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NANOTECHNOLOGY UPDATE

PROFILE

Serge Haroche
2009 CNRS Gold Medal

CNRS advancing the frontiers


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Deadline for application: January 15, 2010
Protein misfolding and assembly in ageing and disease
Roscoff (Bretagne) June 5-9, 2010
Deadline for application: March 5, 2010
Imaging brain circuits in health and disease
Roscoff (Bretagne) June 30 – July 4, 2010
Deadline for application: March 15, 2010
Cell division: time and space
Roscoff (Bretagne) September 11-15, 2010
Deadline for application: May 15, 2010
Mental retardation: from genes to synapses, functions and dysfunctions
Roscoff (Bretagne) October 7-11, 2010
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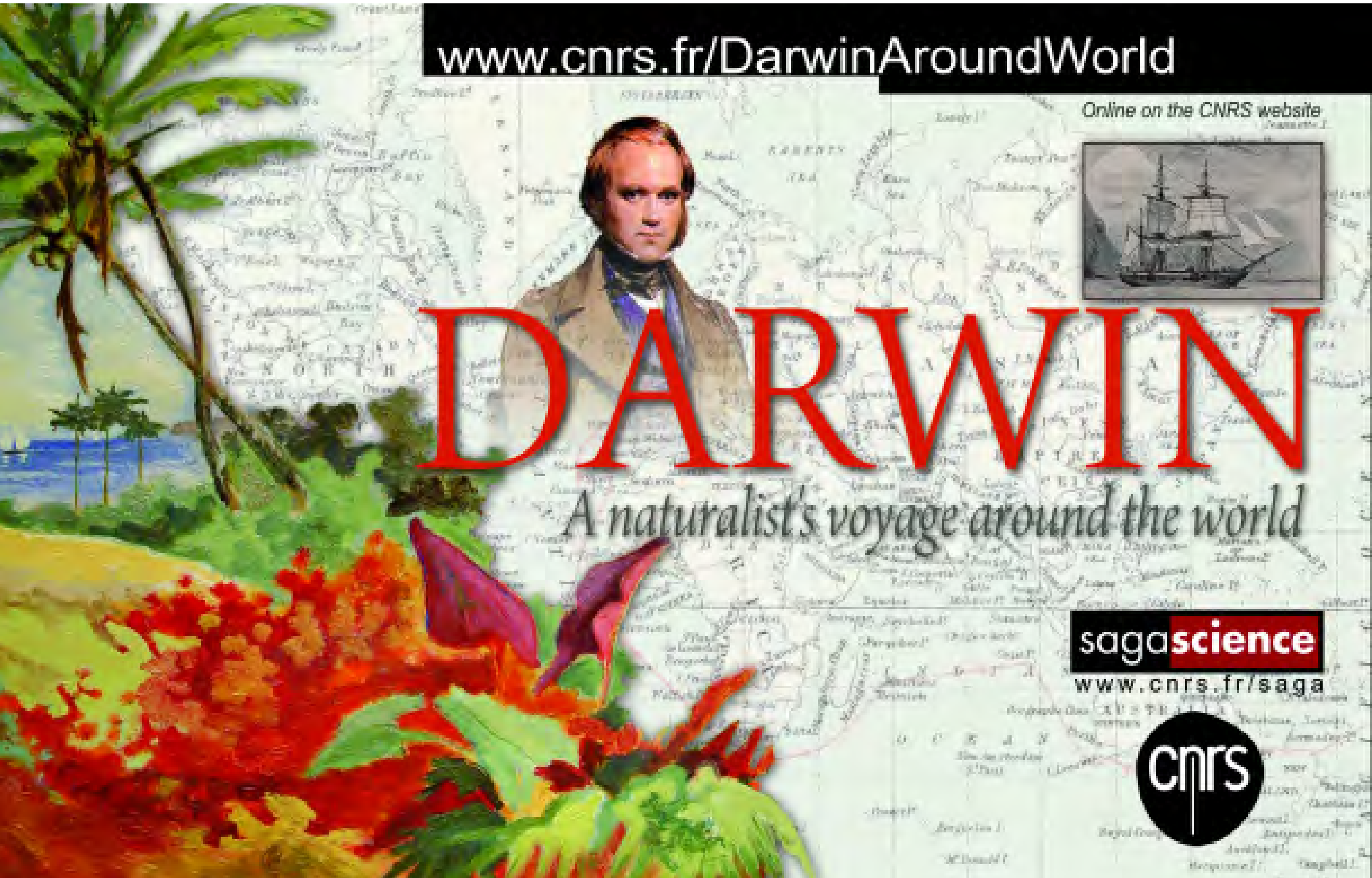
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contents

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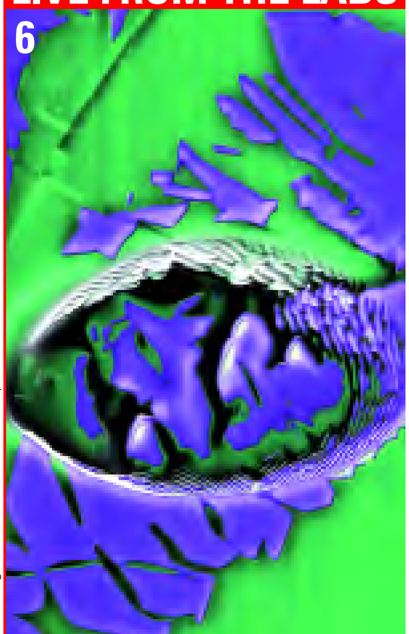

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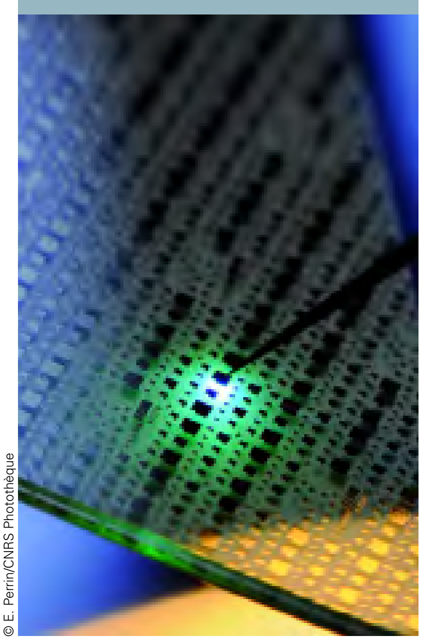

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→ **Reorganization**

Structural Reform at CNRS

CNRS is undergoing a major structural overhaul, in line with the new national guidelines on French scientific research. Eight institutes have been created to replace the organization's eight existing departments, bringing the total number of CNRS institutes to ten (*see inset*).

They will be endowed with more autonomy and flexibility than the former scientific departments.

They will also take on new tasks. Besides running the laboratories, which the departments also handled, they will act as funding agencies for targeted thematic and/or multidisciplinary programs.

These changes are being implemented in the context of a general reform of the French research sector.

Over the past five years, the French government has created the ANR,[1] in charge of funding research projects; launched the AERES,[2] an evaluation agency for higher education and research; and implemented a major reform aimed at giving universities more autonomy.

Once universities become autonomous, the coordination and integration of research across the country will become the responsibility of institutions like CNRS. This is likely to give the institution greater influence and responsibility for exploring new avenues of research.

1. Agence nationale de la recherche. www.agence-nationale-recherche.fr/Intl
2. Agence d'évaluation de la recherche et de l'enseignement supérieur. www.aeres-evaluation.fr/

The Ten CNRS Institutes

* Institute of Chemistry (INC)
* Institute of Ecology and Environment (INEE)
* Institute of Physics (INP)
* Institute of Biological Sciences (INSB)
* Institute for Humanities and Social Sciences (INSHS)
* Institute for Computer Sciences (INS2I)
* Institute for Engineering and Systems Sciences (INSIS)
* Institute for Mathematical Sciences (INSMI)
* National Institute of Nuclear and Particle Physics (IN2P3)
* National Institute for Earth Sciences and Astronomy (INSU)

For more information: www.cnrs.fr/en/aboutCNRS/institutes.htm


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Death of Claude Lévi-Strauss

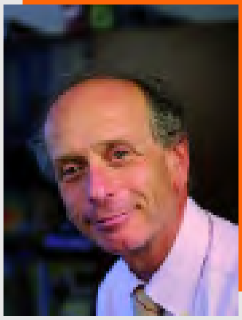
The ethnologist and anthropologist Claude Lévi-Strauss died on October 31st at the age of 100. An emblematic figure of these two disciplines and CNRS Gold Medalist in 1967, he established the Laboratoire d'anthropologie sociale[1] in Paris. Author of over 20 publications including the well-known *Tristes Tropiques*, Lévi-Strauss is considered to be the father of modern anthropology. His essays were based on his ethnographic missions in the Amazon during the 1930s. According to anthropologist Frédéric Keck,
"his work has inspired the greatest studies in humanities: those of Foucault, Deleuze, and Bourdieu. It has had an outstanding international influence, with no equivalent in modern French thinking."

1. CNRS / Collège de France / EHESS.

→ **339** This is the number of patents filed by CNRS between July 2008 and June 2009, compared to 284 for the previous 12 months. Forty-four percent of these new patents are already being exploited. In total, CNRS expects to receive €56 billion in royalties for 2009. CNRS is one of the ten public research organizations filing the most patents in the US, an important first for a European organization.

Michel Spiro New President of the Cern Council

Currently director of CNRS' National Institute of Nuclear and Particle Physics (IN2P3), Michel Spiro has been elected president of the Cern Council, the European organization for nuclear research. "This is a great honor," he said. "I will become the Council's 20th president, with the important responsibility of following in the footsteps of my illustrious predecessors. I will directly succeed Professor Akesson, who has made the Council evolve significantly over the past few years. Given the first results of the Large Hadron Collider (LHC), the future promises to be very exciting. Discoveries made at LHC will be the ones that shape the future of particle physics in the world, and hence of CERN and its operations."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editorial

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Michel Lannoo
CNRS advisor for nanoscience and nanotechnology.

Nanotech at CNRS

Nanoscience and nanotechnology aim to create, control, and above all, use objects or sets of objects of extremely small size—close to the atomic or molecular scale. At this scale, matter presents novel properties that can be used for a host of new applications. While in general nanoscience mostly focuses on the knowledge we can obtain from such systems, nanotechnology is centered on their applications in industrial or medical fields.

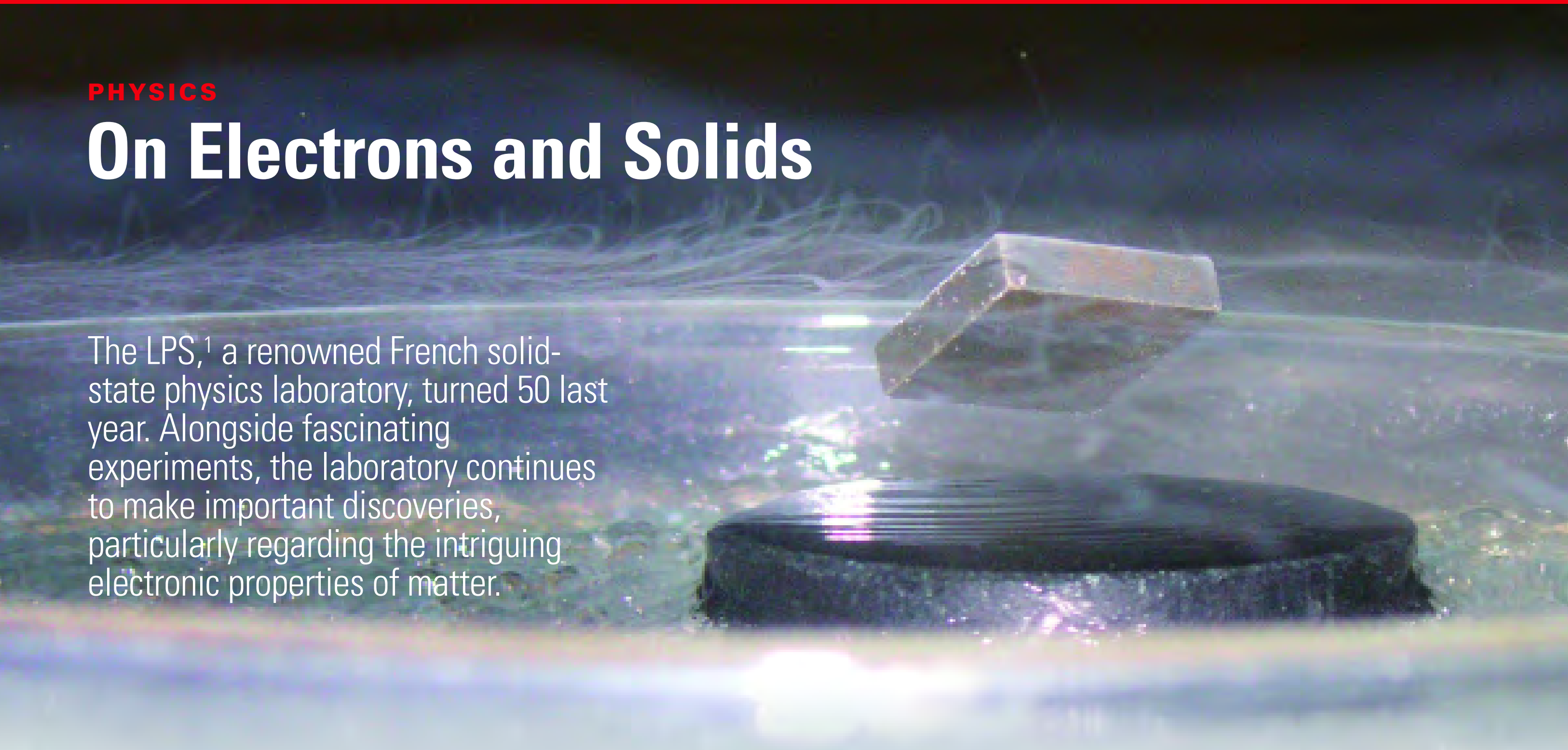
Though often believed to have resulted from a sudden revolution, the field has in fact evolved over decades. And during those years, important discoveries paved the way for today's scientific advances: major breakthroughs in instrumentation, manipulation at the atomic level, together with continuous progress in surface science, colloids, interfaces, aggregates and more generally new findings in materials science. To these can be added miniaturization in micro- and nanoelectronics, the manufacturing of micro- and nanosystems, and the field's increasing importance to biology.

The creation of the American NNI (National Nanotechnology Initiative) in the year 2000 played an important role in pushing research towards more technological applications. By stressing this emerging field's vast potential for innovation, the NNI implied that nanotechnology was key to economic development in the 21st century. Truly interdisciplinary, nanoscience and nanotechnology carry a major potential for innovations to address the many issues facing today's society: health (by creating better medical applications), information and communication technologies, sustainable development and the environment, or energy production and storage, to name but a few.

