INVESTIGA I+D+i 2017/2018

SPECIFIC WORK GUIDE ON “NANOTECHNOLOGY AND HEALTH”

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Introduction

Nanoscience, nanotechnology and new materials have been one of the five strategic lines of every edition of the Investiga IDI Program (http://www.programainvestiga.org/). This is due to the fact that thesesubjects have become key areas in the present and future research of the most developed countries in the world, and due to their sharp socioeconomic impact. It can be mentioned here that already 17 years ago in the United States, the National Nanotechnology Initiative (NNI, http://www.nano.gov/) was launched, whose purpose was to achieve that said country were a world leader in the application of nanotechnology in many sectors. What is more in the European Union, nanoscience and nanotechnology have been a strategic research axisboth for the 7th Framework Progamme and the Horizon 2020 Programme.Other regions and countries, such as China, Japan, Russia, Brazil, etc., have appeared with great impetus on the world panorama and invest many resources on researchon these subjects. We can mention that China now leads scientific production in nanotechnology.

One characteristic of nanotechnology is itstransversal nature; that is to say that it can be applied to a great variety of sectors, which has made it possible for each edition of the Investiga I+D+I Programto be able to tackle a different aspect. In the past editions, the proposed subjects have been: nanotechnology and smart materials, nanotechnology and its application in sports, the impact of nanotechnology in agriculture, food and cosmetics, nanorobots, the fascinating and versatilegraphene, nanotechnology to wear, the relation between nanotechnology and theimplementation of smart cities and, in the past year, the subject approached was how nanotechnology is going to serve for sustainable development. There are fewer and fewer themes left, but there is one, a star subject, which has yet to be tackled.

On this occasion an aspect of nanotechnology of great social impact is proposed, which allows completion of the subjects which have been dealt with in the previous editions: “nanotechnology and health”. In this way the work which will be presented by the participants of the Program will have to carry out an analysis of the meeting points(not necessarily all of them) between nanotechnology and our health. The purpose of choosing this subject is to achieve that the participantsdelve into the fascinating world of nanotechnology, identifying its peculiarities, showing its huge potential for generating new materials, medications and devices which can help improve human beings' health, prolonging their life in better conditions. Moreover, another equally important aim is to make the participants see that nanotechnologyalso has a less positive side, as occurs with every technology. Automobiles, chemical products and nuclear power plants are examples of technologies which have contributed progress to humankindbut which implicitly carry many risks, which we must manage adequately, in order to weigh up the benefits and risks in the end, and thus decide upon the way in which they must be used and the regulations they must be submitted to. In the case of nanotechnology it is known that certainnanomaterials are potentially dangerous for health and the environment. It is very important that the use of nanotechnologies be as safe as possible for everyone, so there are studies being carried outaiming for them not to be perceived as a threat to society, thus slowing down expectations about their development. It is important that the papers done by the participants bear in mind this duality (the benefits and the risks) especially in this edition in which the subject of health is being dealt with.

In short, in the line of this subject there is the opportunity to try to take advantage of the fascination evoked by the tiny in order to promote curiosity for science, increase knowledge about the technologies which are going to surround us in the middle-long term, and encourage the critical spirit of the participants, who will be the citizens of the future of our country, some of them as consumers and users, others as entrepreneurs, others as research scientists, and a few perhaps as political leaders.

In the second section of this document, the main aspects which characterize nanotechnology will be reviewed. The third section focuses on outlining several ideas about the subjectproposed in this edition of the Investiga I+D+I Program (the connection between the "nano" and health). The fourth sectionraises a series of questions and particular themes which can be used for debates in the classrooms and to participate in the Open Forum of the Investiga I+D+I Program. The ideas which are exchanged betweenthe participants will be the seed for the papers which the students will develop later on. The fifth sectionprovides some advice about the elaboration of the papers. This document ends with a small set of references which can be useful in order to plunge into the subject of nanoscience and nanotechnology as well as into the connection of nanotechnology with health.

