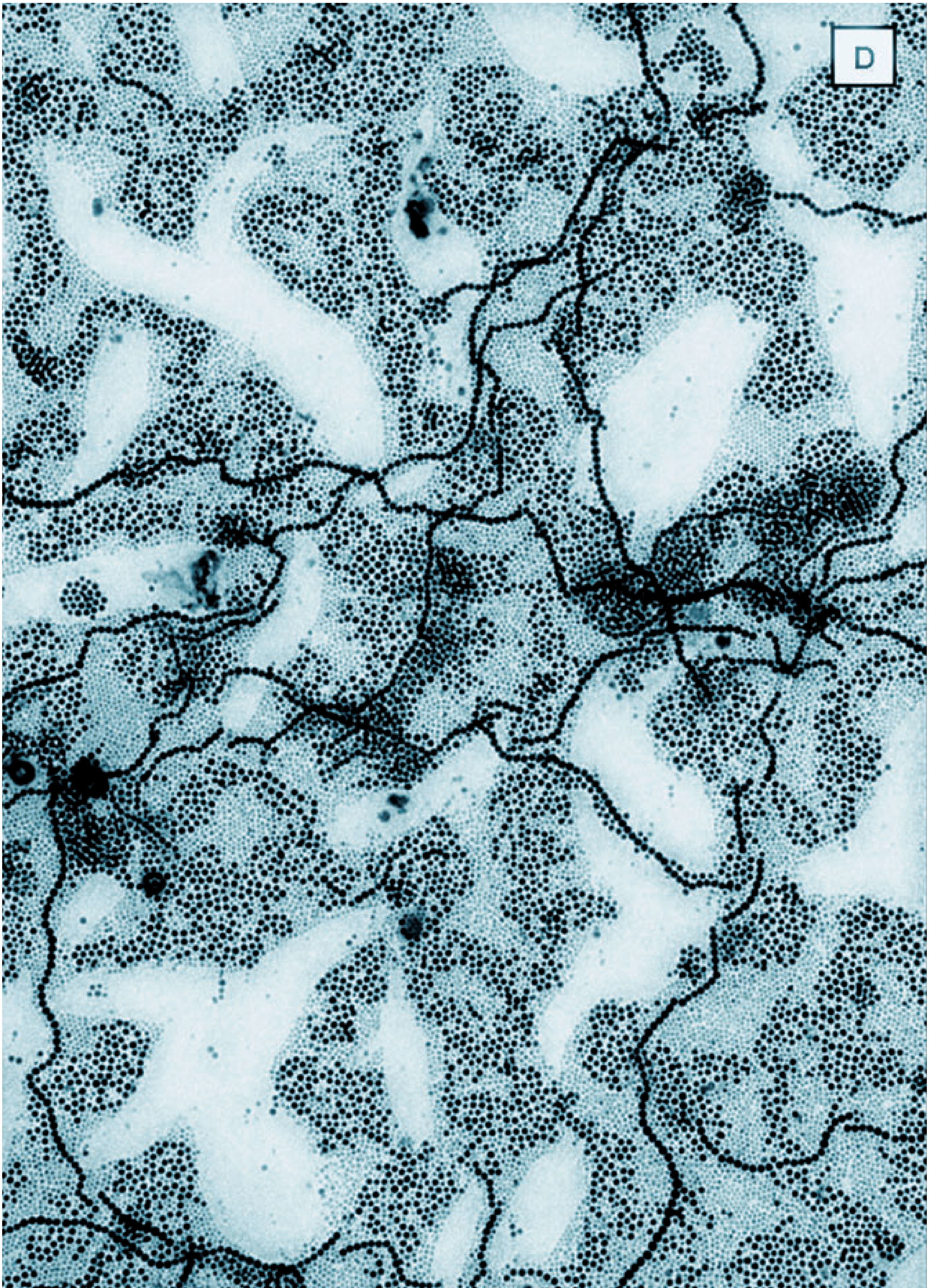


Víctor Puntes. *Cobalt*, 2009. Digital photograph, UltraScan Gatan camera, 50 x 70 cm.

# CREATIVITY AT THE SERVICE OF FUTURE PROGRESS

## THE NEW BOOM IN NANOTECHNOSCIENCE

Guillermo Muñoz-Matutano and Fernando Sapiña

Currently, a host of research-project applications contain the prefix *nano*. However, this could be more closely related to a new industrial explosion than with the emergence of new conceptual proposals. Society has also been touched by the euphoria that, in some cases, could be called a "craze"- but proposals from the most cautious sectors are far from science fiction. Among these we find biomimetics, which takes the solutions that living beings have adopted during the evolutionary process as a reference point. By uniting these technical and academic visions we generate a third more realistic view of these pet hates. Perhaps this is an alternative that provides collective genius creatively and possibly sustainably at the service of future developments.