In this context, CNRS is a major player in the field, as illustrated by the 2007 Nobel Prize laureate Albert Fert. Its strategy, centered around scientific creativity and innovation, benefits from its interdisciplinarity, which is essential to developments in nanoscience and nanotechnology. With close to 5000 researchers involved in the field, spread across intramural or joint laboratories, 7 large technological facilities and 9 local facilities shared by several laboratories, CNRS is one of the largest contributors to French research in nanoscience.

France's coordination in nanoscience has been bolstered by the creation of six competence centers—called "C'Nanos"—which form a support network for the scientific community on a national scale. The ANR—France's research funding agency—continues to play an important role by financing and supporting projects in the discipline. A recently launched government program in nanoscience research—"Nano-Inov"—is dedicated to boosting industrial innovation and transfer via three "integration" centers (Grenoble, Saclay, and Toulouse).

But nanoscience and nanotechnology have also raised public concern. A responsible approach within the field requires scientists to work diligently, in terms of traceability, ethics, and public information. As a major European interdisciplinary institution, CNRS must play a leading role in safeguarding these ethics, and anticipating the far-reaching consequences of such research. In this context, it has recently created the Strategic Unit for Nanoscience and Nanotechnology, which will not only promote and develop nanoscience research, but also assess and examine all the relevant ethical issues associated.



PHYSICS

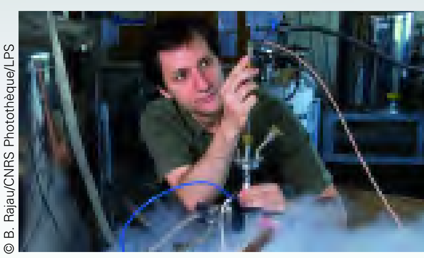
On Electrons and Solids

The LPS,[1] a renowned French solid-state physics laboratory, turned 50 last year. Alongside fascinating experiments, the laboratory continues to make important discoveries, particularly regarding the intriguing electronic properties of matter.

It looks much like any other control room: two computers, a panel with screens and buttons, electric cables and pipes that run from the ceiling to the floor—and even a few tools, including a soldering iron in the corner. But the real "attraction"—and one of the solid-state physics laboratory's latest acquisitions—lies behind the glass panel: a super-powerful 14-tesla[2] magnet that could pull the keys right out of your pocket.

LPS researchers are expecting wonders from this magnet that should expose undiscovered quantum properties of matter in nuclear magnetic resonance (NMR) experiments, a technique used to determine the properties of each electron in a sample. "We finished setting up this new lab two months ago," explains LPS researcher Julien Bobroff. "Apart from the magnet, everything was made in-house: the cryostat, the spectrometer, the computer software... And with remote access, experiments can continue round the clock!"

For LPS Director Jean-Paul Pouget, "developing original instrumentation is one of our trademarks. What's more, our aim is to tackle all aspects of solid-state physics, from the study of the structure of materials to their electronic properties, and to do this via a strong link-up between experiment and theory." This has been the methodology of the LPS since its creation, exactly 50 years ago. And it soon produced results. Not a decade had passed before it received funding from two major scientific awards given to Raimond Castaing in 1966, and to André Guinier, Jacques Friedel, and Pierre-Gilles de Gennes in 1967. In fact, two of the last four French Nobel prize-winners in physics—Pierre-Gilles de Gennes (1991) and Albert Fert (2007)—worked at the LPS at one point in their careers. But Pouget prefers to focus on the lab's present activities.



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MAGNETIZATION, CONDUCTION, OR BOTH

Solid-state physics, which ranges from electronics to nanotechnology and also encompasses biology, is flourishing. And renewed interest in the physics of electrons in materials is the perfect illustration.

"The general area of study is materials in which electrons have difficulty moving about because they are constrained to one or two dimensions, and thus hinder each other. At first sight, these materials should be poor electrical conductors and therefore of little interest. But paradoxically, it is in these materials that the most surprising properties have been observed in the past few years," Bobroff explains.

The archetype of these new states of matter, in which the LPS specializes, is "high temperature superconductivity," observed in materials composed of multiple layers of copper oxide (cuprates) or more recently, iron pnictides. This complex name hides one of the greatest mysteries in physics today: superconductivity. It occurs in metal when the temperature approaches absolute zero (-273.15 °C) and is characterized by the disappearance of resistance to the flow of electric currents.

Since the 1960s, physicists have known that superconductivity results from the interaction between electrons and vibrations in the crystalline matrix in which they circulate.

In the case of cuprate oxides, superconductivity takes place at a much higher temperature, with the

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LPS physicists conduct very low temperature experiments to elucidate the quantum properties of superconductors.

Left: Using their new magnet, the researchers will be able to study the electronic properties of different materials with unrivalled precision.

The superconductor state of this oxide (in black) is demonstrated in a magnet levitation experiment. In fact, superconductivity is characterized by the expulsion of any magnetic field outside of the sample. This is known as the Meissner effect.

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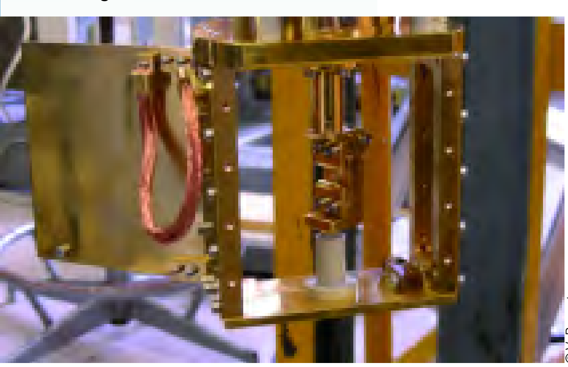
This low-temperature manipulator, used on the Soleil synchrotron, was made at the LPS, and illustrates the laboratory's ability to produce original instrumentation.



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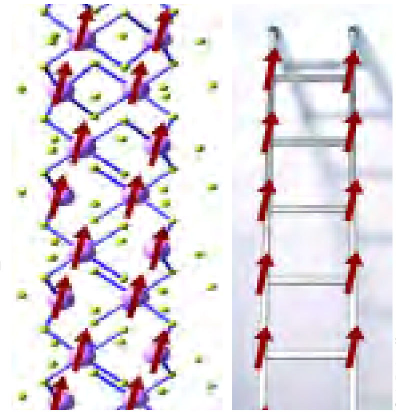
current record observed in one oxide standing at -135 °C, which is still cold, but much less than for metals. This makes scientists believe that superconductivity could one day be achieved at room temperature, leading to materials that could convey electricity over great distances without any loss. To this day, the origin of superconductivity in oxides has not been elucidated. "What's even more mysterious is that you only need to slightly tweak an oxide to turn it from a superconductor to a magnetic insulating material," says Bobroff.

The physicist and his team recently discovered something surprising. In an NMR experiment on a pnictide, the researchers discovered that the electrons exhibited both properties of magnetism[3] and superconductivity at the same time. "It's fascinating because, in principle, magnetism and superconduction have a tendency to be mutually exclusive. Yet our results suggest that they could have a shared origin in the case of pnictides," exclaims the researcher.

To get these results, the LPS researchers worked in close collaboration with physicists and chemists from the SPEC,[4] a division of condensed matter physics of the French atomic energy commission (CEA). As Pouget explains: "With the CEA, the University of Orsay, and the different laboratories located in Palaiseau, the LPS has access to an extraordinary scientific environment. To make the most of this, we initiated in 2006 an advanced research network called the 'triangle of physics,' which enables funding for common projects among the different associated laboratories." Véronique Brouet, another specialist of high critical temperature superconduction at the LPS, is preparing to work with another neighbor, Soleil, the national synchrotron radiation source,[5] on what are known as photoemission experiments. "The laboratory has built some of the equipment used on certain lines of Soleil, particularly the photoemission line," explains the physicist. "This technique provides insights into the relationship between the energy of an electron and the direction in which it propagates within a material. It is thus a complementary technique to NMR which, for its part, provides information on the spatial distribution of electrons."

Schematic representation of the magnetic moments (or spins) of copper atoms within an oxide sample known as a spin ladder.



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FROM DISORDER TO ORDER

Using NMR technology, LPS researchers have also obtained remarkable results on what are known as spin ladder materials, in which the crystal lattice forms the rungs of a ladder, at the end of which the electrons are positioned. In a standard material, at very low temperature, the spins of all the electrons are either all lined up in the same direction or oriented head to tail. The material is then said to have magnetic order. Conversely, in a spin ladder, the electrons are oriented in all directions. The material is thus magnetically disordered.

"Collaborating with Nicolas Laflorencie, a young theoretician working in the laboratory, we have shown that by randomly removing one magnetic atom out of 100, the system, until then disordered, becomes ordered," explains Bobroff. It would be similar to having one's bookshelves reorganized alphabetically after randomly removing a few books.

Are these strange quantum effects simply good fun for a few fringe specialists? Maybe, but it was also in the LPS in 1988 that the Nobel prizewinner in physics, Albert Fert, discovered another strange property of condensed matter known as magnetoresistance, the phenomenon behind an emerging type of electronics based on magnetism, now known as spintronics. "The important thing is to ensure that the laboratory does not become an ivory tower," says Pouget. "For instance, we encourage collaboration with other institutions, with industry, and even between our different research teams because it is at the very interface between existing disciplines that new ones appear." The researchers of the LPS are thus active on all fronts of condensed matter. With their new NMR-dedicated magnet, it is unlikely that the electron specialists will be left behind.

Mathieu Grousson

THE LPS IN FIGURES

The LPS is one of the largest French research centers specialized in condensed matter. Between 200 and 250 people work at the LPS on a daily basis, including 61 CNRS researchers, 35 academics, 50 engineers, technicians, and administrative staff, and 35 PhD students. Eighteen research teams are grouped together around three main research topics: "New electronic states of matter," "Physical phenomena with reduced dimensions," and "Soft matter and physics-biology interface." The topics of research thus extend from superconductors to living tissues, while encompassing liquid crystals and nano-objects. Between 2005 and 2008, the LPS produced 650 publications, including 500 articles in international scientific journals with peer-review committees.

1. Laboratoire de physique des solides (CNRS / Université Paris-XI).
2. The tesla is the unit used to measure magnetic fields. By way of comparison, the magnetic field of the Earth is around 50 microteslas.
3. In other words their spin (internal magnetization) is oriented in a favored direction.
4. Service de physique de l'état condensé (CNRS/ CEA).
5. Synchrotron radiation is an electromagnetic radiation emitted by electrons in movement.

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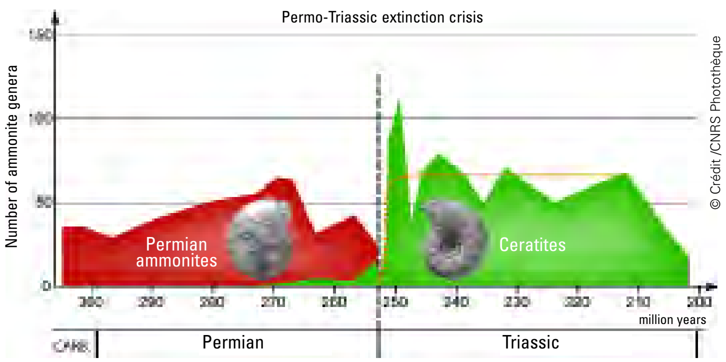
PALEONTOLOGY

Getting Over an Extinction Crisis

Over the course of millions of years, the Earth regularly undergoes extinction crises during which biodiversity plummets. Then, a few species that survive the disaster diversify again. A group of laboratories in France and Switzerland, bridging decades of past data with extensive fieldwork and statistical modeling, has shown that this revival can happen astonishingly fast.[1]

The team found that in the wake of the Permo-Triassic mass extinction[2] (252.6 million years ago), ammonites,[3] an extinct group of marine animals, rebounded in merely one million years, and not in tens of millions of years as previously thought. “Relatively soon after the crisis, biodiversity started up again, and new species rapidly appeared in the oceans in masses, resuming levels of diversity comparable to those just before the event,” says Gilles Escarguel from the PEPS laboratory[4] in Lyon, who worked on the project.



While different groups of ammonites coexisted during the Permian (red), only one group, ceratites (green), survived the Permo-Triassic mass extinction.

Researchers believe a single species, among the two or three that survived, is at the origin of the post-crisis diversification. They indexed 860 ammonite genera[5] from 77 different past oceanic basins all over the world.

Some of the fossil samples were already present in databases from previous studies, and the remainder were collected over the past seven years mainly from the US and southern China (Guangxi). The field investigation is still taking place in Tibet and Pakistan. The specimens were hard to gather, since these mollusks typically do not fossilize during a crisis-event, due to the ocean’s severely deteriorated conditions.

“Surprisingly, living beings actually regenerate much more quickly than the ocean retrieves its physical and chemical balance,” explains Escarguel.

This finding helps predict what might follow the sixth major extinction phase that our biosphere has currently entered. Recovery after a downfall spans tens of thousands of human generations, but is remarkably sturdy. According to Arnaud Brayard from the Biogeosciences laboratory[6] in Dijon, who based his PhD work on this topic, “life always manages to survive somewhere and to rediversify, even if we’re not sure exactly how this happens. It may take a long time, but it will eventually reappear.”

Melisande Middleton

1. A. Brayard et al., “Good Genes and Good Luck: Ammonoid Diversity and the End-Permian Mass Extinction,” *Science*, 2009. 325: 1079-80.
2. Documented as the largest mass extinction over the past 550 million years, killing more than 90% of marine species.
3. Ammonites are fossil mollusks related to present-day octopus, squid, and cuttlefish.
4. Paléoenvironnement et paléobiosphère (CNRS / Université Lyon-I).
5. A genus is a set of closely related species.
6. Biogéosciences (CNRS / Université de Bourgogne).

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ENZYMOLOGY

A Green Answer to Heavy Metal

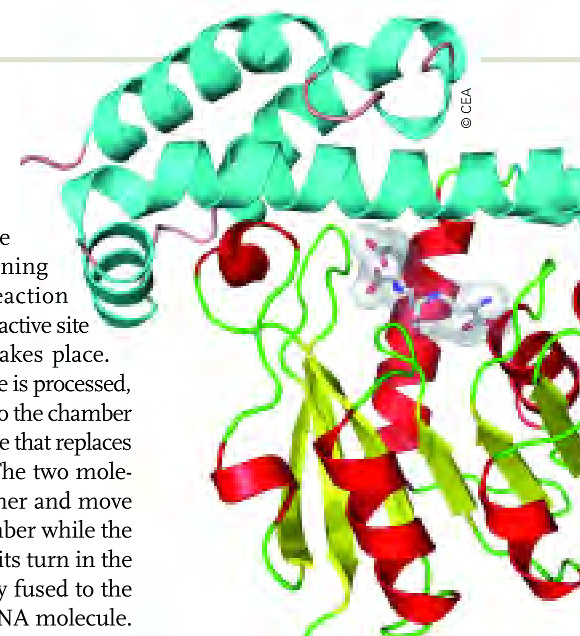
In the ongoing fight against pollution, plants offer a valuable contribution by collecting, transforming, or removing pollutants from soil or water—something called phytoremediation.