Nanoscience and Nanotechnology: key aspects

What is “nanoscience”? In a simple way, “nanoscience” can be defined as the structured accumulation of interconnected knowledge which makes it possible to understand how nature works when it is observed on a tiny scale, the so-called “nanoscale”; that is to say, when objects are observed with a size of a fewnanometers and their properties are studied. By the way, a nanometer is a really small unit of length: 1 nanometer equals 0.001 micrometers or microns, 0.000001 millimeters, or 0.000000001 meters. The same chain of equivalences can be written using scientific notation:1 nm = 10-3µm = 10-6 mm = 10-9 m. It is evident that the prefix “nano” (from the Greek “nanos”, dwarf) is used to refer to small but ever so small things.

On the other hand “nanotechnology” goes beyond nanoscience, and aims to convert the basic knowledge which the latter provides us with in relation to the new properties of the materials in order to improve the currentgoods and products or propose other radically new ones. In this way it is clear that nanotechnology essentially has to do with the application of the knowledge which stems from nanoscience. The generation of knowledge requires great investments which can turn profits if said knowledge isset into motion. The generation of knowledge is developed fundamentally at universities and research centers, while the application of knowledge will have to be developed attechnology centers and companies.

It is often thought that nanoscience and nanotechnology are modern or almost futuristic terms, which we bump into in comics, films, novels or television series. However, they are not so new since nanoscience research has been carried out at research laboratories for nearly fifty years now. Way back in 1959, Physics Nobel Prize winner Richard Feynman anticipated many of the concepts and instruments which are currentlyhandled in this fascinating discipline. However, it is true that it has been in the last 15-20 years when nanoscience and nanotechnology have experienceda spectacular boost by governments, institutions and companies, which have realized their huge possibilities. I will mention as an example that the first initiative of great dimensions to promote nanotechnology was launched in the United States and was called the “National Nanotechnology Initiative” (http://www.nano.gov/). This interest has led to huge investments with which new laboratories have been started, expert scientists and engineers in these subjects have been trained, prototypes and demonstrators have been made, etc. Given that the term “nanotechnology” is the one that has had the most impact on the media and on society, from now on it will be the one used in this document to refer both to the basic aspects andthe applied ones.

The nanoscale, which is also usually called “nanoworld”, is a setting inhabited by different types of “nano-objects” and “nanostructures”, among which we can include atoms, molecules, nanoparticles, carbon nanotubes, graphene, metal nanowires and semiconductors, DNA strands, proteins, ribosomes, viruses, etc. This “nanofauna” is interesting because itexhibits a series of phenomena which would not be demonstrated if their size were much larger. This is what gives everything “nano” a great added value with regards to the “micro” or the “macro” and that is why it is said that the “nano” is different. Why would there be interest in the small, from a technological standpoint, if there weren’t a high added value?

But why do these new properties appear? There are several reasons. On the one hand, it is know that the atoms on surfaces behave differently to atoms which are found inside the object, since they have different surroundings. As an object becomes smaller and smaller, it is observed how the proportion of atoms on the surface becomes greater and greater. For example, in a nanoparticle 100 nm in diameter, 1-2% of its atoms are on the surface, while in a nanoparticle of 3nm that percentage grows to approximately 60%. You can say that the 3 nm nanoparticle is more a surface than a volume. Therefore, as an object gets smaller, the weight of the surface properties starts to become more and more important and the role of the atoms inside is less relevant.

However, it is not just about the importance of surfaces, but rather, moreover, as the size of objects becomes smaller and smaller, other phenomena appear which only the intriguing Quantum Mechanicscan explain. Quantum Mechanics must be understood as the “manual of laws and rules” which scientists have written in order to understand nature, rules and laws which explain how molecules and other more and more complex objects are formed, and how these objects react when facing mechanical deformations, electric fields, magnetic fields or light. But there is no need for alarm since the participants of the Investiga IDI Program are not going to have to study thefundamentals of thisexciting discipline (only those who study physics, chemistry, or electronic or telecommunications engineering later onwill be able to deepen their knowledge of it). For now, they must know that a series of “quantum” effects appear in nano-objects which provide them with interesting properties. For example, the quantum effects cause that the electrons moving around inside a nanoparticle can only have certain energies, which we call permitted energy levels. Furthermore, as the nano-object becomes smaller, the permitted values for these energies change. As a consequence, many electric, magnetic or optical properties which depend on these energy levels are also modified as the size of the object changes. For example, the nanoparticles of certain semiconductor materials change color as their diameter grows, running through nearly the entire range of colors of the rainbow.

