

2009

PUBLIC DEBATE

Development and regulation of NANO technologies

MINISTRY FOR ECOLOGY, ENERGY, SUSTAINABLE DEVELOPMENT AND THE SEA • MINISTRY FOR THE ECONOMY, INDUSTRY AND EMPLOYMENT • MINISTRY FOR LABOUR, LABOUR RELATIONS, THE FAMILY, SOLIDARITY AND URBAN AFFAIRS • MINISTRY FOR HIGHER EDUCATION AND RESEARCH • MINISTRY OF DEFENCE • MINISTRY FOR HEALTH AND SPORT • MINISTRY FOR FORD AGRICULTURE AND EISHERIES



Scientific progress over the past thirty years has considerably improved our understanding of the world of the infinitely small: on scales of a nanometre (a billionth of a metre), matter has

special properties that the nanotechnolo-

gies seek to exploit. Such properties hold out promise for many applications at the frontiers of physics, chemistry and biology. They are already widely used in computing, especially for information storage, and in the mobile phone sector. They are also being used in more limited, although promising, fashion in many other areas such as building materials, cars, aviation, textiles,

sports equipment, cosmetics and pharmaceutical products. Since this is a new and as yet little understood field, it is important to improve our understanding of the potential impact of nanotechnologies on health and on the environment, and to establish appropriate supervision with regard to both monitoring and controls.

The work of the Grenelle environmental forum has led the Government and Parliament to recommend a public debate about the general options with regard to the development and regulation of nanotechnologies, in accordance with measures that aim to involve the general public with the fundamental policies that will shape the future of our society.

The public authorities, anxious to promote responsible development of such technologies and their applications, therefore wish to take into account the expectations and concerns not only of the various stakeholders but also of the entire general public, in order to decide on the policies that will underpin their action in this matter.

With this in mind, a letter of referral jointly signed by the seven Ministers principally concerned¹ has been addressed to the National Commission for Public Debate (Commission nationale du débat public, CNDP). The Commission has decide to organize a public debate and has entrusted its coordination to a Special Commission for Public Debate (Commission particulière du débat public, CPDP).

This documents sets out in summary form the subject and related issues. These are more fully developed in a file available to the public².



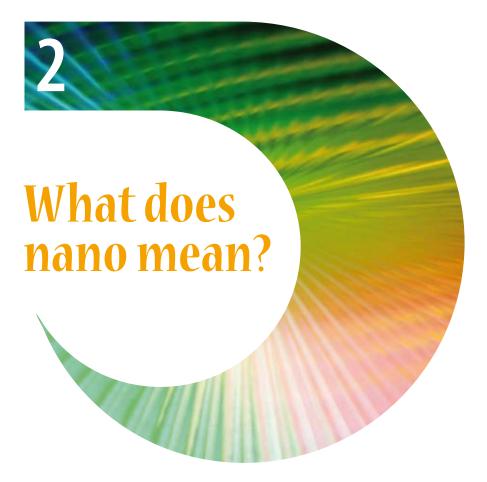
Spider silk

The spider provides us with an example of a natural wonder on nanometer scales. It produces a thread made up of interwoven proteins which combines three qualities: resistance, the ability to stretch, and lightness. This spider silk is more resistant than a steel wire of the same diameter, while being much lighter and more flexible.

² See information file 2009 on the web site: www.debatpublic-nano.org



¹ The Government Ministers responsible for ecology and sustainable development, the economy and industry, labour, research, defence, health and agriculture are jointly in charge of this debate.



Nano comes from the Greek nanos, meaning a dwarf. Used as a prefix before a unit of measurement it means a billionth of that unit. So a nanometre (abbreviated to nm) is a billionth

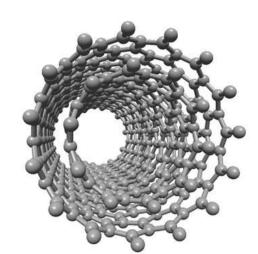
of a metre. By way of example, an object one nanometre across is 500 000 times

smaller than the thickness of a line drawn by a pen.

The nanoparticles and nano-objects developed by nanotechnologies are assemblages of atoms or molecules whose size is 100 nanometres or less. On this scale, matter often has specific physical and chemical properties due to the small size of the objects and to their large surface area compared to their volume. For example, a nano-object

is usually more chemically reactive than its ordinary microstructured (i.e. a thousand times larger) counterpart. It may also have far greater mechanical resistance or thermal and electrical conductivity. Its ability to combine with other molecules can be modified and used, for example, to carry drugs into the body or to capture environmental pollutants.