To counter heavy metal waste, for example, vegetal tools rely on molecules like nicotianamine (NA), a small molecule crucial for transporting the ionic forms of metals such as iron, zinc, and copper, throughout plant organs. But mystery surrounding how NA—which has proven aptitude for nickel detoxification—is synthesized, has so far prevented its potential from being fully explored. A team from IBEB[1] working at the CEA’s[2] Cadarache research center, and from INRA[3] in Montpellier has now unlocked the mechanism that produces NA, paving the way for new biological tools.[4]

The key to NA synthesis lies in nicotianamine synthase (NA-Synthase), a plant enzyme that is extremely difficult to isolate. To overcome this obstacle, the researchers examined NA-Synthase-like enzymes in the archaea[5] *Methanothermobacter thermautotrophicus* after noticing that “NA-Synthase in eukaryotes finds distant counterparts in certain archaea,” explains Pascal Arnoux from the CEA. They have thus uncovered the secret to NA’s synthesis in the reaction chamber buried at the enzyme’s heart.

So how exactly is NA made? 3D structure analysis of the NA-Synthase-like enzyme at work reveals that one by one, three molecules of the substrate S-adenosylmethionine penetrate a tiny opening to the enzyme’s reaction chamber, to reach the active site where the reaction takes place. Once the first molecule is processed, it is pushed deeper into the chamber by the second molecule that replaces it in the active site. The two molecules then link together and move further into the chamber while the third molecule takes its turn in the active site. It is finally fused to the duo, completing the NA molecule.

With this finding, the design of NA-reliant biosensors for detecting heavy metals in the environment can now be optimized. “This result



3D structure of the NA-Synthase from *Methanothermobacter thermautotrophicus*.

PHYSIOLOGY

The Many Roles of Melanopsin

Two CNRS studies help further understand the mechanisms by which melanopsin—a new photopigment found in the human retina—regulates non-visual functions of light such as the synchronization of the sleep-wake cycle and the pupillary reflex.

About a decade ago, when rods and cones were considered the only photoreceptors of the vertebrate eye, a previously undetected photopigment was identified: melanopsin. It has been shown to regulate a wide range of non-visual functions, such as the synchronization of the circadian rhythms and the sleep-wake cycle with the light-dark cycle.

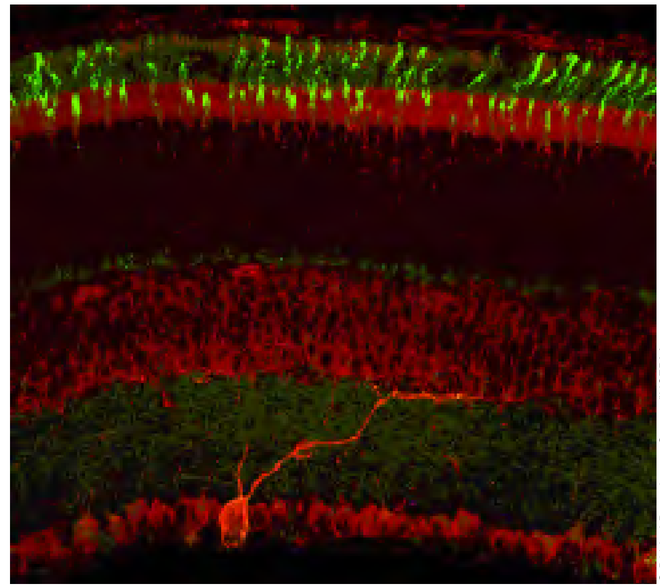
Two main mechanisms regulate sleep: the circadian mechanism, which determines the optimal time for sleep, and the homeostatic system, which keeps track of how long the body is awake and asleep, and triggers "sleep pressure" when the body suffers from sleep deprivation. Though light was known to influence the circadian mechanism via melanopsin, its effects on non-circadian processes were considered minor. Now, in a recent study,[1] a team from CNRS' INCI[2] reveals that light detection by melanopsin acts directly on non-circadian mechanisms and that circadian and non-circadian routes interact with one another.

The researchers used melanopsin-deficient transgenic mice, a model traditionally used to study non-circadian aspects of sleep. Transgenic mice and control mice were placed under various light-dark schedules, and their sleep-wake patterns and sleep electrocorticography were recorded.

In mice, sleep is induced by light, and alertness by darkness. In their study, the scientists observed that melanopsin-deficient mice slept about one hour less than control mice during light phases, and that their level of alertness, induced by darkness, was lowered. Despite their lack of sleep, electrocorticography recordings showed that melanopsin-deficient mice did not "catch up" on sleep. On the contrary, they presented a trend of decreased sleep, which suggests that depriving mice of melanopsin disrupts their homeostatic system. More generally, these observations suggest that light influences the sleep-wake cycle not only through circadian routes, but also non-circadian mechanisms, both via melanopsin. "Confirmation of these findings in humans could lead to important applications for light therapy and better lighting management," says Patrice Bourgin, co-author of the study.

The second study,[3] led by CNRS researcher Howard Cooper,[4] investigates how melanopsin responds to light stimulation.

In 2005, *in vitro* studies had revealed that the transduction of light signals by melanopsin more closely resembles that of invertebrate photopigments than vertebrate rods and cones. When a photon is absorbed by melanopsin, a response is elicited but the photopigment also becomes desensitized. In contrast to rod and cone photopigments that require the enzymatic retinoid cycle to restore their light sensitivity, melanopsin uses the absorption of a second photon to regenerate the photopigment. This light-driven reversibility, called "bistability," is what enables melanopsin to maintain a sustained response to light stimulation, contrary to rods and cones, which only respond to transient changes in light.



Section of a mouse retina showing the cones of the outer layer (green), and a large melanopsin-expressing ganglion cell (red) in the inner layer.

To explore this process *in vivo*, the team studied the pupillary light reflex in humans. Input from all photoreceptors causes the human pupil to constrict. However, the scientists observed that rods and cones only allow an initial transient constriction of the pupil, whereas melanopsin produces a stabilized state of sustained constriction in response to light. The team suggests that "a normal sustained pupillary constriction requires melanopsin, which remains photosensitive even during extended exposure to light," says Cooper. The authors hypothesize that exploiting melanopsin's bi-stability and its sustained response capability could lead to clinical applications for improving phototherapy to treat dysfunctional circadian rhythms of sleep, or seasonal depression.

Clémentine Wallace

1. J.W. Tsai et al., "Melanopsin as a sleep modulator: circadian gating of the direct effects of light on sleep and altered sleep homeostasis in Opn4(-/-) mice," *PLoS Biol.*, 2009. 7(6): e1000125.
2. Institut des neurosciences cellulaires et intégratives (CNRS).
3. L.A. Mure et al., "Melanopsin bistability: a fly's eye technology in the human retina," *PLoS One*, 2009. 4:e5991.
4. Photoréception et chronobiologie (Inserm U846).

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also paves the way for developing molecules related to NA as novel actors in the field of bio- and phyto-remediation," indicates Arnoux.

Fui Lee Luk

1. Institut de biologie environnementale et de biotechnologie (CNRS / CEA / Université Aix-Marseille II).
2. Commissariat à l'énergie atomique.
3. Institut national de la recherche agronomique.
4. C. Dreyfus et al., "Crystallographic snapshots of iterative substrate translocations during nicotianamine synthesis in archaea," *PNAS*, 2009. 106: 16180-4.
5. Unicellular micro-organisms that thrive in extreme conditions.

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BIOTECHNOLOGY

Cellular Biology on a Chip

Researchers at the Toulouse-based LAAS[1] have devised new types of chips enabling three-dimensional imaging of cells and experimentation at the single-cell level.

No matter how good a microscope's resolution, the two-dimensional view in its eyepiece will only reveal a small part of a cell's mysteries.

"To get 3D images," explains Aurélien Bancaud of LAAS, "a researcher would need multiple images of the cell from multiple angles"—a process that up to now was both slow and damaging to the cells being studied.

Bancaud has devised an elegantly simple solution—a mirrored chip[2]—with an unlikely inspiration. "When you walk into certain hotel bathrooms, there are mirrors that you can adjust to see yourself head-on or from the sides. Basically, we adopted that technology, but adjusted the size for yeast cells," says Bancaud.

Of course, he is simplifying matters. Bancaud, whose background is in biophysics, used the LAAS microfabrication facility to create a tiny silicon wafer, into which were grooved several trenches. When coated with a thin sheen of aluminum, the sides of these grooves formed a two-angled mirror.

Yeast cells with fluorescent-tagged proteins, when passed through the trenches of this reflective "lab on a chip," become visible from multiple angles in a single viewing. These images can then be combined to create a three-dimensional model that gives researchers a deeper understanding of their subjects.

The device is especially useful for tracking fast biological reactions, like those involving DNA, without risking damage to the cells through the multiple light flashes required by more cumbersome 3D imaging techniques. Bancaud's particular interest is to study yeast chromosomes, and the first experiments using the chip tracked the actions of a fluorescent-tagged chromosome in yeast cells, which he was able to capture in almost real time.

Although the size and angle of the mirrors are easily adjustable, the technology is currently best suited to smaller cells like yeast; the larger the cell, the more distant its organelles from the mirror. Bancaud is collaborating with researchers in Paris to test the feasibility of using his chip to observe neurites—small projections from a neuron.

While yeast cells are easily trapped and guided by Bancaud's reflective trenches, lymphocytes are much more difficult to pin down. Lymphocytes are like cellular butterflies in the human circulatory system: they flutter about freely in the currents.

And if lymphocytes are butterflies, Liviu Nicu is an avid collector. With colleagues in Grenoble, the LAAS-based physicist has developed a method for pinning down lymphocytes to a microscopic chip.[3] By doing so, scientists can now study these key elements of the body's immune system on an individual cell basis.

"The challenge is that these cells do not normally stick onto a surface, because they move about constantly through the blood vessels in our body. To study how the cell operates on a single cell level, you have to find a way to stick the cell onto a surface and study it while it is still alive on this surface," explains Nicu.

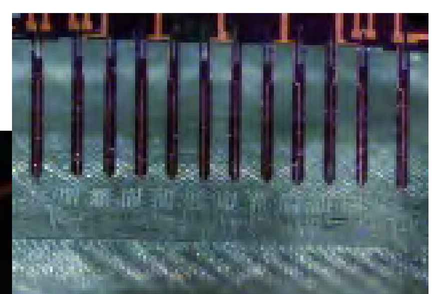
The solution is to glue each cell into place in an orderly fashion. He thus devised a "bio-pen" —a series of micro-scaled silver silicon cantilevers. Each pen is filled with a biological solution, which is deposited by simple contact onto surfaces for different applications.

In this case, the solution was specifically formulated to hold slippery lymphocytes in place, though the system could easily be adapted for other types of cells or viruses. The end result is a chip containing orderly rows of cells. Each cell can then be exposed to stresses and chemicals, and its reactions tested and measured individually—unlike in the free-flowing chaos of a Petri dish, where tracking the reaction of a single cell is almost impossible.

"The challenge is to look at the pathologies on the single-cell level," says Nicu. The applications for this system are many: it could be used in drug screening, for example, and the technology has already been licensed by a French private company (Microbiochip, Paris) for manufacturing protein chips on-demand.

Mark Reynolds

Bio-pens depositing specific antibodies on a slide to trap live cells.



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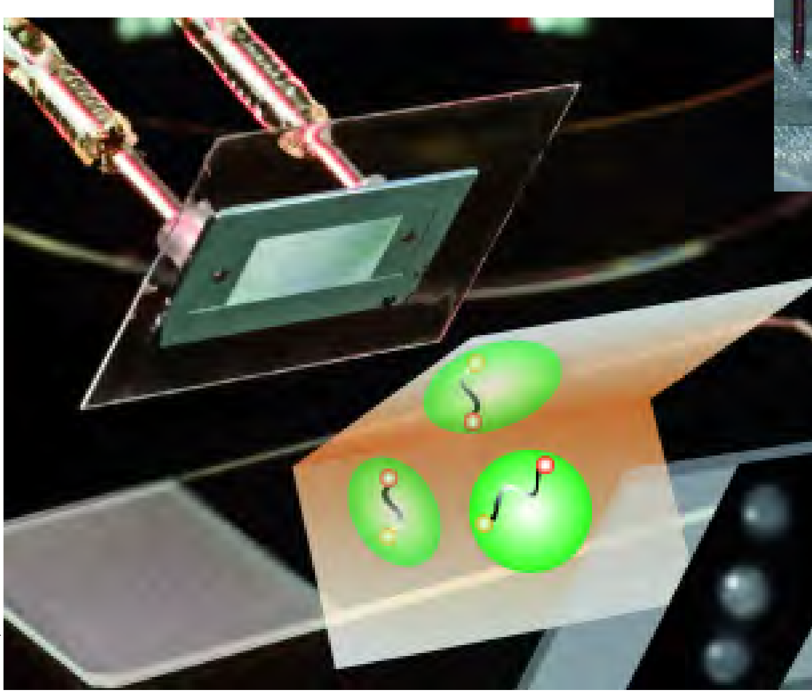

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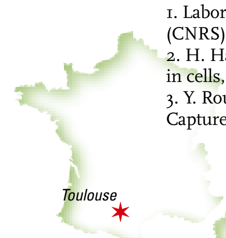

A hundred of V-shaped micro-mirrors (orange scheme) allow 3D imaging of biological material (here yeast nuclei, in the lower right corner) by this lab-on-a-chip device.

1. Laboratoire d'analyse et d'architecture des systèmes (CNRS).
2. H. Hajjoul et al., "Lab-on-chip for fast 3D particle tracking in cells," *Lab on a Chip*, 2009. 9: 3054-8.
3. Y. Roupioz et al., "Individual Blood-Cell Capture and 2D Capture on Microarrays," *Small*, 2009. 5: 1493-7.

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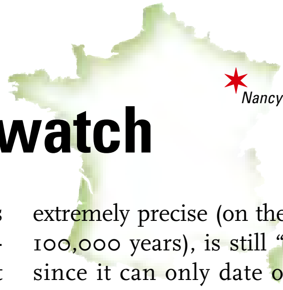
COSMOCHEMISTRY

Isotopic Stopwatch



New high-precision analyses of the aluminum radioisotope 26 (^{26}Al) reveal that it was distributed homogeneously across the nascent Solar System, giving researchers fundamental insight into its chaotic beginnings.

To come to this conclusion, scientists looked at the oldest solid materials in our Solar System, primitive meteorites known as chondrites. These are made up of round grain-like particles—called chondrules—and calcium-aluminum-rich inclusions (CAIs).

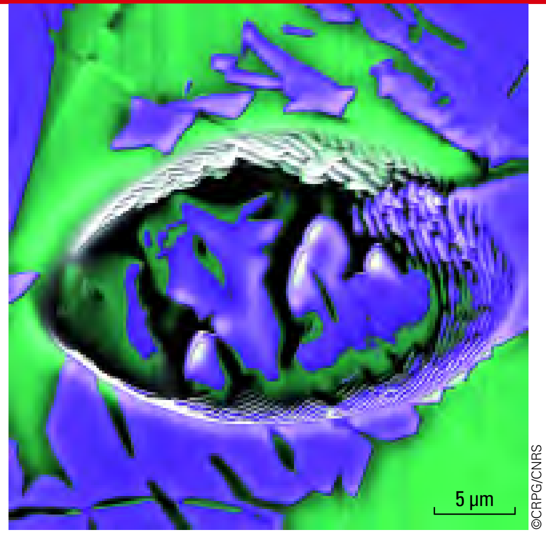
For the past 30 years, cosmochemists have dated meteorites using ^{26}Al, a short-lived isotope with a half-life of just 730,000 years, which is believed to have been abundant during the formation of the Solar System, more than 4.56 billion years ago.