The effects which have been previously mentioned are called “size effects” and they are rather disturbing, since for each size and shape a nano-object has, it shows different properties. This, which seems like mayhem, is in reality the great strength of nanotechnology: if you control the size and shape of a nano-object, you can control its properties and we are thus in a position to take better advantage of them. The idea is fascinating. Therefore, the final aim of nanotechnology is to control, by means of physical and chemical methodologies, the shape, size and internal order of nano-objects and nanostructuresin order to freely modify their properties. For example, controlling the size and shape of nano-objects, you can modify theirelectrical conductivity, their color, theirchemical reactivity, their elasticity, etc. It is said that we canmanufacture “made-to-measure materials” or that we can “calibrate” (or “tune”, in young people’s slang) the properties of materials at will. This control of matter at a nanometric scale is continually improving thanks to powerful physical tools and new chemical reactions, which make it possible to manufacture nanodevices andsynthesize nanomaterials. Moreover, sophisticated instruments allow us to observe what is happening in the nanoworld. Among these instruments we can highlight the newtransmission electron microscopes, the scanning tunneling microscope (STM), the atomic force miscroscope (AFM) or the powerful latest-generation electron microscopes. These tools allow for observation and in some cases even the direct manipulation of atoms and molecules. For nearly 25 years now, human beings have already known how to manipulate atoms, one by one, to make small artificial structures. Nanotechnology has grown up before our very eyes and it can be said that it will soon reach adulthood!

The ideas and tools which are used in nanotechnology are evolving non-stop thanks to the contributions made by biologists, chemists, physicists, engineers, mathematicians and doctors. Nanotechnology is an absolutely multidisciplinary field, open on many fronts. This is so because the components of matter, atoms and molecules, are the same for all of these scientific specialities. On the nanoscale, we all use the same fundamental “bricks”: atoms and molecules. Said fusion of disciplines is called “technological convergence”. Nanotechnology is a great process of convergence which is currently still being forged. Furthermore, it should not be forgotten that biology plays a key role within nanotechnology, since life is in itself pure nanotechnology. All you have to do is observe the inside of a cell to realize that it carries out all of its functions thanks to “nanometric machines”, which operate perfectly thanks to the very long evolutionary process. Moreover, biology presents to us before our very eyes a great arsenal of solutions and strategies which allow us to solve specific problems. Biology isan endless source of “bioinspiration” which can deliver solutions to problems which appear in other areas such as the science of materials or chemistry.

To finish this long introduction, it must not be forgotten to mention that the “nanoproducts” conceived from nanotechnology are gradually invading the economic sectors in their entirety: materials, electronics, information technologies and communications, energy and environment, transport, construction, the textile sector, biotechnology, health, agriculture, food, etc. Nanotechnology is now starting to become a big business and it can be asserted that the future will be “nano”. In this new context, it is very important to bear in mind the possible side effects (generally negative) which the advances in nanotechnology might have. These possible negative impacts are not exclusive to nanotechnology;every technology has its friendly face and its dark side: nuclear energy, thermal power plants, vehicles, airplanes, etc. It is very important to be informed about the pros and cons of each technology so that, as educated, critical citizens, we can know the implications of all sorts which nanoproducts might have, and thus demand for there to be adequate rules and regulations to guaranteemanufacturing, commercialization, consumption and recycling safe both for people and the environment.