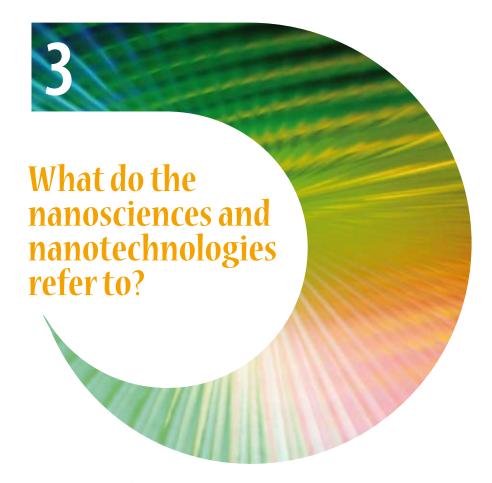
Nanoparticles are generally mixed in small quantities into the mass or surface of existing materials in order to enhance their physical or chemical characteristics. For instance, nanostructured concrete sets three times faster than ordinary concrete, while a tennis racket strengthened with carbon nanotubes is lighter, more flexible and tougher.



Carbon nanotubes

One of the different ways in which carbon atoms can combine are as nanotubes, which are concentric hollow tubes with an internal diameter of around one nanometre. They have variable physical, mechanical and thermal properties, and remarkable characteristics that depend on the size of the tube and on its length, such as great resistance to stretching and to high temperatures, conductivity, absorption, etc.





The terms 'nanosciences' and 'nanotechnologies' first began to be used in the 1980s with, on the one hand, the invention of the scanning tunneling microscope which made it possible to ob-

serve, and therefore better understand, the surface of matter and its properties, and move individual atoms under certain conditions, and, on the other, the synthesis of new objects that were nanometer-sized or smaller.

The term 'nanosciences' refers to any research that aims to understand and make use of the phenomena, physical laws and properties that govern such objects. They constitute a knowledge base of the novel and specific phenomena that take place on this scale. The term 'nanotechnologies'

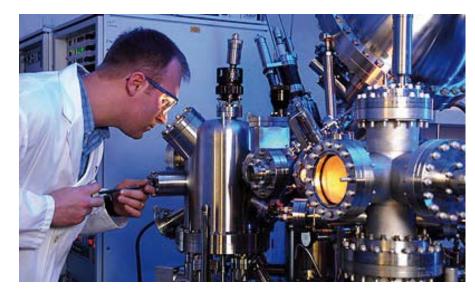
refers to the instruments, production techniques and applications that make use of such phenomena.

The nanosciences and nanotechnologies cover a wide range of knowledge and technologies that fall within many traditional disciplines, such as chemistry, physics, materials science, technology, the life sciences, medicine and environmental sciences. The unifying factor has to do with the size of the objects studied and the tools that enable them to be manipulated.

Major progress has been made over the past twenty years both in characterizing nanoparticles and in synthesizing nanomaterials. Today, controlling matter on nanometre scales is still a scientific and technical challenge, but it is also becoming a major economic issue due to its many potential applications.

Scanning tunneling microscope

The scanning tunneling microscope, invented in 1981, makes it possible to observe and move individual atoms







The specific properties of nanomaterials on which the development of nanotechnologies is based make it possible to contemplate novel applications in practically every sector of activity.

By consuming less material they could

make a direct contribution to sustainable development. They also pave the way to novel solutions to major challenges facing us in the twenty-first century, such as energy storage, the fight against pollution and prevention of infectious diseases.

On a global level, available studies predict a market worth €450 to 1 850 billion by 2015 (in comparison, the world automobile market represented €1 100 billion in 2005). Several hundreds of thousands of jobs in France could depend on this by that date. Such prospects are giving rise to intense global competition, especially with regard to Research and Development. European funds assigned to the nanosciences and nanotechnologies totalled €530 million in 2006 (as compared with \$1.77 billion allocated in the same year by the US). France, which funded its own programmes in this field to the tune of €83 million in 2008 through its National Research Agency (Agence nationale de la recherche, ANR), comes in fifth place in the world with regard

to the number of scientific publications on the subject. In order to strengthen cooperation between laboratories and business and improve their ability to make use of the results of such research on the market, in April 2009 the Government announced the launch of the Nano'Innov plan, endowed with €70 million.