Though no longer in existence, this isotope radioactively decays to the magnesium isotope (^{26}Mg), which can be effectively measured. This dating method, although extremely precise (on the order of 100,000 years), is still "relative," since it can only date objects in relation to one another.

To make it reliable, and allow scientists to retrace a precise chronology of the formation of solids, one would have to prove that the aluminum isotope was distributed homogeneously throughout the early Solar System.

This is what Johan Villeneuve from CRPG[1] and his colleagues set out to show.[2]

The team used the secondary ion mass spectrometer (SIMS), a high-precision tool that can measure isotope abundance in natural rock samples, to analyze the Semarkona meteorite. This chondrite, which fell in India in 1940, has remained relatively unaltered by thermal and chemical changes since its formation, more than four billion years ago. They found that although Semarkona's chondrules have very different formation ages, spanning a range of about three million years, their ^{26}Al initial content is very homogeneous.



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The glassy matrix (green) embedding pyroxene crystals (purple) in this sample from the Semarkona meteorite is the oldest glass known in the solar system.

"Since the aluminum isotope's homogeneity is present in the oldest materials as well as in more recent constituents, this homogenisation must have occured very early on," explains Villeneuve. This validates the use of ^{26}Al as a chronometer to measure the timing of chondrule formation.

"It also helps us understand the Solar System's evolution models," adds Villeneuve, "since such solids underwent the first condensation and accretion processes that finally led to the formation of planets."

The next step is to establish possible correlations between the chondrules' formation times and their petrographic and chemical characteristics.

Marion Girault-Rime

1. Centre de recherches pétrographiques et géochimiques (CNRS).
2. J. Villeneuve et al., "Homogeneous distribution of ^{26}Al in the Solar System from the Mg isotopic composition of chondrules," *Science*, 2009. 325: 985-8.

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BIOCHEMISTRY

Enzyme Displays Astonishing Property

Marielle Lemaire and her team at SEESIB,[1] who study enzymes that form sugar analogues, have made an accidental and unexpected discovery: an enzyme that can produce both glucose and fructose depending on the substrate it uses.

Her team and that of Pere Clapès[2] in Spain are looking for therapeutic solutions to treat diseases affecting the lysosome, an organelle of the cells whose function is intra-cellular digestion, carried out by over 50 enzymes. In these rare genetic afflictions, a deficient gene leads to the production of ill-built enzymes, which cannot play their natural role of biocatalyst. Their deficiency generates a toxic accumulation of metabolites (the natural substrates or molecules upon which an enzyme acts) within the cells.

For a few years now, a therapeutic strategy called "chaperon molecular therapy" aims to create small chaperon molecules, which, combined with the ill-built enzyme, will restore its functional form and reinstate its biocatalytic properties. The researchers' goal is to produce chaperon molecules that look like the natural substrate of the targeted enzyme so that chaperon and enzyme will easily interact with one another.

In this field, Lemaire was particularly interested in some glycosidases, enzymes that digest sugars in the lysosome. Her team wanted to create specifically-designed chaperons that resembled sugars and would be tested as chaperons for glycosidases. To do so, one can use enzymes that catalyse the formation of sugar analogues. A few months ago, her team began studying one of these "resource" enzymes: D-Fructose-6-phosphate Aldolase, which usually produces sugars from the fructose family. What they stumbled on was an unusual peculiarity: this specific aldolase also creates sugars of the glucose family, an ability never described before within the scope of this enzyme group. "What makes this enzyme exceptional is its ability to catalyse reactions with varied substrates. Usually, enzymes, like locks, only work with one key and only generate a reaction with specific molecules," explains Lemaire.

This "exotic" property, "absolutely stunning for scientists working in our field," has been described in an article labelled VIP—Very Important Paper.[3] The perspectives opened by this discovery remain to be explored: from diabetes treatment to artificial sweeteners, it will all depend on where industry takes it.

Marie-Hélène Towhill

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2. Instituto de Quimica Avanzada de Cataluña-CSIC, Barcelona.
3. X. Garrabou et al., "Asymmetric Self- and Cross-Aldol Reactions of Glycolaldehyde Catalyzed by D-Fructose-6-phosphate Aldolase," *Angew Chem Int Ed Engl.*, 2009. 48: 5521-5.

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GEOPHYSICS

Earth's Good Vibrations

Our planet is humming, and this hum relates to the Earth's structure below its crust. This finding,[1] that also promises to help delve into the structures of planets beyond our own, was revealed by a collaboration between teams from the University of Tokyo's Earthquake Research Institute and the Institute of Earth Physics of Paris (IPGP).[2]

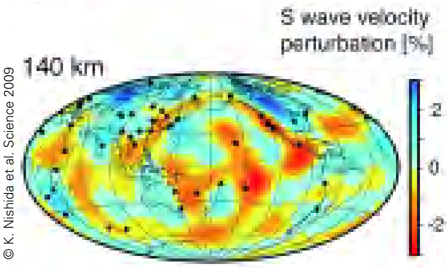
In 1998, Japanese scientists discovered that vibrations coursing through the Earth generated a hum, said to result from the interaction between solid landmasses and fluid layers of air and water. Since then, researchers have been listening very attentively to our planet's song, trying to read more into the melody.

For though this low-frequency[3] hum may elude human ears, it nevertheless speaks volumes—literally.

Until now, the Earth's subsurface has been explored by tomographic methods, where section images are compiled from earthquake data. Images can be created on the basis that seismic waves evolve as they travel through various geological formations. For example, they travel more quickly through cold, dense volumes than through hot, less dense ones.

While traditional tomography can only use data from strong earthquakes to generate images, the Franco-Japanese team has come up with an alternative that "could work without quakes, relying instead on the Earth's perpetual and ubiquitous hum," says Jean-Paul Montagner of the IPGP.

Using data from 1986 to 2003, the team analyzed the hum's sound waves gathered by 54 stations around the globe. As hum variations caused by atmospheric disturbances or ocean swells occur randomly, it is



© K. Nishida et al. Science 2009

Shear wave velocity perturbations, here measured at a depth of 140 km, and collected at stations all over the world (black dots), tell scientists about the Earth's structure.

possible to track the speed and path of specific sounds passing through the Earth's crust and thus establish phase-velocity maps.

By associating wave velocity fluctuations with variations in the mantle's physical and chemical composition, the team successfully derived a 3D model of the upper mantle.[4] The feasibility of this approach, capable of plunging to depths of 500 km, is confirmed by its correlation with mantle models established from seismic data.

Where the team's method promises to go even further is in the exploration of other terrestrial planets. Since the existence of quakes on such planets is not demonstrated, the team posits that their mantles may instead be modeled by tapping into their hums. This solution, Montagner believes, could work "on Mars and Venus, planets with atmospheres dense enough to excite their own hums." Ideally, this possibility would be tested by setting up a network of stations on the planets and operating them for several years.

Fui Lee Luk

1. K. Nishida et al., "Global Surface Wave Tomography Using Seismic Hum," *Science*, 2009. 326: 112.
2. Institut de physique du globe de Paris (CNRS / Université Paris Diderot / IPG).
3. Frequencies of 2-10 mHz.
4. Indicating the speed at which a given phase of a wave travels.

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CELL BIOLOGY

Stem Cells: Renewal vs Differentiation

Hematopoietic stem cells (HSC) can potentially give rise to any of the blood cell types. But when a stem cell divides, how is the decision taken to simply duplicate itself or to differentiate into a specific new cell type?

A team led by Michael Sieweke at the Immunology Center of Marseille-Luminy[1] addressed this question by examining how hematopoietic stem cells generate myeloid cells, a type of white blood cell that fights infections. To gather evidence, lab member Sandrine Sarrazin investigated the very first divisions of stem cells drawn from mouse bone marrow.[2]

"To isolate stem cells, we harvested all the cells contained in the bone marrow, then sorted hematopoietic stem cells by Fluorescence Activated Cell Sorting (FACS)," she explains. These cells were then either studied *in vitro* or reinjected into the spleen of a mouse, to follow their commitment to the myeloid lineage *in situ*."

The team discovered that the decision to generate myeloid cells results from the joint action of two proteins. One is located inside the cell (a transcription factor, which turns different genes on or off), while the other is a cytokine—a small protein that carries signals locally between cells and stimulates them to proliferate. "We have shown that the transcription factor MafB modulates stem cells' sensitivity to the cytokine M-CSF," explains Sieweke. When MafB level is high, stem cells are less sensitive to the action of M-CSF. Conversely, reduced levels of MafB make it possible for the cytokine to stimulate the stem cell to specifically give rise to myeloid cells.

Although focused on hematopoietic stem cells, this study might be relevant for other types of stem cells. It may also provide clues on how abnormal blood stem cells multiply in leukemia, and help develop treatment methods. Potentially, one might also learn how to orient the differentiation of blood cells in a deliberate direction, for example making more white blood cells to fight an infection.

Melisande Middleton

1. Université Aix-Marseille-II / CNRS / Inserm.
2. S. Sarrazin et al., "MafB Restricts M-CSF-Dependent Myeloid Commitment Divisions of Hematopoietic Stem Cells," *Cell*, 2009. 138: 300-13.

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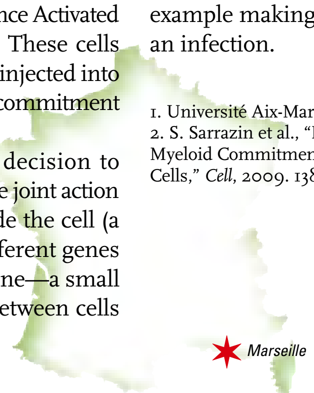


GEOPHYSICS

Largest French Glacier Melting

The Cook ice cap in the Kerguelen Islands, a French territory in the southern Indian Ocean, has shrunk at an ever increasing speed over the last 20 years.[1]
Matching satellite data from 1991, 2001, and 2003 with historical data from 1963, researchers from LEGOS[2] observed a 22% volume loss over the 40-year period, a process which accelerated in recent years.
On average, the ice mass has thinned by 1.5 meters per year, a much faster pace than that recorded for other glaciers in the world.
Scientists believe global warming, through high temperatures and low precipitation since the 1980s, is partly responsible for the melting. But since the ice loss started in the 1960s,

NEUROBIOLOGY

Memory Improves with Sleep

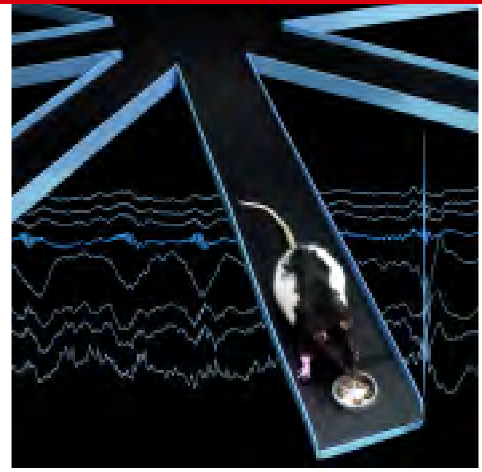
Not only does “sleeping on it” help with decision-making, it also lets us memorize important information acquired during the day. Recent research throws new and astonishing light on this process.

Though apparently asleep, a healthy rat is busy memorizing its way through a specially-designed maze it had earlier been placed in.

These neurophysiological processes, specifically the mechanisms of memorization during sleep, were recently investigated[1,2] by researchers from LPPA.[3]

According to the most widely-accepted hypothesis, during sleep a dialogue takes place between two structures in the brain—the hippocampus and the cortex—which enables long-term memorization of information in the cortex. Yet until now, this dialogue had never really been observed. To meet this challenge, the researchers implanted electrodes in the brains of rats to observe ongoing neural activity. The rodents were placed in a maze where they had to learn a specific task, such as turning right at each junction, for example. Once they had understood the task, they were allowed to go to sleep.

The scientists were then able to compare neural activity during wakefulness and sleep. “When the rat was carrying out its task, neuronal assemblies[4] developed which were activated simultaneously in the cortex and hippocampus. Then, during sleep, we observed that the same patterns were reproduced,” explains LPPA researcher Adrien Peyrache. In other words, the rat was dreaming about the maze: the cortex and hippocampus together “replayed” the events that the animal had just experienced, letting the rat assimilate new knowledge. But there is more: “We realized that neural activity during sleep corresponded to that which occurred when the rat had understood a task during wakefulness. In other words, the brain only replayed episodes in which the rat’s behavior was the most efficient.” Thus the animal first and foremost retained what would prove useful to him.



© G. Girardeau

Sleeping right after this exercise will help the rat remember where to find the food in the maze.

The other part of this research concerns the role of the hippocampus in this dialogue with the cortex. Cortex-hippocampus interactions occur specifically when the latter emits very rapid electrical oscillations called “ripples.” “The most common hypothesis is that ripples allow memory consolidation during sleep, probably by transferring labile memories to the cortex,” explains Gabrielle Girardeau, another researcher at LPPA. This is the hypothesis that the scientists wanted to test.

For this, they placed rats in a chamber shaped like an eight-pointed star. A reward was placed at the end of three of the points (always the same). The rats were encouraged to explore the star to find the reward, and were then allowed to go to sleep.

During their sleep, the scientists used electrodes to apply very weak electrical pulses to the rats’ hippocampi. Though this did not wake the rodents or disturb other parts of their brain, it specifically blocked the ripples.

The result was that during the 15-day experiment, treated rats found it difficult to memorize the rewarding points of the star, unlike the control rats that were highly successful. “The ripples thus play a fundamental role in memory consolidation, probably by transmitting information to the cortex.”

Sebastián Escalón

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2. G. Girardeau et al., “Selective suppression of hippocampal ripples impairs spatial memory,” *Nat. Neurosci.*, 2009. 12: 1222-3.
3. Laboratoire de physiologie de la perception et de l’action (CNRS/ Collège de France).
4. A subpopulation of coordinated cells whose synchronous discharge is associated with internal process and information encoding.