Nanotechnology and health

Health surely continues to be the main subject of concern for most human beings and it partly conditions their perception of wellbeing. Throughout the 20th century, medicine incorporated knowledge proceeding from other scientific branches, managing to improve the techniques ofdiagnosis and treatment. Physics and engineering have contributed instrumentation and equipment which are familiar to all of us: optical and electron microscopes, radiographs via x-rays, nuclear magnetic resonance, systems to carry outultrasounds, pacemakers, laser surgery, etc. The science of materials made possible the development of new implants. For their part, biochemistry and chemistry have made it possible to understand a great many processes which take place in our organism, have developed precise analysis techniquesand have provided us with a great amount of pharmaceutical products. The result has been a generalized increase in life expectancy, especially in the most developed countries, in which moreover there has been an aging of their population, making it necessary to increase the healthcare expenditure and redefine the aims of the healthcare systems.More recently medicine, always open to contributions from other scientific fields, and nanotechnology haveapproached one another to constitute what has come to be called nanomedicine, a term which refers to the entire array of knowledge and technologies related to the nanoscale which are taken advantage of to improve diagnoses, treatments and disease prevention. We will revise these three aspects in this section of the document.

New diagnosis systems

One of the aims of nanotechnology is the development of simple, fast, precise diagnosis systems by means ofin-vitro analysis (in which the sample is removed from the patient to be analyzed in a laboratory). These systems will be able to determine multiple indicators from small quantities of the sample, thus facilitating a swift diagnosis. Many of these analyses will be carried out using small biosensors developed through nanomanufacturing techniques. These biosensors will be able to detect fragments ofstrands of nucleic acids, enzymes, antibodies, proteins, viruses, bacteria, etc.so they will be able to be used in biology, medicine, environmental sciences, agriculture, food and security. Nanotechnology is fostering new strategies for the design of biosensors, like the ones based on quantum dots conveniently functionalized to determine the presence of a certain substance or like the ones based onmicrolevers which are used in atomic force microscopes. In the past decade intensive use has been made of another type of biosensor, the so-called DNA biochip (or microarray). At present, biochips typically consist of detection units less than 100 nm in diameter, and some detection units have even been developed consisting of individual molecules.

Nanotechnology is also expected to have an influence on different types of diagnoses based on imaging. The ultimate aim of these techniques is to provide images on a molecular scale of the different structures which make up tissues and organs, both of healthy ones and throughout the different phases of an illness and its treatment. Many diagnostic imaging techniques require the use of contrast agents and nanotechnology is now managing to reduce them to sizes previously unimaginable. For example, nuclear magnetic resonance makes it possible to obtain a contrast between tissues of different composition, but said contrast can improve substantially if magnetic nanoparticles of iron oxideare used as a contrast agent, which once functionalized are able to recognize and bind with certain biological targets, proteins or cells which are associated with a specific illness.

New therapies and treatments

The treatments of diseases will also be affected by the contributions of nanotechnology. Nanotechnology will improve the strategy called controlled drug release, by means of which theactive principle one wishes to have reach a specific area suffering an illness joins a transport system which runs the drug release in the right place. In this case, the medication moves through the bloodstream or thecytoplasm until reaching its destination for the total or partial release of the active principle. The nanometric-sized transport and drug-release systems which are being developed are based on different nano-objects: micelles, liposomes, dendrimers, nanoparticles, fullerenes, carbon nanotubes, the so-calledpolymer combinations or modified viruses. Currently several hundred medications are commercialized which use diverse types of vehicles for their administeringvia different paths. If the same nanoparticle ornanometric entity which carries the drug can be used to make the diagnosis (through Nuclear Magnetic Resonance), you would speak of “theragnosis” (a mixture between therapy and diagnosis).This has been a trendy concept over the past few years.

Besides these medications, nanotechnology opens new opportunities as occurs in the case of thermal therapies based on the use of nanoparticles. Let’s suppose that we have a magnetic nanoparticle which has been functionalized so that it loses its possible toxic nature and incorporates some biomolecule able to detect and bind with a specific biological target. Now let’s imagine that by means of powerful magnets, we can guide these nanoparticles through the inside of the organism to the tissue or organ where the tumor is which one wishes to attack. Once the nanoparticles reach the target, we can apply controlled doses of electromagnetic fields which cause the swift heating of the nanoparticles. This local increase in temperature eliminates the diseased tissues in that location due to the denaturing of the proteins which make it up.

