migoni, F.P. Fanizzi, Porphyrin - Cis-Platin drug system for HeLa cells photodynamic, International Journal On Advances in Life Sciences, 1(1), 2009, pp.36-45
5. R.M. Ion, D. Munteanu, Nanotechnology - Nanorobotics - Nanomedicine, METALURGIA INTERNATIONAL vol. XIV (2009) 43-46
6. RM. Ion, G.C. Cocina, TPPS4 Nanotubes Architecture for Nanorobots with Application in Cerebral Aneurysm, Proc. Int. Conf. Bio-Inspired Computational Methods Used for Difficult Problems Solving - Development of Intelligent and Complex Systems, Tg. Mures Romania and Romanian Academy Bucharest Romania, pp. 207-215, 2008
7. A. Cavalcanti, B. Shirinzadeh, T. Fukuda, S. Ikeda, Hardware Architecture for Nanorobot Application in Cerebral Aneurysm, IEEE - Nano 2007 Int'l Conf. on Nanotechnology, 2007
8. A.H. Faraji, P. Wip, Nanoparticles in cellular drug delivery, Bioorganic and Medicinal Chemistry, 17(8), 2009, pp.2950-2962
9. D. Munteanu, R.M. Ion, G.C. Cocina - Comparative Study Of Single- And Multi-Wall Carbon Nanotubes With Application In Cerebral Aneurysm, BRAIN. Broad Research in Artifficial Intelligence and Neuroscience, ISSN 2067-3957, Volume 1, October 2010, Special Issue on Advances in Applied Sciences.
10. R.M. ION, D. MUNTEANU, G.C. COCINA, Concept of artificial neural network (ANN) and its application in cerebral aneurism with multi walls, carbon nanotubes (MWCNT)" Proceedings of the 10th WSEAS International Conference on NEURAL NETWORKS (NN'09), Prague, Czech Republic, 2009", pp. 104-107.
11. D. Munteanu, R.M. Ion, NANOMATERIALE CU APLICATII IN VITRO LA ANEVRISMELE CEREBRALE", "PRIORITATILE CHIMIEI PENTRU O DEZVOLTARE DURABILA PRIOCHEM, SINAIA, p. 98, ICECHIM, Bucuresti, 2009

5 Colophon

Colophon

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

www.irresistible-project.eu

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