It has been ten years since the twenty-first century began. This interval, albeit short, is long enough to review the hopes and dreams that hung in the balance at that time. We can recall what happened in the ambits of Science and Art during the first decade of the last century. Evolution and revolution featured in both areas. Planck and Einstein are two of the greatest names in the Science of that decade. The dramatic changes in Art were represented by names like Picasso, Braque, Apollinaire, Matisse, Marinetti... It was a great prelude to the huge leap in knowledge, the advent of avant-garde art, of the compelling social changes to be experienced in oncoming decades.

«SINCE THE END OF THE TWENTIETH CENTURY, NANOTECHNOSCIENCE HAS BECOME ONE OF THE MOST HIGHLY DEVELOPED AND PROMOTED DISCIPLINES IN ECONOMIC AND POLITICAL ENVIRONMENTS»

### NANOHISTORY: BETWEEN TECHNOLOGY AND SCIENCE

At the end of the twentieth cetury the terms *nanoscience* and *nanotechnology* burst into the media. Since then, nanotechnoscience has become one of the most highly-developed and promoted disciplines in economic and political environments. Nanoscience is defined as the study of phenomena and the manipulation of materials at atomic, molecular and macromolecular levels. Nanotechnology, on the other hand, is the design, characterization, production and application of structures, devices and systems by controlling shape and size on a nanometric scale.

Since the birth of nanotechnoscience, an official version has taken shape, encompassing its characteristics, fields of work, including its history. The following milestones are usually cited: beginning with Feynman and his 1959 lecture «There's plenty of room at the bottom»; then the use of the term *nanotechnology* by Professor Taniguchi, from the University of Tokyo, in 1974; followed by the invention of the microscopic probe in 1981; and subsequently the development of fullerenes and carbon nanotubes in 1985 and 1991. However, perhaps this official history of nanotechnoscience leaves out many other details. Just as Orwell warned us: «He who controls the past, controls the future.» So, we should remember that Faraday synthesized gold nanoparticles in his laboratory back in the nineteenth century. Electron microscopy, first developed in 1931, is also one of the major techniques employed in nanotechnoscience. At the time, Feynman's lecture, one of the major references when talking about this discipline, had no impact whatsoever; it was rediscovered by Conrad Schneiker in 1985 and incorporated into the official

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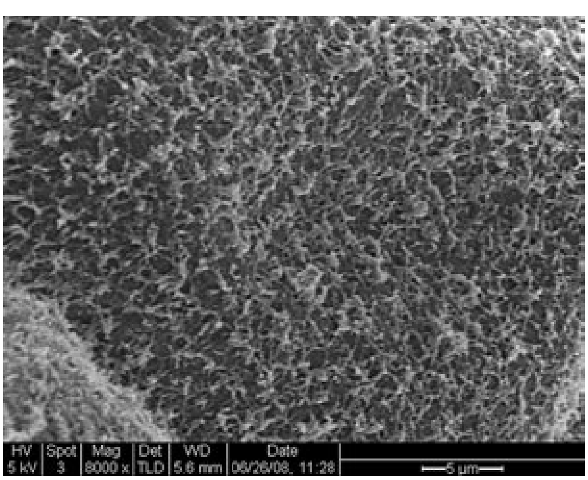


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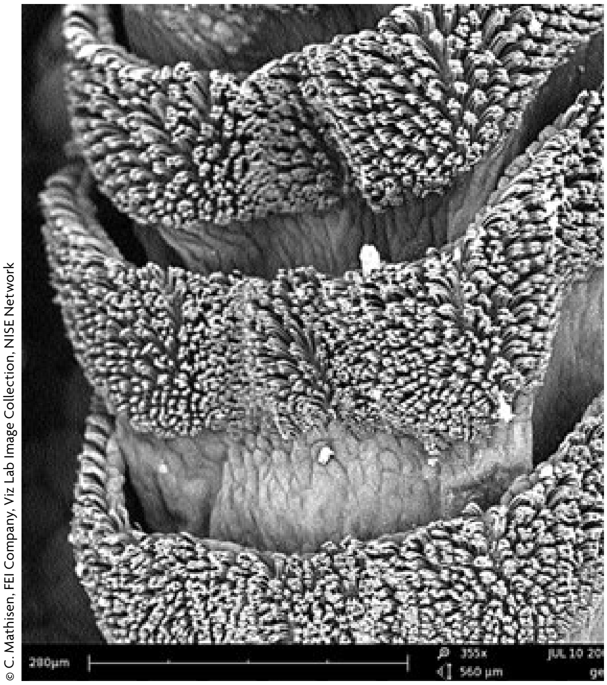
The lotus effect. The self-cleaning properties of leaves of different plant species are based on their superhydrophobic character. Water is repelled by the leaf surface, and this repulsion is due to the combination of a microstructured surface formed by leaf cells, cells that, in turn, are covered with nanoscale wax crystals. These wax crystals cause the leaf surface to repel water, and this property is enhanced by surface roughness. Both aspects are essential: water repellent surface and micro and nanoscale roughness. This property implies that with a minimum sloping angle of the leaf, a drop of water can travel over the surface and in the process drags the dirt particles deposited on its surface. Based on the understanding of this fact, materials have been developed with self-cleaning coatings. These materials can be incorporated into paint for surfaces or textiles.