Implants

Another application of nanotechnology is its ability to provide new biomaterials which facilitate the regeneration of tissues. Nearly 40 years ago, the first biocompatible materials started to be synthesized based on ceramic or composite nanostructured materials which did not trigger the rejection of our immune system. These biomaterials, with great mechanical resistance and a long half-life, were used in bone or dental implants. We can highlight the biomaterials manufactured fromaluminum, zirconium or zinc oxides. Many of them are still being used and have been improved thanks to the incorporation of carbon nanotubes or other types of nano-objectsfor the purpose of increasing the half-life of the implants. In addition, the nanomaterials can incorporatebactericidal nanoparticles or are able to release other substances (like growth factors),causing the implants of the future to be much more efficient. Moreover, the implants will be equipped with certain devices which will be able to measure how their adaptation evolves, their degree of deterioration, etc.

The applications of nanotechnology in medicine go beyond the ones already presented and can also be found inbandages, surgical supplies, and lighting equipment inoperating rooms. You can also talk about the impact of nanotechnology on food, a subject which is connected to health, after all.

Not everything is so positive

As already mentioned previously, nanotechnology hasa dual nature, which must also be taken into account when speaking about the subject of health. On the one hand, nanotechnology promises huge, revolutionary possibilities, but on the other, it presents some risks which must be known in order to control them. At the present time, we are witnessing the first phase of the insertion of nanotechnology into our lives either through sophisticated nanoelectronic devices or through a series of unsophisticated products based on nanoparticles, carbon nanotubes and other types of nanomaterials. Although it is true that generally speaking, the nanomaterials used cannot be easily freed up from the products they are a part of, it could happen that this release occurs gradually, throughout the products' useful life or once they have beendiscarded. Are these nanomaterials dangerous? Do they accumulate in our body or in that of other animal or plant species? What effects would be produced by said accumulation? In general, nanomaterials are manufactured from substances harmless to living beings and the environment, follow current regulations and have the required authorization for their manipulation. However, these regulations refer to conventional materials, and we already know that matter in a nanometric format displays properties different to the ones it has on themacroscopic scale. Therefore, there is no absolute certainty about the effects of these nanomaterialson our environment and our health, and nothing can be asserted concerning its harmlessnessuntil the relevant studies have been carried out. This aspect of nanomaterials must be taken into account for the future commercialization and social acceptance of nanotechnology.

Subjects to reflect upon, debate and develop in the papers

As we have seen in the previous section, nanotechnology can develop into nanomedicine, a disciplinewhich can have a great impact on our health, but some nanomaterials can have negative effects on the health of workers and users. We find ourselves once again before the dual nature of a scientific advance. With everything that we have read so far, it is clear that the participants in this edition of the program can ask questions like the following ones, with the aim of establishing the lines of work:

- What is nanotechnology?
- Which matters do we include when we speak about health?
- Which advances in nanotechnology have an impact on medicine?
- How will nanotechnology affect the development of disease diagnosis systems?
- How will it affect the treatments of diseases such as cancer, AIDS or Alzheimer's?
- Are nanomaterials used as markers? What kind?
- Will nanomaterials have an impact on the design of implants?
- Will these be smart implants?

- Will nanomedicine be available to the entire world, or is it only reserved for rich countries?
- Are there many nanodrugs out on the market?
- Are diverse types of nanomaterials harmful to the environment or to people?
- Are they all dangerous or just some of them? Will the negative effects depend on the concentration?
- What effects can they have on health?
- Can they accumulate in our body?
- Are they more dangerous for the workers who manipulate them or for consumers?
- Can the nanomaterials which we create accumulate in the environment?
- What can be done so that nanotechnology is introduced without risks?