The major areas of research in France that have been given top priority as part of this plan are micro-nano-electronics, biology and health, and energy, as well as the study and control of the possible impact of these new technologies.



One of the most promising fields for the application of nanotechnologies is that of energy: will they help to build a sustainable world?





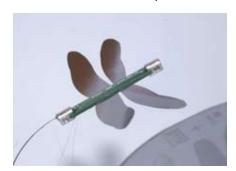
According to a recent inventory, 800 products present on the market incorporate the result of nanotechnology research. Today, none of them are entirely made

up of nanomaterials, but many contain a small quantity that is enough to alter its

properties. In the areas of pollution cleanup (water and soils) and of drinking water, nanoparticles are used because of their high reactivity. In the healthcare field, nanotechnologies are leading to progress in prevention (vaccines), diagnosis (nuclear magnetic resonance imaging, marker analysis), and treatment. Therapeutic strategies are being developed that use the transfer of drugs by nanovectors directly to the areas to be treated, especially in the fight against cancer.

In the fields of electronics and information and communication technology, they make for more rapid access to information and for increased processing power and data storage capacity. There are also applications for national defence and internal security (night vision systems, acquisition and processing of data on objects and individuals, etc). Nanotechnologies can help to strengthen the protection of soldiers (biological and chemical detectors, protective and self-repairing fabrics, etc) and increase the efficacity of weapons systems.

In the food industry, available information indicates that, although nanoparticles are scarcely present in the food we consume (with the exception of silica nanoparticles that have been in use for several decades), such materials are already helping to improve the effectiveness of food packaging. (They could also increasingly find use in the future in food supplements and additives, as is already the case in some countries). Upstream, applications in farming (fertilizers) and animal husbandry (veterinary medicines) are under development.



Finally, many everyday consumer goods already incorporate nanomaterials, such as tyres (longer lifetimes), cosmetics (action against the effects of free radicals), varnishes and paints (anti-corrosion and micro-scratches), sports and leisure goods (lighter and tougher tennis rackets and bicycles), and fabrics (anti-crease, anti stain and anti-odour).

Hummingbird drones

Hummingbird drones illustrate the possibilities for miniaturisation opened up by nanotechnologies, for both civilian and military applications.





The physical and chemical properties of nanomaterials suggest that particular attention should be paid to the undesirable effects they might have on health and the environment.

More than for other substances, it is essential to take into ac-

count not only their chemical composition but also the factors that help to give nanomaterials their specific properties, such as their average size, distribution, shape, surface state, crystal arrangement and ability to aggregate.

When carrying out toxicological and ecotoxicological studies, real exposure conditions as regards dose and frequency should be taken into account. They should in par-

ticular distinguish between cases of repeated exposure through contact with everyday products and equipment and cases of accidental exposure (pollution, accidental ingestion, work accidents, etc).

Preliminary studies on exposure of humans to certain nanoparticles via respiratory, digestive and cutaneous routes have begun. For instance, the toxicity not only of well characterized synthetic nanoparticles, but also of complex mixtures such as air pollutants, has been demonstrated and their mechanism of action analysed. One of the difficulties is that such studies have to reproduce in the laboratory the real conditions of dispersion and diffusion of nanoparticles. Consequently, the tools and methods used to characterise and assess their effects throughout their life cycle, which are those used for more voluminous particles, need to be adapted to deal with nanoparticles. This work is in its initial stages and is still incomplete. It needs to be completed in order to be able to anticipate risks and keep up with the rapid expansion of nanotechnologies and their increasingly diverse applications.

In addition, efforts to improve our understanding of the biological and environmental effects of nanomaterials need to go hand in hand with further thought on monitoring and supervising nanotechnology production.

With regard to protection of workers the necessary legislation already exists, both in the areas of industrial production and use and in research laboratories. The prevention of nanotechnology-related risks comes within the application of French labour law regulations relating to the prevention of chemical hazards (chemical agents that are hazardous or carcinogenic, mutagenic



In 2007, it is estimated that in France between 2 000 and 4 000 workers are liable to be exposed to nanomaterials in production facilities for manufactured nanoparticles.

or have toxic effects on reproduction). Nonetheless, technical and metrological procedures need to be drawn up in order to fully implement this legislation.