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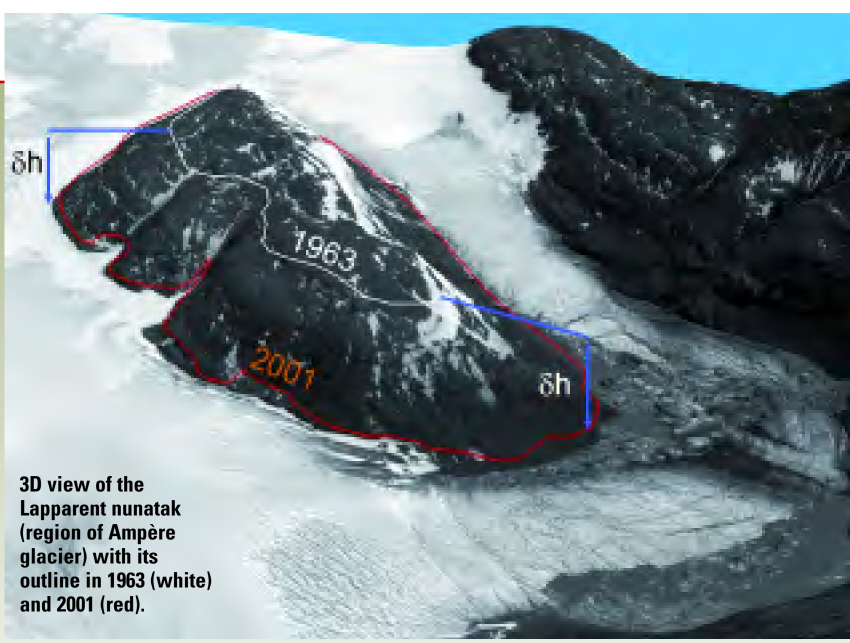

3D view of the Lapparent nunatak (region of Ampère glacier) with its outline in 1963 (white) and 2001 (red).

© CNES 2003 / Distribution Spot Image / Traitement E. Berthier (LEGOS)

researchers also put the blame on the glacier’s delayed response to the natural warming that followed the Little Ice Age, a cold period that ended in the second half of the 19th century.

1. E. Berthier et al., *J. Geophys. Res.,* 2009. 114 doi:10.1029/2008JF001192.
2. Laboratoire d’études en géophysique et océanographie spatiales (CNRS / IRD / CNES / Université Paul Sabatier).

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PALEONTOLOGY

In the Footsteps of the Largest Dinosaurs

In early October of last year, CNRS announced the discovery, near the city of Lyon, of the largest dinosaur footprints ever found. How significant is this discovery and what can these footprints tell us about the animals that left them?

When Marie-Hélène Marcaud and Patrice Landry, two nature enthusiasts, came across oval tracks 1.5 m long in Plagne in April 2009, they immediately reached out to Pierre Hantzpergue and Jean-Michel Mazin from the PEPS laboratory.[1]

"These tracks were left by some of the largest animals to ever walk the planet," says Mazin, who is studying the large soil depressions, together with geologist Hantzpergue. Beyond their unusual size, Mazin also notes the presence of a fold of limestone sediment towards the front of the prints. "The fold was formed when the animal's paw sank into mud," he explains.

He also recognizes evidence of quadruped locomotion, with alternating prints made by the front and back paws. "In this case, the animal footprint partly overlaps its handprint. The handprint thus only appears as a thin crescent-shaped print at the front of the footprint."

As for Hantzpergue, he is dating the footprints by biostratigraphy. "This involves studying the different strata which have built up under the footprints to analyze the fossils within them, notably ammonites," he explains. Ammonites went through a very rapid morphological evolution, which makes it possible to date, in relative terms, the strata where they are found to within 150,000 years. This is a precise enough estimate, given that the dinosaur tracks are more than 150 million years old.

Beyond simply breaking a size record (the largest footprints until now measured 1.2 m) "what interests us is the wealth of information these footprints will reveal about the animals who left them," says Mazin. "We will be able to understand how they walked." And it must have been something of a challenge, considering the animal's weight. According to known sauropod skeletons, the footprints suggest these dinosaurs were more than 25 meters in length and weighed more than 40 tons. The weight at which a living being would collapse under its own weight is only 10 or 20 tons off...

To reconstruct a few minutes of the life of a 40-ton giant from these footprints—some 20 have already been uncovered—the researchers want to work with biophysicists who will provide biomechanical equations for quadruped locomotion, models that have already been used on smaller dinosaurs from the same family. Using the distance between footprints, the researchers hope to calculate the speed at which the animal was moving—probably no more than 4 km/h—as well as determine its acceleration and deceleration. The angle between footprints left by the right and left feet is expected to reveal the maneuverability of the animal, which was probably very limited. "To turn, they probably needed to stop first," adds Mazin. "They were certainly incapable of running, and were pretty much trudging along, keeping three paws on the ground at any one time. In fact, even to lift a single paw must have required a huge effort."

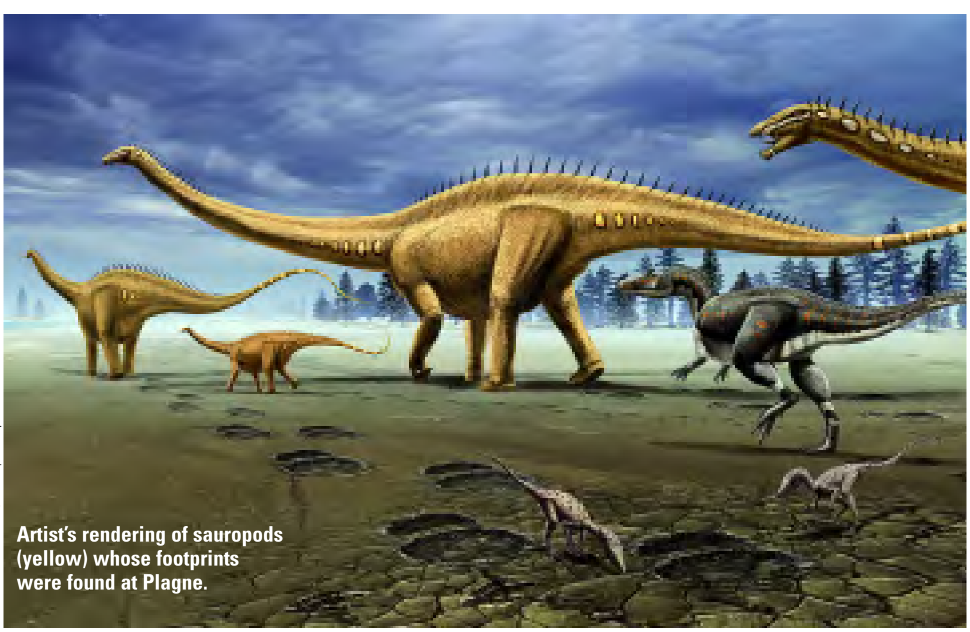
What were these dinosaurs doing in an area that was covered by sea for millions of years during the Jurassic period? "We know that at the end of this period, the region was frequently immersed," says Hantzpergue. These dinosaurs, which were 300 km further north, probably took advantage of a drop in sea level to head south. Vegetation-covered islets, interspersed throughout this vast muddy plain, probably provided food for the expedition. "To know more, we need to reconstruct the lives of these sauropods, mainly by using fossils of other animals we hope to find," says the geologist.

So, how did the footprints survive until now? Made in carbonated mud and preserved from the paths of other animals, they probably dried fairly quickly in the sun. "They were then covered by several hundreds of meters of sediment, and later exposed through the erosion that created the Jura's topography," says Hantzpergue. More recently, a path used to carry wood led to the removal of the top layer of soil, virtually exposing the footprints.

Further exploration has suggested the presence of other tracks, hundreds of meters away, under 10 to 50 cm of earth and plant cover. Uncovering them will mean digging up a meadow of several hectares. The whole area needs to be mapped, through laser survey of the tracks and aerial photography. This research is expected to take three to four years for a team of 30 people whom the researchers hope to recruit. They will also need to secure funding, possibly from the regional authorities of the area, in order to pursue their work and uncover more sauropod footprints.

Charline Zeitoun

1. Paléoenvironnements et paléobiosphère (CNRS/Université Claude Bernard Lyon-I).



Artist's rendering of sauropods (yellow) whose footprints were found at Plagne.

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ECOLOGY

Uncharted Territory

Last October, a group of explorers crossed one of the last unknown expanses on Earth, the Cordillera Darwin in Tierra del Fuego, southern Patagonia. CNRS researchers took advantage of this unique expedition to collect samples that will help them understand how species adapt to the harshest climates.

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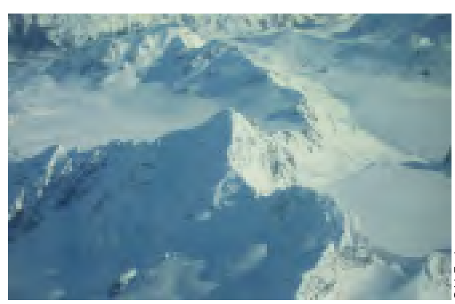
There is little doubt the spirit of great explorers like Darwin, Humboldt, or Bougainville escorted the French expedition which left in late September to travel through one of the last unexplored regions on Earth, the Darwin Cordillera in the southernmost part of Patagonia.

The participants included mountaineers, researchers, photographers, as well as a filmmaker and a writer. As during the golden age of world exploration, all aspects of discovery were present on this six-week expedition, aptly called "A Darwin dream."

"The original idea came from a group of mountain guides who wanted to set up an expedition to an unexplored region of Earth. They settled on the Darwin Cordillera fairly quickly. Even though some of the coastal peaks of the range have been climbed, no one has ever attempted to cross the entire length of the range," explains Sandra Lavorel, CNRS senior researcher at LECA[1] in Grenoble. "Yvan Estienne, the expedition leader, wanted to add a scientific dimension to the project. That's how I got involved." As an ecosystems specialist for regions with extreme climates, she planned the scientific project together with Sébastien Ibanez, also from LECA, who actually participated in the expedition and collected the samples. For once, it is the expedition itself that determined the direction of research and the experiments to be conducted. "The mountaineers wanted to leave at the beginning of spring for the Southern Hemisphere, when the snow bridges still fill crevasses. That's why we decided to base our research on trees, the only plant form that would emerge from the snow cover."

In Patagonia, the team trekked a 100 km across passes, peaks, and unknown glaciers.



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More specifically, researchers decided to look at the subantarctic beech *Nothofagus pumilio*. Although this beech originated in the Southern Hemisphere and is well adapted to rigorous climatic conditions, it cannot grow above a certain altitude. "Research carried out in New Zealand on related beech species shows that the altitude limit is not only climatic—if the only issue were temperature, beech forests would be found at higher altitudes." Previous observations in Chile and New Zealand point to an "invisible barrier" that beech trees cannot cross.

What is the true nature of this barrier? The scientists will attempt to test two hypotheses. The first one focuses on the availability of nutrients. If above a certain elevation trees cannot draw enough phosphorus and nitrogen from the soil, they are not able to grow. The other complementary hypothesis has to do with the microbial diversity of the soil. For nutrition and growth, trees rely on the activity of soil bacteria and fungi that recycle nutrients. The growth barrier for trees may result from differences in the abundance and species of microorganisms in forest soils.

During the one-month expedition, Ibanez, aboard the Nueva Galicia vessel which served as the expedition's logistical base, performed several excursions to take soil and leaf samples. He collected 120 samples, around 15 kg altogether, in the three plant communities that are distributed along an altitude gradient from sea level up to 650 meters. "This is the most difficult but also the most beautiful field work I've ever done," he comments. "Sometimes, to reach the most interesting areas, it was necessary to cut a path through ice fallen from the glaciers, or to dig holes over a meter deep in the ice," he adds.

The collected samples are now being analyzed at a Chilean laboratory[2] which LECA has been cooperating with for several years. DNA samples will be brought back to LECA to be sequenced in order to characterize the local microbial biodiversity.

One of the key assets of this research is that it was carried out in virgin ecosystems. "When we do research in the Alps, for example, we know we are working in places that have been cleared, colonized, and used for agriculture or forestry throughout history," says Lavorel. "In this remote part of Tierra del Fuego, there has been no human interference. All the physiological traits of the species are directly related to climatic conditions." The expedition should lead to insights into the evolution and adaptation of species to the harshest climates. And these will provide precious information at a time when climate change is hitting subantarctic regions full on.

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2009 CNRS GOLD MEDAL

Serge Haroche: Photon Tamer

Serge Haroche is the recipient of the 2009 CNRS Gold Medal, the highest French scientific award. This outstanding physicist was able to carry out some of the most elaborate thought experiments ever imagined by the inventors of quantum physics, over a hundred years ago, in order to observe the infinitesimally small.

Niels Bohr once argued that truth and clarity could not simultaneously be achieved, but Serge Haroche's work shows us that they can be," says MIT Professor Daniel Kleppner, talking about the 2009 CNRS Gold Medal laureate.

As the leading pioneer of quantum theory, Niels Bohr, together with Werner Heisenberg, Erwin Schrödinger, and a few other scientific heavyweights, revealed the strange world of the infinitesimally small. They imagined a number of thought experiments to illustrate the state superposition of particles, and Serge Haroche, now 65, has worked hard over the last 30 years to turn these experiments into reality.

At such a scale, one can neither measure nor accurately predict both the velocity and position of a particle at the same time: it can be both here and there, or spin clockwise and counterclockwise. The quantum systems are so to speak "suspended" between different classical realities, their state being described by so-called "quantum superpositions." "In our work, we observe the state superpositions of systems made of a few particles," Haroche explains. "Our goal is to catch the moment when a system ceases to be quantum and becomes classical. This transition from one world to the other is called decoherence. It happens because the coherence of the system is somewhat disturbed by its macroscopic environment which forces it to take an unambiguous stand in the classical realm."

Haroche has become a master in the art of catching quantum coherence, i.e., the state superpositions of particles. To observe this phenomenon, he confines a few photons to a trap (*see box*), forcing them to bounce back and forth, more than a billion times, between two highly reflective mirrors. In this device, called an electromagnetic cavity, the captive photons survive more than a tenth of a second before decaying into the mirrors. This gives Haroche enough time to observe their quantum state and witness the decoherence phenomenon.

In the 1970s, he was the first to suggest using highly excited atoms as probes to detect radiation with very high sensitivity. In the cavity experiments, these probes, called Rydberg atoms, cross the cavity and carry away with them a print of the photonic state, just like X-rays can take prints of a body's internal structures. In this way, the photons' state is revealed as an abstract picture containing all the information about its quantum features. Such studies of single quantum systems would have amazed Bohr, Heisenberg, or Schrödinger.

Haroche's interest in science began when he arrived in Paris in 1956, after a childhood spent in Casablanca (Morocco). In high school, he discovered a passion for math and realized with amazement that nature obeyed mathematical laws. Admitted to the prestigious "Ecole Normale Supérieure" (ENS) in 1963, he particularly appreciated the fact that he could immediately start working in a research lab.

Three years later, he began working on his PhD in the Laboratoire de Spectroscopie Hertzienne at ENS (now renamed Laboratoire Kastler Brossel[1]), which was—and still is—at the forefront of quantum physics research. At the time, major leaders in the field were working there, like Jean Brossel, who was later awarded the CNRS Gold Medal (1984), or Alfred Kastler, the winner of the 1966 Nobel Prize in Physics. His thesis advisor, Claude Cohen Tannoudji (1997 Nobel Prize in Physics) guided Haroche's first steps into the world of atoms and photons.

After an early appointment at CNRS, Haroche moved to Pierre and Marie Curie University where he became physics professor in 1975, while keeping his research activity at ENS. Between 1981 and 1993, he also held both visiting and part time positions at Stanford, MIT, Harvard, and Yale.