General advice

It is recommended to bear in mind the following guidelines:

- Carry out the paper trying to focus on the proposed subject, avoidingelaborating on other themes which also have to do with nanotechnology.
- The paper must focus on the connection between nanotechnology and health.
- The paper must be specific, not very long, avoiding too lengthy introductions to nanotechnology.
- As you can see, there is a lot to the subject, so it is better to concentrate on some specific aspects (diagnosis, therapy for certain diseases, a certainfamily of implants, etc.)
- Structure the paper in well-differentiated sections and sub-sections.
- Write clearly, without spelling mistakes and with good syntax.
- Avoid plagiarizing other works or websites. “Cutting and pasting” is not allowed. Phrases quoted literally must be in quotation marks and their source must be conveniently cited.
- Make a good selection (it needn’t be very long) of references.
- Includephotos, graphics or pictures (citing their source) only if they are related to the written text.

- Do not include the set of pictures at the end. You have to attempt to insert each image or photo in the place where it corresponds with its caption.
- If it is possible, it is recommendable to include some activity or experience of your own: surveys and their analysis, an interview with researchers, a description of laboratory visits, experiments carried out in the classroom, etc.
- It is also important to include reflections and opinions of your own (sufficiently reasoned) in the paper.
- The authorship must be clear in the document (preferably on the first page, next to the title) as well as the school or institute of origin.

References and support materials

Before listing some references of possible use, it must be mentioned that an Internet browser can find tens of millions of sites related to nanotechnology. In this as in other subjects, there is a surplus of information and, therefore, you must be cautious when choosing the most suitable sources of information, this phase being of great importance to correctly carry out the research work. The references which are shown are related to nanotechnology in general and some have been added related to the subject of nanomedicine. The search for more specific references about the proposed themes is part of the work which each participating student must develop. These references, together with the ones which appear in the forum, are just the starting point of a long road which will last several months. Good luck!

Links related to the subject "Nanotechnology"

- Guides prepared in previous editions of the Investiga I+D+iProgram for the subject of Nanotechnology, together with the presentations carried out by the student finalists, can be downloaded at:
  - http://www.fundacionsanpatricio.com/investiga/pdf/Guiananociencia.pdf
  - http://www.fundacionsanpatricio.com/investiga/pdf/guias2011/GUIANANOTECNOLOGIAPARALAALIMENTACIONYELCONSUMO.pdf

- http://www.fundacionsanpatricio.com/investiga/pdf/guias2012/GUIA_NANO-ROBOTS.pdf
- http://www.fundacionsanpatricio.com/investiga/pdf/nuevosmaterialesparaeldeporte.ppt,http://www.fundacionsanpatricio.com/investiga/pdf/PresentacionNanotecnologia.ppt
- http://www.fundacionsanpatricio.com/investiga/pdf/LINEA%204%20-%20NANO.ppt
- http://www.fundacionsanpatricio.com/investiga/pdf/guias2014-15/GUIA4_INTRODUCCION_NANOTECNOLOGIA-NANO_QUE_LLEVAMOS.pdf

- "Unidad Didáctica de Nanociencia y Nanotecnología" ("Didactic Unit on Nanoscience and Nanotechnology) (J.A. Martín-Gago, E. Casero, C. Briones y P.A. Serena, FECYT, 2008).Available free in the digital version on the website http://www.fecyt.es or at the address http://www.oei.es/salactsi/udnano.pdf
- P.A. Serena's presentation on nanotechnology (PowerPoint). Available at http://www.fundacionsanpatricio.com/investiga/pdf/presentaciones2013-14/PresentacionNanotecnologia-AutorExpertoPedroSerena.ppt
- P.A. Serena's presentation on nanotechnology (PDF). Available at http://www.fundacionsanpatricio.com/investiga/pdf/presentaciones14_15/PresentacionNanotecnologiametodologiasymaterialesparaelaula.PedroSerena.pdf
- "¿Qué sabemos de la Nanotecnología?" ("What do we know about Nanotechnology?") (P. A. Serena, Editorial La Catarata andthe CSIC, Madrid, 2010).
- "El nanomundo en tus manos" ("The Nanoworld in Your Hands") (J.A. Martín Gago, C. Briones, E. Casero and Pedro A. Serena, Colección Drakontos, Editorial Crítica, 2014).
- "La nanotecnología.Explorando un cosmos en miniatura" ("Nanotechnology. Exploring a Miniature Cosmos"), A.J. ACOSTA JIMÉNEZ (RBA, Barcelona, 2016).
- "¿Qué sabemos de los riesgos de la Nanotecnología?" ("What do we know about the risks of Nanotechnology?")(M. Bermejo and P. A. Serena, Editorial La Catarata andthe CSIC, Madrid, 2017).
- The National Distance Education University (UNED) and the CSIC collaborate on the broadcast of the TV series "¿Qué sabemos de la nanotecnología?" ("What do