Lizards' and other reptiles' feet, such as the gecko shown in the images, are an example of functionality linked to a nanostructure. The gecko's ability to climb vertical walls or even to remain anchored to a ceiling, holding its entire weight, is related to its feet structure in the form of microfilaments. Each of these filaments is divided into between 100 and 1000 nano-sized spatulas. This natural form of adhesion could be replicated to develop special suits and boots that would help climbing or a firm anchorage which could be advantageous in spacewalks.

history shortly after. And, although it is recognised that this area is inherently interdisciplinary, the truth is that it is difficult to find joint working groups, where biologists, physicists, chemists... really work side by side. Possibly this difference between the official theory and the discourse of scientific and technological historians could be based on the different viewpoints and interests of private companies with technological interests, on the one hand, and academic environments with scientific interests, on the other. But today universities are moving further and further away from the old and perhaps outdated academic splendour and ever closer to the golden glow of commercial and business management.

## NANOMANIAS AND NANOPHOBIAS

Now, early in this millennium, nanotechnology has become one of the most powerful vehicles known for restructuring economic models. This progress is solidly based on existing scientific knowledge, although current nanoscience also takes advantage of the emergence of these new technologies to develop new knowledge and scientific milestones are set. However, something else is emerging, which is also called nanotechnology: a social movement based on parallelism, approximation and expectation. In social sciences, popular enthusiasm for a set of unreasonable and ill-defined expectations is often called a *mania*. Thus, we call it «nanomania». This movement was born in 1986 when Eric Drexler published the book *Engines of Creation*. He imagined what would be possible if self-replicating nano-assemblers were created. Drexler assumed that, in the future, it would be possible to build nanorobots capable of manufacturing any macroscopic object or device, one atom at a time.

«SOMETHING ELSE IS EMERGING, ALSO CALLED NANOTECHNOLOGY, A SOCIAL MOVEMENT BASED ON PARALLELISM, APPROXIMATION AND EXPECTATION»

Many people have concluded that these self-replicating nano-assemblers are not only theoretically possible, but may come about in the near future. Such dreams sketched by nanomania have led to a backlash of alarm, namely nanophobia: fear of all kinds of terrible evils that may emerge from a Pandora's Box of nanotechnoscience. The better known evil is the gray goo. What if these assemblers go beyond our control? They could spread themselves dangerously. There is speculation concerning accidents or even malicious use: in the same way that people create computer viruses and worms, there might be people wanting to create a plague of this kind.

However, scientists doubt that these artificial nano-assemblers can become a reality, even in the long term. One researcher who is critical of these applications is Smalley, Nobel Prize in Chemistry for the discovery of fullerenes. Smalley says that there are inherent problems that make these artificial nano-assemblers physically impossible. However, Drexler's ideas were based on a real system and self-replicating nanoscale assemblers: biological organisms themselves. These systems can be defined as a series of nanomachines that self-assemble, and control or produce other nano

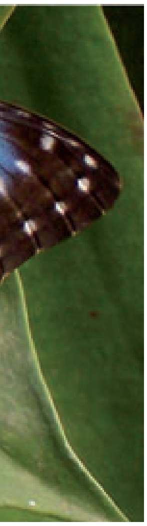
**«NANOMANIA HAS LED TO A BACKLASH OF ALARM, NAMELY NANOPHOBIA: THE FEAR OF ALL KINDS OF TERRIBLE EVILS THAT MAY EMERGE FROM A PANDORA'S BOX OF NANOTECHNOSCIENCE»**

structures. Whether it is possible or not to build nano-assembling nanorobots in the future, the reality is that we ourselves, at the cellular level and from a bio-molecular point of view, are a living example of such self-replicating mechanisms. Furthermore, living beings use the properties of nanostructured materials to solve a variety of problems.