Today, Haroche is head of the "Electrodynamics of simple systems" group at the Kastler Brossel laboratory and professor of quantum physics at the Collège de France. He has authored more than 170 publications and has received a number of scientific awards. As for the CNRS

CATS IN A CAVITY

Cavity experiments carried out by the team at the Laboratoire Kastler Brossel (LKB) study the strange nature of the principle of superposition by performing what physicists call a "Schrödinger's cat" experiment, in reference to a famous thought experiment formulated by Erwin Schrödinger in 1935.

To illustrate the superposition of particle states, Schrödinger imagined the following set-up: in a sealed box are placed a cat and a flask of poison whose condition depends on the state of a radioactive atom. If the atom decays, the flask shatters, killing the cat. If it doesn't decay, the flask remains intact, and the cat alive. According to quantum theory, there is a time during which the state of the atom is uncertain: it is just as likely to have decayed as to have remained intact. In other words, the atom is in a superposition of two states, and so is the cat: there is no way of knowing whether it is dead or alive, it is both things at once.

In the experiments at LKB, the cat is replaced by a

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Serge Haroche and his colleague Igor Dotsenko are setting up a cavity experiment.

Gold Medal, "I consider it an acknowledgment of a team's work and a mark of CNRS' commitment to basic research," he says.

Haroche is already thinking about the future, with a full program ahead: "Our objective is to improve the cavity experiments in order to control decoherence: we want to find ways to delay it as much as possible and better understand why it occurs," he adds. He also wants to further some of the possible applications of his work in quantum information physics. "This field has been thriving over the last 15 years and has led to the development of innovative technologies such as quantum cryptography."

Haroche is a team player and never misses an opportunity to pay tribute to his students and co-workers, primarily Jean-Michel Raimond and Michel Brune, who have been his students and are now his colleagues and co-workers at the Kastler Brossel laboratory. "I could have done nothing without them," he says. "The work rewarded today is their achievement as much as it is mine."

Emilie Badin

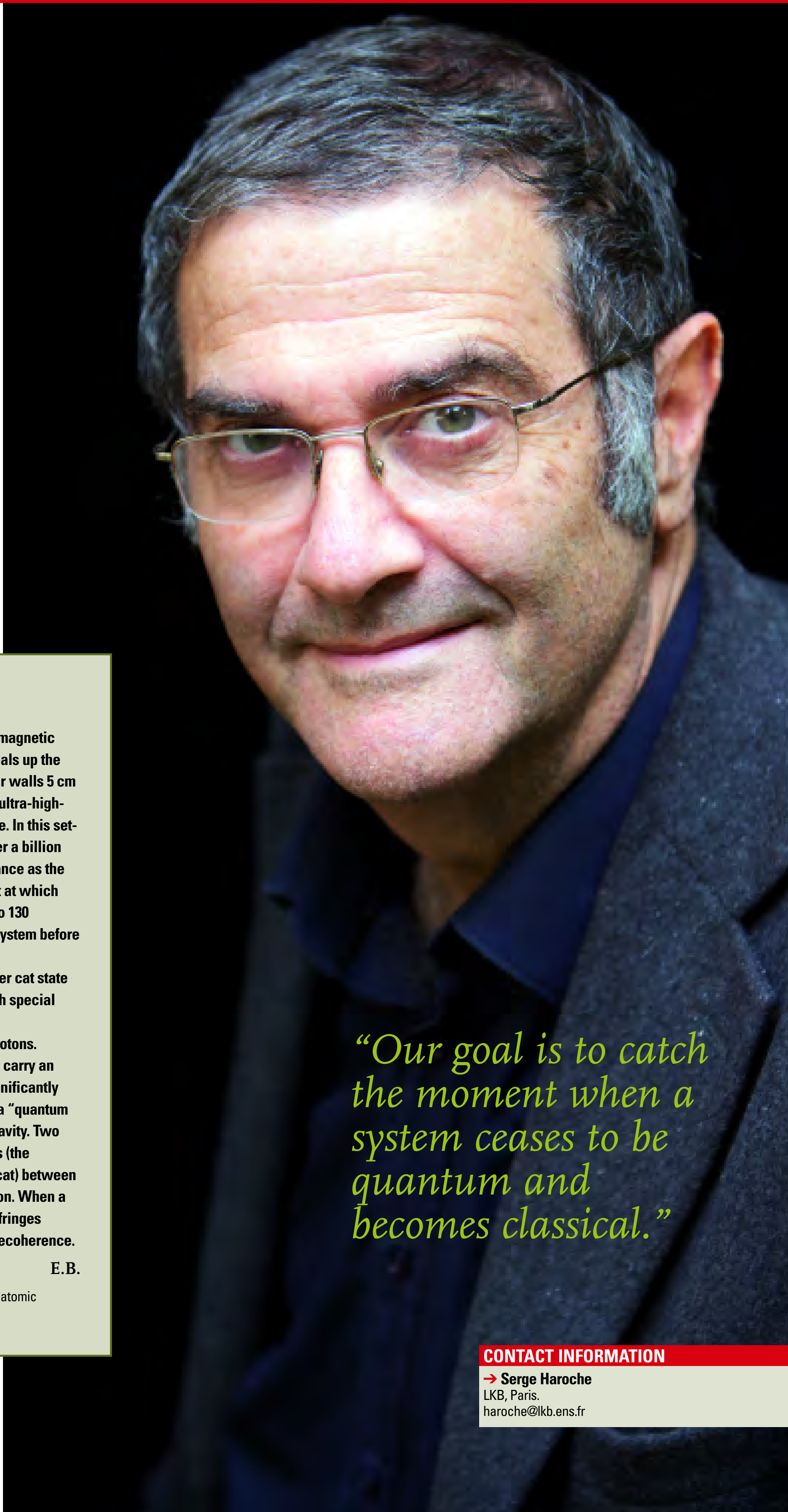
1. CNRS / ENS Paris / Université Paris-VI.

handful of photons (from the microwave region of the electromagnetic spectrum). To capture the superposition of states, the team seals up the photons in a cavity, or more specifically between two circular walls 5 cm in diameter that face each other. The walls are covered with ultra-high-reflectivity mirrors cooled to a near absolute zero temperature. In this set-up, the photons bounce back and forth between the walls over a billion times, which means that they travel 40,000 km, the same distance as the circumference of Earth. This considerably delays the moment at which they are absorbed by the mirrors. Their lifespan is extended to 130 milliseconds, which is enough time to observe the quantum system before decoherence takes place.

But how can the quantum system be prepared in a Schrödinger cat state and then be observed? The key is to prepare and detect it with special probe atoms—atoms placed in a Rydberg state through laser excitation[1]—which are extremely sensitive to microwave photons. Crossing the cavity one by one, the Rydberg atoms manage to carry an imprint of the field state without absorbing light energy or significantly disturbing the system. From these imprints, the team creates a "quantum map," a kind of image of the state of the field trapped in the cavity. Two peaks can be distinguished, the signatures of classical states (the equivalent of the "dead" and "alive" states of Schrödinger's cat) between which are interference fringes, signs of quantum superposition. When a quantum map of the field as a function of time is created, the fringes progressively fade away, revealing the process of quantum decoherence.

E.B.

1. Named after the physicist Johannes Rydberg, one of the founders of atomic spectroscopy.



"Our goal is to catch the moment when a system ceases to be quantum and becomes classical."

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NANO-TECHNO-LOGY UPDATE

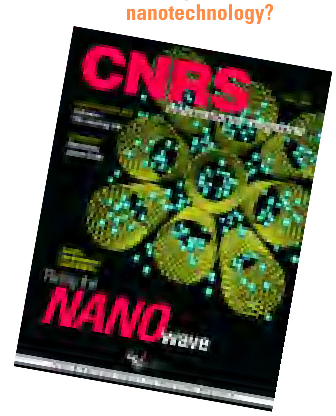
Nanotechnology is already a part of everyday life. Carbon nanotubes, for instance, are used in the manufacturing of golf clubs and golf balls, as well as bicycle frames. Nanomaterials are also used in cosmetics (sunscreen, anti-ageing creams, etc.), tires, electronics, paints and varnishes, or anti-bacterial systems in some washing machines.




Four years ago, CNRS International Magazine covered the spectacular take-off of nanoscience and nanotechnology, set to revolutionize entire disciplines, from medicine to electronics. What progress has been made since then? Are there already real-world applications? Have there been any catastrophic failures? What new challenges face today's researchers—and what is France's role in this rapidly-expanding field? Last October, the country's public debate commission (CNDP),[1] launched a national debate on nanotechnology. CNRS International Magazine revisits the field and explores its latest discoveries to take a look at the current state of play. Our first finding? That nanotechnology is indeed delivering on its promise.

Special report by Philippe Testard-Vaillant

Cover of the Spring 2006 edition of CNRS International Magazine. Four years on, what are the latest developments in nanotechnology?



Nanoscience and nanotechnology are developing so fast that they are now among the top fields in research and innovation across Europe, the US, and Asia, and are thus playing an increasingly important role in the global economy. Currently estimated at €100 billion, analysts forecast that the international nanotechnology market will reach €1.7 trillion by 2014 and make up an astonishing 15% of the world's manufacturing output. We are far indeed from nanotechnology's first faltering steps, and US physicist Richard Feynman's provocative 1959 lecture in which he stated that the entire Encyclopaedia Britannica could fit on the head of a pin. "There is plenty of room at the bottom," he prophetically remarked.

No longer confined to the laboratory, nanotechnology is now very much a part of everyday life, with the ubiquitous presence of nanoelectronics in the computing field, the encapsulation of drugs in nanoparticles, or microdevices for medical analysis and diagnosis. Then, there are nanostructured titanium nitride coatings to extend the lifespan of cutting tools, nanofiltration of ground water and wastewater, silver nanocrystals as an antimicrobial barrier in band-aids, inorganic nanoparticles incorporated into paints as additives to increase their resistance to abrasion, inorganic nanoparticles used as UV absorber in sunscreen, nanocatalysts, nanocomposite packaging materials, and so on.

"In the race towards ever-increasing miniaturization, electronics was without a doubt at the cutting-edge five years ago," says Jean-Michel Lourtioz, director of the Institute for Fundamental Electronics (IEF).[2] "But today, research that blends micro- and nanotechnology with biology and medicine also blossoms at the forefront, and is making significant progress."

ENTER THE NANOWORLD

To begin with, it is worth defining some terms. Nanoscience "aims to explore the novel >

physical, chemical, and mechanical properties that matter takes on at scales of a billionth of a meter, while nanotechnology tries to make use of such properties in all sorts of marketable end-products," explains Claude Weisbuch, of the PMC laboratory.[3] There are two ways of making nano-objects: the top-down approach, which consists in gradually shrinking material structures until you finally reach dimensions that are less than 100 nm; or the bottom-up approach, which consists in manipulating matter such as atoms and molecules so that they build nano-objects.

For purists like Christian Joachim, from CEMES,[4] the term nanotechnology should be restricted to the latter approach. He believes that the definition has become far too broad, and that in 95% of the cases, the term "nanotechnology" is wrongly used.

In fact, when it comes to building objects atom by atom, or experimenting with a single molecule, there has been tremendous progress over the past five years, which can be attributed to scanning tunneling microscopes (STM) and atomic force microscopes.[5] "Very recently, researchers at the IBM Research center in Zurich succeeded in mapping chemical bonds inside a molecule of pentacene," Joachim enthuses. This is a bit like using X-rays to see inside the human body. Yet the most fascinating progress is in the field of mechanics. "We can make molecule-motors, molecule-gears, molecule-wheelbarrows, etc., with sizes of one to two nanometers. There's even an 'entertaining' international competition on who can make the first molecule-car equipped with four wheels and an engine! Though no one really knows what applications these molecule-machines might have, this is teaching us how to design machines or circuits in a single molecule."

NANOSCIENCE VS NANOTECHNOLOGY

How well is France doing in this highly aggressive international competition? With some 3500 yearly publications on the subject, France takes an honorable fifth place, behind the US, Japan, China, and Germany. As for research in nanotechnology, France, with less than 2% of worldwide patents, is at a considerable disadvantage.

In this field, "France is in the 'ivory tower' category," says Alain Costes, from LAAS.[6] "In other words, we have problems turning the results of our scientific research into technical innovations that can boost economic growth through filing patents. And without a strong reaction within the French scientific community, faced with extremely successful newcomers such as Taiwan, South Korea, Singapore, Israel, and Russia, we will gradually fall even further behind the group of nations

Precision DRUGS

There are already a dozen or so nanodrugs on the market, mainly aimed at treating cancer (Caelyx, Doxil, etc.) or serious fungal infections (Ambisome), or used for liver imaging (Endorem).

The nanoparticles used in these drugs are 70 times smaller than a red blood cell and are completely biodegradable. They deliver their active principles directly to the diseased organ, tissue, or cell. Yet not all these nanomedicines have the same properties.

First-generation nanomedicines are recognized by the immune system as foreign bodies and are therefore eliminated via the liver, which makes them very useful, but only for liver diseases.

On the other hand, second-generation nanocarriers—so-called "stealth"—are covered with hydrophilic, flexible polymers that make them invisible to the immune system. These nanovectors remain in the general bloodstream for a much longer period, and can be used to target other afflictions, like degenerative brain diseases. Third-generation nanocarriers are now being introduced. "Their main advantage is that they are decorated by 'homing devices' (such as vitamins, hormones, antibodies, peptides, etc.) that can selectively recognize the targeted diseased cells," explains Patrick Couvreur, director of the PPB laboratory.[1] These hyper-miniaturized "missiles" can also carry metal nanoparticles, meaning that the drug can be released at will via ultrasound or radio-frequency heating.

Another application of nanovectors that looks highly promising is the delivery of chunks of DNA to cells. "Completely replacing a defective or missing gene is still extremely tricky," says Couvreur. "Yet nanovectors could be engineered to deliver small fragments of nucleic acids so as to inhibit, for example, the expression of a cancer or a viral gene."

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Liposomes, vesicles measuring tens to hundreds of nanometers, make excellent nanovectors for drugs.