we know about nanotechnology?"). This series consists of 17 episodes which can be accessed through the link https://canal.uned.es/serial/index/id/875

- The European Union has started up several initiatives related to the dissemination of Nanotechnology. One of the most important ones is NANOYOU, where you can find resources in English and in Spanish for secondary education teachers and students (http://nanoyou.eu/)
- On the website http://www.nanotechproject.org/inventories/ there is an inventory of Nanotechnology products (PEN project) in which nearly 2000 products are already mentioned which contain some type of nanocomponent.
- Another inventory of products (over 5000) at http://product.statnano.com/
- And yet another inventory (over 2000) at http://nanodb.dk/
- The beauty of the nanoworld can be observed in picture gallery finalists of the international contest SMPAGE, co-organized by the CSIC and the Universidad Autónoma de Madrid (http://www.icmm.csic.es/spmage). These galleries are of free use and can be used to illustrate papers or in class.
- The daily newspaper "El Mundo" has a complete section devoted to nanotechnology full of news, articles and interviews. http://www.elmundo.es/elmundo/nanotecnologia.html
- In Spain, a great many research groups that work on the subject of nanotechnology are grouped in the Red Española de Nanotecnología (NANOSPAIN) (http://www.nanospain.org).
- National Nanotechnology Initiative of the United States (NNI, http://www.nano.gov/)
- Nanotechnology in the Horizon 2020 Program of the European Union (http://ec.europa.eu/research/industrial_technologies/nanoscience-and-technologies_en.html).
- "WTEC Panel Report on Nanotechnology Research Directions for Societal Needs in 2020 Retrospective and Outlook", September 30, 2010, Editors Mihail C. Roco, Chad A. Mirkin, Mark C. Hersam, WTEC,NSF, United States. (http://www.nano.gov/sites/default/files/pub_resource/wtec_nano2_report.pdf)

- European Nanotechnology landscape report, ObservatoryNANO, 2010, http://www.nanotec.it/public/wp-content/uploads/2014/04/ObservatoryNano_European_Nanotechnology_Landscape_Report.pdf

Links related to the subject “Nanotechnology and Health”.

- ALISIVIATOS, P. (2001): “Nanotecnia en medicina” en Investigación y Ciencia ("Nanotechnia in Medicine" in Research and Science), 302:63-69.
- LECHUGA, L. (2006): “Nanobiotecnología: avances diagnósticos y terapéuticos” ("Nanobiotechnology: advances in diagnoses and therapies") in the magazine Revista Sistema Madri+d, 15:43-52.
- Website of the Plataforma Española de Nanomedicina (Spanish Nanomedicine Platform): http://www.nanomedspain.net
- European Union. The European Technology Platform for Nanomedicine: http://www.etp-nanomedicine.eu/public
- Website on nanomedicine of theUnited States' National Institute of Health: http://nihroadmap.nih.gov/nanomedicine/
- INSHT (2015): Safety and Health at work with Nanomaterials. Instituto Nacional de Seguridad e Higiene en el Trabajo (National Institute of Safety and Hygiene at Work) (INSHT), Madrid, Spain.Available at: http://www.insht.es/
- European Union. Policies about public health and nanotechnology: http://ec.europa.eu/health/nanotechnology/policy/index_en.htm