Similarly, the safety of foodstuffs containing nanomaterials is controlled via scientific risk assessment by independent health safety agencies and permits delivered by the public authorities, which enables their harmlessness to consumers to be verified before they are marketed.

Nonetheless, it is essential to continue to attempt to improve information about the presence of nanomaterials, as provided for by recent legislation relating to the implementation of measures decided by the Grenelle environmental forum, and to improve our knowledge about measurement of exposure and the effectiveness of protective equipment, which needs to be adapted according to the results of risk assessment.





Like all new technologies, the nanotechnologies raise questions, especially ethical ones, about their potential uses as well as about possible abuses.

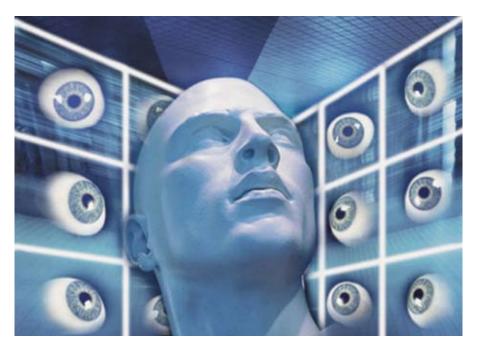
Their predictable development particularly raises questions about their impact on sustainable development: is there not a risk that the reduction in requirements for energy and natural resources caused by their use will paradoxically lead to an excessive consumption of goods and associated services that is little concerned with sustainability and moderation? Is there not also a risk that the control by a small number of actors of the conditions of development and dissemination of nanotechnologies and nanomaterials will widen

certain gaps, for instance between the developed world and the emergent and developing countries?

In the long term, the development of identification and monitoring nanodevices of the RFID (Radio Frequency Identifying Device) type, which are essential in order to meet the growing need for traceability, raises questions with regard both to their judicious use and to the protection of individual liberties: since such devices will have become invisible, might they not be incorporated into everyday objects and be used to collect information which belongs to the

private sphere? Might they not be used to serve reprehensible goals?

Finally, some people predict that the convergence of nanotechnologies with biotechnology, information technology and the cognitive sciences may make it possible to enhance human performance or lead to the creation of 'building bricks of life' that would help to blur the frontier between living, non-living and artificial matter. Even though these are distant prospects, there are currently no theoretical reasons to prevent them coming about, together with all the bioethical issues this would raise.



The convergence of nanotechnologies with biotechnology, information technology and the cognitive sciences (the so-called NBIC convergence) raises concerns and ethical issues: could it not lead to a convergence between life and artefacts that goes beyond the enhancement of human performance, or to the creation of synthetic building bricks of life, or even of artificial life?





Today, the interest shown in nanotechnologies, whether in laboratories, in industry or by the general public and consumers, is a result both of the pressure of internse international

competition and of the need to clear up uncertainty about the potential risks associated with the products and materials which stem from them. The precautionary principle, which in France is a constitutional obligation, governs this debate just as much as the need for information, openness and dialogue with all the actors involved in this developing technology.

The application of this principle should not be allowed to curb the pursuit of progress: on the contrary, it aims to enhance our understanding, clarify choices, control impacts and avoid harmful effects. The research effort in this field, which is backed by the Government, is already moving in this direction.

Three priorities have emerged up until now: it is necessary to speed up the characterisation of nanometre-scale substances and specify how exposure to them occurs, how they spread and the effects this may have on the human organism and on the environment; inform the general public and involve them in prior debate about scientific and technical choices; and continuously adapt legislative and regulatory supervision as knowledge makes progress, incorporating recommendations that result from consultation with all stakeholders.

These three approaches should as far as possible be part of coordinated activity at international level, and should take into account action already carried out in various

countries, as well as by the European and international authorities.

The debate entered into with the general public aims to provide widespread factual information about nanotechnologies to enable as many people as possible to keep up with this rapidly developing field. It will provide information about the public's expectations about hoped-for benefits; their questions about the expected applications, their impacts and possible alternatives; and their concerns and needs for knowledge. From a more technical point of view, the results of this debate should contribute to the work being carried out on standards (ISO, AFNOR) and the European REACH Regulation relating to chemical substances. They will also form a set of references for the pursuit of dialogue with all stakeholders, both in France and throughout the world.







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PHOTO CREDITS

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