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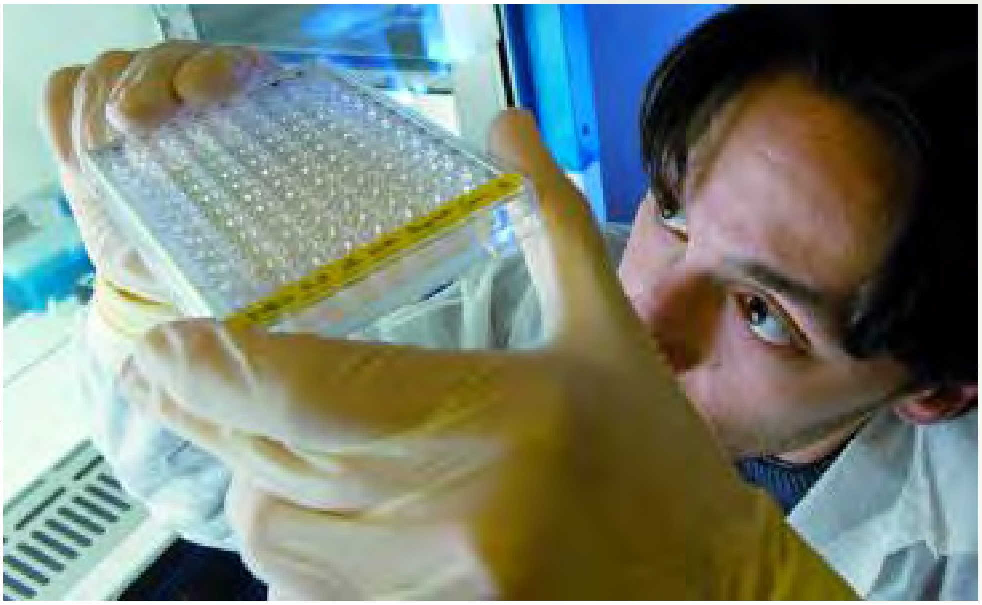

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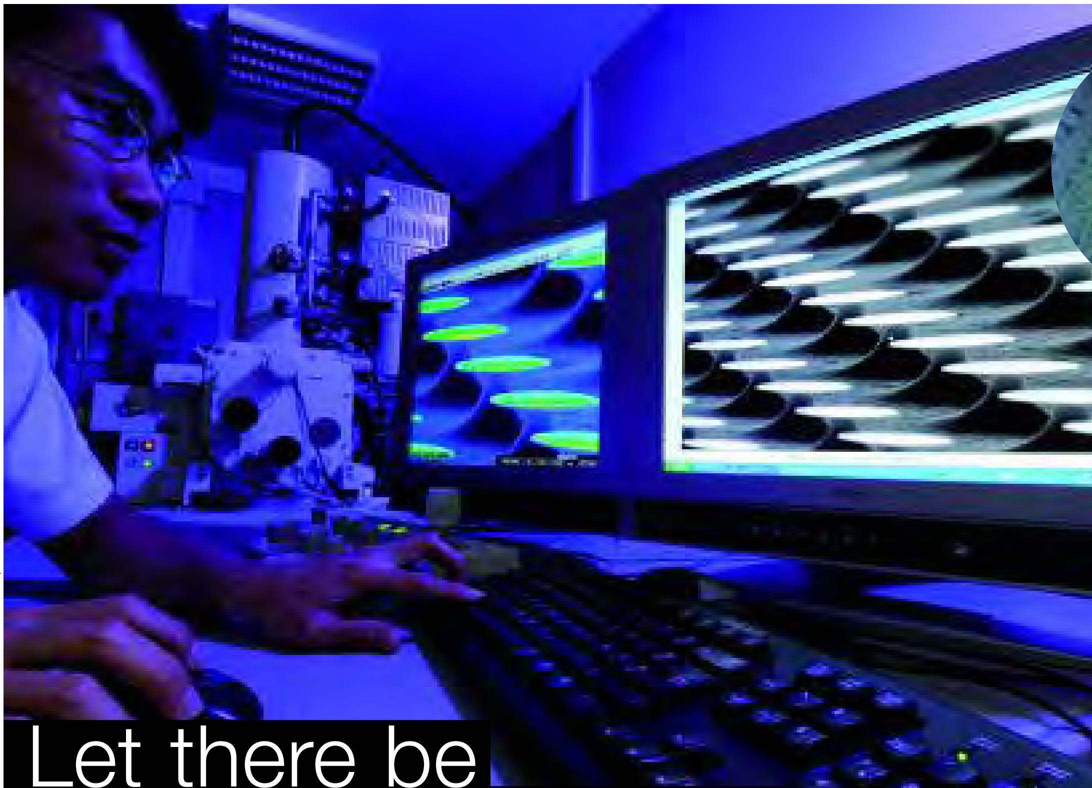
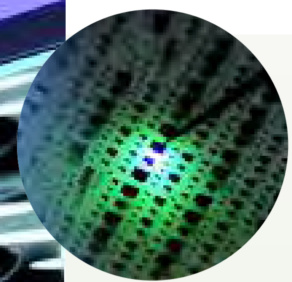
Researchers incubate nanodrugs with mouse cancer cells to screen for novel anticancer drugs.





Test set for the light-emitting properties of LEDs.

Let there be NANOLIGHT

The future is already bright for light-emitting diodes (LEDs), which are based on semi-conducting materials—mainly gallium nitride. In fact not a month goes by without engineers finding a new use for LEDs in television sets, remote controls, automobiles, cell phones, street and interior lighting, etc. "But we're now trying to incorporate nanocrystals into them, rather than the conventional layers that convert blue to yellow, as in fluorescent tubes," explains Jean-Yves Duboz, director of CNRS' Research Center for Heteroepitaxy and its Applications (CRHEA).[1] Nanocrystals emit photons (light) when electrons (i.e., an electric current) pass through them, and the color of the light emitted depends on the size of the nanocrystal. "White light is obtained by a clever mix of red, blue, and green photons, which means that you have to couple three LEDs," explains Duboz. "What we're trying to do here is to develop LEDs that only use a single crystal that can directly emit all colors. To do this, we insert nanometer-sized components in the crystal, which are little chunks of various sizes that emit blue, green, red, etc., together producing white light. On paper, it's an ideal solution, though for the moment our LEDs are still not powerful enough." Although their output is actually very efficient, the white LEDs now on the market have a luminous efficacy of 100 lumens[2] per watt (lm/W), as opposed to 60 to 80 lm/W for fluorescent lamps and 16 lm/W for incandescent bulbs. "There are prototypes that reach close to 200 lm/W," Duboz continues. "But if LEDs are very efficient when they work at low currents, their efficacy falls off a little (75 lm/W) at the higher currents needed for cheaper street and industrial lighting."

Photonic crystals could soon be used to improve LED efficiency.

To get around this problem, researchers make use of photonic crystals, a type of light cage made up of a regular arrangement of nanostructures that works like reflective road signs. This should "improve the directionality of LEDs," comments Henri Benisty, from LCFIO,[3] "preventing them from dispersing light in all directions."

Scanning electron microscope image of micro-disks of aluminum gallium nitride, a semi-conductor used to make LEDs.

1. Centre de recherche sur l'hétéroépitaxie et ses applications (CNRS).
2. The lumen is the unit of light flux.
3. Laboratoire Charles Fabry de l'Institut d'Optique (CNRS / Université Paris-XI).

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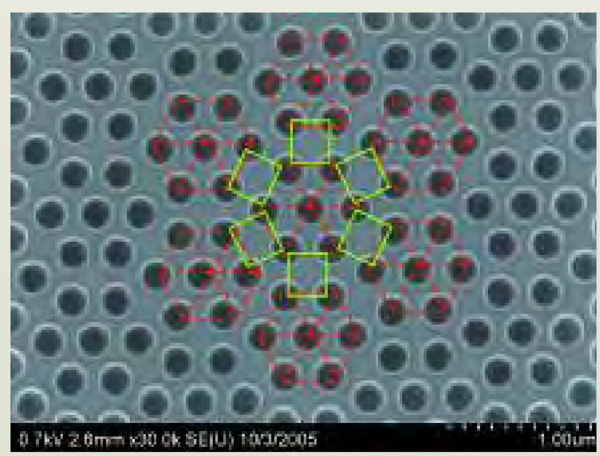


that will play a leading international role in the economic development of nanotechnology."

As a result, last May saw the launch of the Nano-Innov plan. Last year, it was provided with a €70 million budget to be managed by the French National Research Agency (ANR), which is already granted for 2010. The program is set to create three major technological integration centers at Saclay (south of Paris), Toulouse, and Grenoble. "These three complementary clusters will make it possible, for the first time in this key sector, to closely associate scientific research and industrial development," says Pierre Guillon, director of CNRS' Institute for Engineering and System Sciences (INSIS).[7] The aim is not to curb nanoscience research, but rather to "make a number of top-level academic groups aware of the potential applications of their work," adds Costes. Eventually, each integration center will have shared facilities covering the entire range of nanotechnology, and will thus be in an ideal position to work hand-in-hand with industry.

With around 170 laboratories and 2000 researchers involved, CNRS is a serious contributor to the plan, and has indeed set nanoscience and nanotechnology as a major scientific priority. >

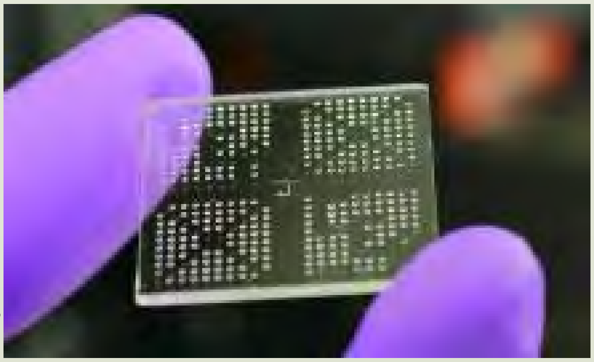
A Lab-on-a-CHIP

Nanomanufacturing technologies are used to develop tools for biology or medicine, like the biochips shown here.

© E. Perrin/LAAS/CNRS Photothèque

Biosensors and biochips are progressing by leaps and bounds, and feature among the most exciting new approaches in nanobiotechnology. Biosensors, though still at the prototype stage, "are used to detect a particular 'biological species' (such as DNA, proteins, viruses, etc.), for instance in a highly complex system like a drop of blood," explains Anne-Marie Gué, of LAAS.[1]

This biochip allows analysis of thousands of proteins or DNA sequences.



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"The possibilities opened up by nanotechnology are far-reaching. For example, scientists can use 'probes'—DNA strands, or antibodies—grafted on silicon nanowires or nanobeams to catch specific molecules." When the target binds to an ultra-sensitive microbeam, the beam starts to vibrate, showing that the target molecule has been captured, while the rest of the system analyzes it. "At the Institute for Fundamental Electronics (IEF),[2] we are developing a novel nano-biosensor. Each beam has an internal channel etched into it along which biological fluid can circulate. So the beam itself is not immersed in the fluid," explains Jean-Michel Lourtioz. "This trick makes it easier to detect variations in the amplitude or in the frequency of vibration."
And then there are biochips, already used by some medical laboratories. Rather than identifying a single molecule in a biological sample, "the objective here is to carry out a large number of analyses at the same time," says Gué. To do this, the biochips are made up of a solid substrate (glass, plastic, or silicon) covered with a microarray of tiny sites on which are placed molecules of DNA, proteins, or chemical groups that can specifically capture complementary DNA or RNA (DNA chips), or proteins (protein chips). "A DNA chip is able to simultaneously analyze anywhere between dozens and thousands of different DNA sequences to identify a virus or detect a specific marker for a disease." Unlike biosensors, signal readout is not incorporated into the biochip, but carried out by external instruments. "One promising development, where both technologies would meet, is the integration of nanobio-sensors at each site of a biochip," adds Gué. But the real challenge is to integrate complete analytical procedures on very small surface areas. Biosensors and biochips could thus become a "lab-on-a-chip" (LOC). In such a device, it would even be possible to integrate lasers, made from semi-conducting nanostructures of the gallium nitride (GaN) and zinc oxide (ZnO) families, which are very much in fashion at CRHEA.[3] "We're testing the feasibility of a nanolaser based on GaN nanowires emitting in the ultraviolet," says researcher Jesús Zúñiga Pérez. Approximately 100 nm across, this laser, integrated on an LOC, could be used to excite organic molecules in a biological sample and analyze the composition of such molecules. But in order to develop these pocket-size labs, researchers need to master fluid dynamics for volumes of less than a nanoliter, and to be able to manipulate biological species right down to the level of a single cell.

1. Laboratoire d'analyse et d'architecture des systèmes (CNRS).
2. Institut d'électronique fondamentale (CNRS / Université Paris-XI).
3. Centre de recherche sur l'hétéroépitaxie et ses applications (CNRS).

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ETHICAL ISSUES

Although nanotechnology opens up many exciting prospects, for some it is already a source of concern."Nanotechnology carries its share of worries," admits Robert Plana, of LAAS. "It comes at a time when science and technology are already under fire from all sides. But if the uncertainties and risks associated with nanotechnology must be explored, scientifically naive and exaggerated warnings should be avoided."

As Weisbuch explains, some people are worried about the invisibility of nano-objects, which implies that exposure could go completely unnoticed. In fact, frequently, nano-objects are not used in nanometer-sized form, but are incorporated into a clearly visible material device like an integrated circuit, for example. The fact that nanotechnology will provide new means to facilitate access and storage of vast amounts of data, including genetic and computer records of individuals, is more worrying. This will no doubt raise new issues with regard to the protection of privacy and freedom.

One key question is whether the large-scale manufacturing of nanostructured materials will lead to the uncontrolled release into the environment of nanoparticles, some of which may be harmful to our health. Among the many public concerns linked to nanotechnology, "this issue has garnered the most media attention," says Stéphanie Lacour, of CECOJI.[8] "Right from the start, a parallel was established between nanotechnology and the precedents set by asbestos and biotechnology—especially GMOs," which had a profound effect in France. Until a few months ago, "there was no specific legal text applicable to nanotechnology, either in France or in Europe," Lacour points out. "But things are moving now. In March and April of 2009, the European Parliament approved two resolutions on the presence of nanomaterials in cosmetic products and food. And the French 'Grenelle Law,' whose Article 42 deals with risks related to nanoparticles, was passed on August 3rd, 2009."

Above all, a new discipline is in rapid expansion: nanotoxicology, whose aim is to describe and quantify the dangers of nanomaterials. "Today there are approximately 2000 articles concerning the ecotoxicity of nanoparticles, as opposed to a mere 50 or so five years ago," says Éric Gaffet, of the NanoMaterials Research Group.[9] "Yet there is an evident shortage, at both a national and international level, of toxicologists and ecotoxicologists working on a subject that is not easy to tackle: a simple gram of TiO_2 (titanium dioxide) nanoparticles, for instance, can contain up to ten million billion nanoparticles, which all differ in size, chemical reactivity, or stability over time." Characterizing the distribution of each parameter (size, shape, persistence in tissue or organisms, etc.) in a sample is very difficult because "every type of nanoparticle has a specific potential toxicity which depends on its lifecycle," explains Gaffet. "Given current human and technical means, it would take an estimated 50 years to test the toxicity of all the nanoparticles already on the market."

Then in order not to test all nanoparticles individually, some research groups, like the one led by Jean-Yves Bottero at CEREGE[10] have developed a procedure that first categorizes >

The Future of OPTICS

Ever heard of plasmonics? This is a specific field of nanophotonics. If the latter studies the behavior of light on the nanometer scale in general, plasmonics investigates how light surfs on the surface of metals using the metal's free electrons—and this has researchers very excited.