## BIOMIMETICS: INSPIRED BY NATURE

Nature has given rise to materials and structures that generate variability through mutation and

Contemporary art is no stranger to new technologies and concepts arising in nanotechnoscience. Victoria Vesna and James Gimzewski have used the very same blue morpho butterfly (above) to build the *Blue Morph* art installation shown on the right. The metamorphosis from caterpillar to butterfly in the chrysalis is expressed as a metaphor for a natural nanofactory. The biological changes that generate the wing nanostructure during metamorphosis appear in sudden bursts of activity similar to the changes that rock the stock market.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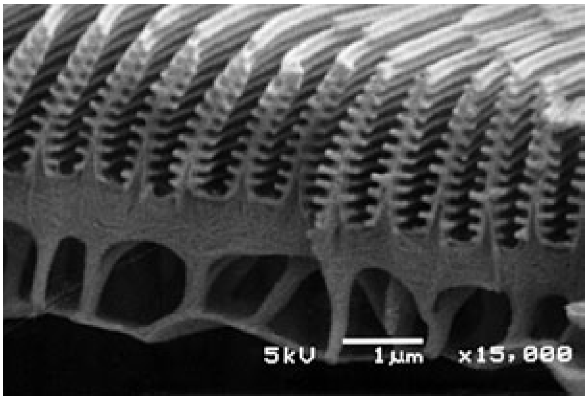

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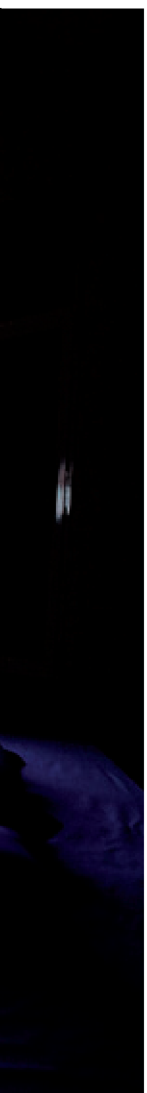
The *Morpho menelaus* butterfly is a species native to Central and South America. The elements that form the wings of this butterfly are organized in periodic nanostructures. The light interacts with these nanostructures in such a way that only the wavelengths of blue are reflected. The colour is associated with the nanostructure of the material and not its chemical constituents. Artificial photonic crystals that simulate this light-matter interaction are being designed in research laboratories. Potential candidates are devices for computer engineering or nano-optics, as well as new industrial applications such as paint and colour-changing dyes.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recombination, with the selection of those that prove most useful in the biological environment where they developed. For example, over millions of years organisms have been using and optimizing biomineral-based materials with exceptional properties. We have microskeletons, biomagnets, teeth, shells, bones... Based on these observations, some researchers introduced the term biomimetics, an understanding of the solutions nature has found to solve its problems, and an understanding of how these solutions can be a source of inspiration to solve our technological problems. Biomimetics can therefore be considered as the technology transfer from nature to man.

In the 1970s a systematic study of the surface characteristics of the leaves of various plants was conducted in the Berlin Botanical Garden, these being observed by scanning electron microscopy. The experimental methodology involved collecting leaves and preparing them to be studied by microscopy. This preparation required cleaning the leaves. Researchers observed that, first, the leaves of certain plants barely needed cleaning and, second, that the leaves of these plants had a very rough surface. Thus, the lotus effect had been discovered: based on the self-cleaning capacity of the *Nelumbo nucifera* leaves. This discovery enabled the development of self-cleaning surfaces.

There are also relationships between the characteristics of some insects and other animals and their nanostructure. For example, how do geckos stay on vertical walls? How can they walk on horizontal surfaces upside down? The gecko's toes are covered with numerous fine hairs, and each one branches off into a multitude of spatula-shaped filaments, which have nanometric dimensions. These structures are well adapted to the surface roughness, so that the total contact area of the gecko's feet is comparatively much higher than that of animals lacking these nanostructures.

The colours of butterfly wings and the shells of some beetles are not based on pigments. Rather, there are lots of tiny nanostructured scales on their surface that interfere with the light. In the case of the *Morpho menelaus* butterfly, the order of the scales' nanostructure makes the light reflected from the wings blue, while in the case of beetles belonging to the *Cyphochilus* genus, the disorder of scales makes the light reflect totally: they are a perfect shade of white.

**«THE COLOURS OF BUTTERFLY WINGS AND THE SHELLS OF SOME BEETLES ARE NOT BASED ON PIGMENTS. RATHER, THERE ARE LOTS OF TINY NANOSTRUCTURED SCALES ON THEIR SURFACE THAT INTERFERE WITH THE LIGHT»**

Thus we have an immense interdisciplinary area where the disciplines converge: biology, physics, chemistry, materials science and engineering, a hybrid science that tests our knowledge, our characterization techniques and our creativity to better respond to future challenges.


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