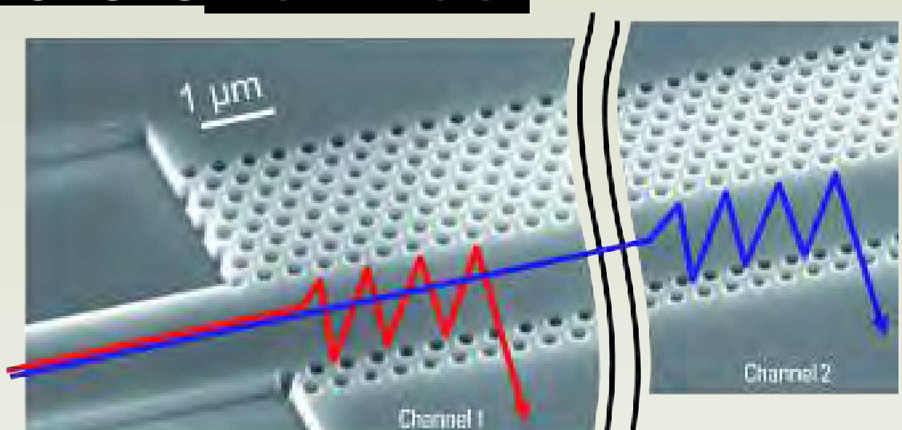
It got a boost in 1998, when Thomas Ebbesen, today director of the Institute of Supramolecular Science and Engineering (ISIS),[1] discovered a completely unexpected phenomenon he dubbed "extraordinary optical transmission" or the "photon sieve."

"A photon sieve is a network of holes pierced in a nanostructured metal surface, at regular intervals and with diameters of 100-200 nm, in other words considerably smaller than the wavelength of visible light," explains Henri Benisty, of LCFIO.[2] "When you illuminate this surface, the quantity of light that comes out on the other side is much larger than the fraction that struck the holes. Even the light that falls next to the holes is channeled to the other side of the sample." Plasmons manage to convey this light into the holes instead of spoiling or reflecting it.

The researchers are trying to make use of these unconventional properties to perform new manipulations of light at nanometric scales. "We're hoping to bring about ultra-localized modifications, far more than what is possible with a laser, for applications in lithography, in biology—for example in the compartments inside a cell—or even to write information at smaller scales on a hard disk," says Benisty.

In addition, plasmonics could improve the efficiency of photovoltaic cells by improving the capture of light and its further conversion within nanostructured materials.

In the field of telecommunications, the use of photons is in rapid expansion, being exploited in much shorter connections within circuit boards for their high throughput. In fact, optical connections should soon be able to second electronic connections, even in electronic circuits ("chips") themselves. "Ultra-densely packed electronic connections are negatively affected by interference and consumption issues," explains Benisty. "We're trying to build nanometrically controlled architectures where optics could be used to transmit the largest or most energy-hungry information flows inside chips."



© H. Benisty /LCFIO et T. Stomeo /Univ St Andrews

A nanophotonic structure used to direct optical information, here two channels carried by two similar wavelengths. This type of system could one day be used in electronic chips.

1. Institut de Science et d'Ingénierie Supramoléculaires (CNRS / Université de Strasbourg).
2. Laboratoire Charles Fabry de l'Institut d'Optique (CNRS / Université Paris-XI).

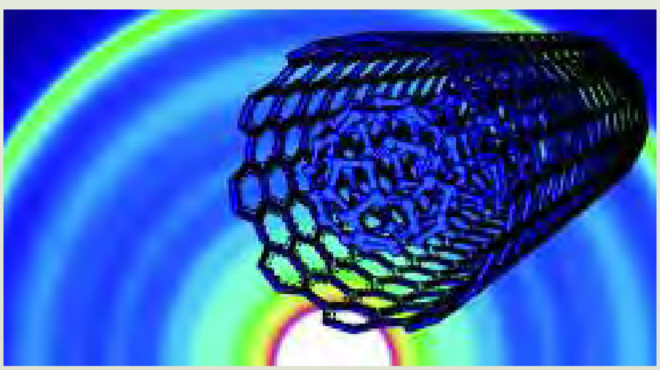
➔ **Henri Benisty,** henri.benisty@institutoptique.fr

The Leading ROLLS

An exhaustive list of all the nanomaterials currently under research or already present in everyday life would be impossible. But leading them all—and by far—are the famous carbon nanotubes, which were discovered in 1991 and have become the showcase of nanoscience. These nanomaterials take the form of hollow cylinders whose surface is made up of one or several rolled up sheets of carbon. They are distinguished especially by their mechanical properties—they are a hundred times tougher and six times lighter than steel, and can undergo considerable deformation under bending and torsional stress—and by their outstanding electrical conductivity.
The use of carbon nanotubes, already found today in a variety of objects, ranging from tennis rackets to bicycle frames and Formula 1 car bodies, "is constantly making new ground, with 7000 publications and 2500 patents throughout the world in 2008," says Pascale Launois, from the LPS[1] in Orsay. "We are particularly interested in new so-called nanohybrids. These are nanotubes inside which are inserted various molecules to try and alter their mechanical or electronic properties." The cylindrical cavity of certain nanotubes—those made up of a single wall—can be used to synthesize molecular chains that exist nowhere else. As Launois explains, "peapods, for example, so called because of their resemblance to real peapods, are made up of chains of C_{60} fullerene[2] molecules inside nanotubes. Fullerenes and other molecules that are confined to nanometric scales in this way have novel physical properties. It might be a long way off, but we can already imagine applications for filtration, desalination of sea water, or storage of radioactive waste."

1. Laboratoire de Physique des Solides (CNRS / Université Paris-XI).
2. C_{60} fullerene contains 60 carbon atoms arranged in a soccer ball-like structure.

→ **Pascale Launois,** launois@lps.u-psud.fr



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Artist's rendition of a peapod structure as determined by X-ray diffraction.

NANOMATERIALS Go Green

The environment could also benefit from nanotechnology, particularly when it comes to wastewater treatment. Researchers are working on the possible use of nanoparticles of metal oxides (iron, titanium, cerium, aluminum, etc.) to treat wastewater or clean up contaminated ground. "When a surface coated with a nanofilm of titanium oxide is exposed to sunlight, it can break down organic pollutants (pesticides) and potentially dangerous disease-causing microorganisms (bacteria and viruses) present in water. But this technique is still uncommon, and only used for the treatment of effluents containing a limited number of pollutants," explains Jean-Yves Bottero from CEREGE.[1] In another process, ceramic membranes based on nanoparticles of iron oxyhydroxide (ferroxanes) are used for the nanofiltration of polluted effluents. This green chemistry holds out great promise, especially in developing countries where water is often contaminated.

1. Centre Européen de Recherche et d'Enseignement des Géosciences de l'Environnement (CNRS / IRD / Université de Provence / Université Paul-Cézanne / Collège de France).

→ **Jean-Yves Bottero,** bottero@cerege.fr
→ **Jérôme Rose,** rose@cerege.fr

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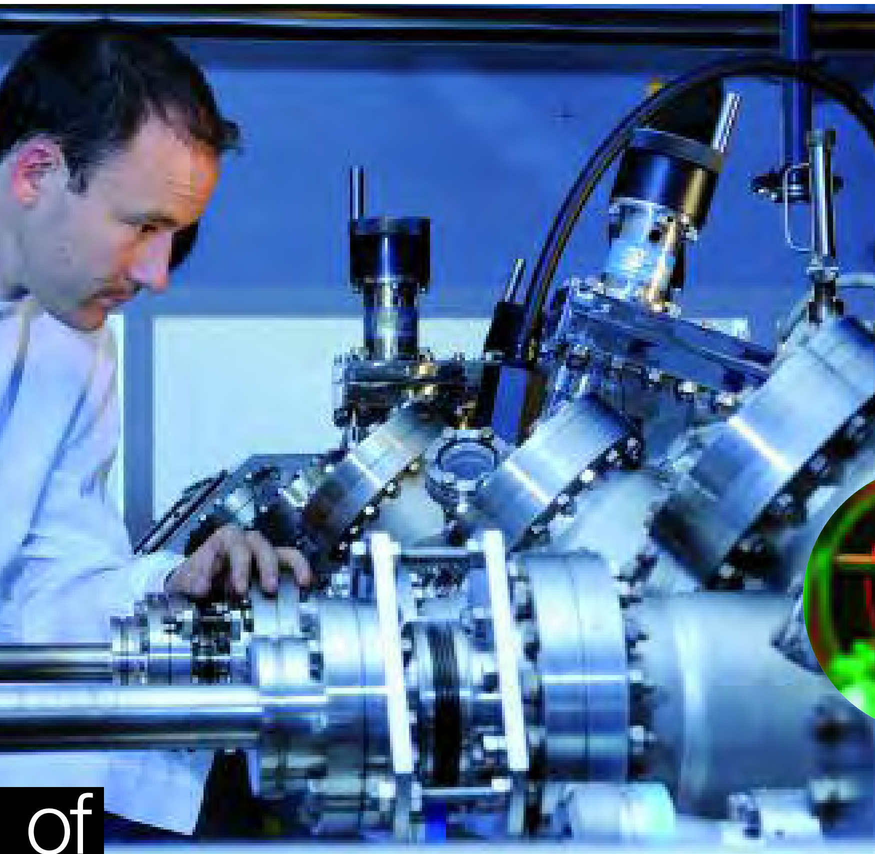
The Eldorado

Each year, the components of integrated circuits get increasingly smaller. They have shrunk from 90 nm in 2004 to a mere 45 nm[1] today, and the silicon wafer industry plans to get them down to 15—or even 10 nm. The reason for this is straightforward: the smaller the basic components of integrated circuits—transistors—the more of them can fit on a chip, resulting in more computing power. To push miniaturization even further, teams of scientists "are exploring all sorts of avenues, like transistors based on carbon nanotubes or silicon nanowires, or even on graphene, a crystal made up of carbon atoms," explains Jean-Michel Lourtioz, director of the Institute for Fundamental Electronics.[2] Nanoscience experts are trying to develop structures on atomic and molecular scales. "The ultimate approach to process information faster is to use just a single atom or a single molecule as a basic electronic building block," says Henri Mariette, of the "Nanophysique et Semiconducteurs" group in Grenoble.[3] But these so-called quantum electronic systems are still in their infancy.
Another very active field is spin electronics, or spintronics. Whereas traditional electronics only uses the



# of ELECTRONICS

Extreme vacuum device used for making nanostructures based on semi-conductors (quantum wells, wires, and boxes).

© P. Avaviau/CEA

Inside view showing the substrates on which the nanostructures are manufactured.

electron's electric charge to send signals through a network of transistors, spintronics makes use of the electron's magnetic properties. This physical property is already being used to store information on hard disks in computers and servers.

Pushing this technology further, researchers hope to use the orientation of electron spin[4] to memorize information in circuits that combine electronics and magnetism. More specifically, spintronics "has given rise to the discovery of other physical properties since the already well-known giant magnetoresistance effect,[5]" says Frédéric Van Dau, director of the CNRS/Thales Joint Physics Unit.[6] "Some phenomena, like 'spin transfer,' even make it possible to foresee a type of memory that could work without having to apply magnetic fields to store information, unlike current devices. This technique should enhance and speed-up the wide-accessibility of Magnetic Random Access Memory (MRAM), which is both faster and does not require energy to keep the information stored."

Beside quantum electronics and spintronics, a third type of electronic technology could well emerge from nanoscience: plastic electronics. Georges Hadziioannou from LCPO[7] is working on semiconducting polymers, carbon-based materials that have properties similar to silicon. Applications include large flexible display screens or foldable photovoltaic cells. "Plastic electronics will not replace conventional electronics, but complement it," adds Hadziioannou. Semiconducting polymers have the significant advantage of being flexible, which means, for example, that they could be placed inside clothing. And above all, they are easier and cheaper to produce than traditional integrated circuits.

1. The size of the "grid," one of the three electrodes that make up a transistor.
2. Institut d'électronique fondamentale (CNRS / Université Paris-XI).
3. Research group belonging to the Institut Néel (CNRS / Université Joseph Fourier) and to the CEA / INAC Grenoble.
4. Electrons can be thought of as small magnets, whose orientation is defined by spin.
5. Discovered by Albert Fert, Nobel laureate in physics.
6. CNRS / Thalès in association with Université Paris-XI.
7. Laboratoire de chimie des polymères organiques (CNRS / Université Bordeaux-I).

➔ **Henri Mariette,** henri.mariette@grenoble.cnrs.fr
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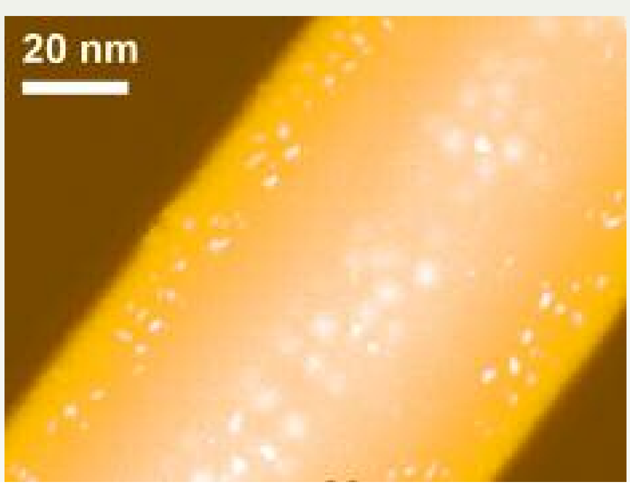
➔ **Georges Hadziioannou,** hadzii@enscpb.fr
➔ **Jean-Michel Lourtioz** jean-michel.lourtioz@ief.u-psud.fr



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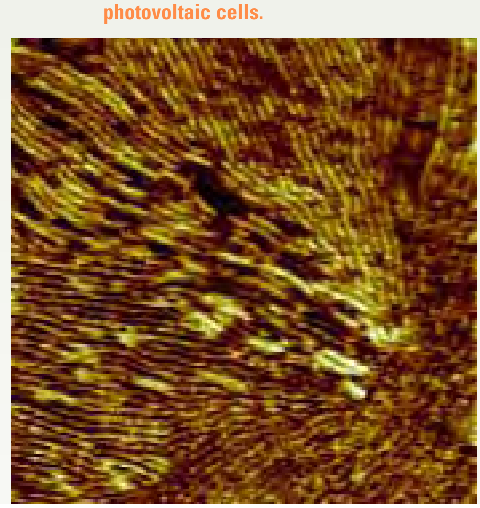
This silicon nanowire, observed by transmission electron microscopy, was obtained by vapor-liquid-solid growth from a gold droplet in the presence of silane. The white stains are gold aggregates selectively formed on the nanowire walls.



© M. Urien/Université Bordeaux 1/LCPO-IMS

Example of copolymer-based nanostructures used to design photovoltaic cells.

nanoparticles in terms of physico-chemical properties and then tries to compare and somehow classify and generalize the biological effects.

Can we already affirm that nanomaterials constitute a genuine health and environmental threat? There is no evidence that they do—but unfortunately, nor is there evidence that they don't. "Nanomaterials should be considered potentially dangerous, as indicated in the report of the French Agency for Environmental and Occupational Health Safety published in June 2008,"[11] adds Gaffet. "Toxicity tests carried out on animal and cell models demonstrate that certain nanomaterials are specifically dangerous, and that they can cross certain biological barriers. However, much more work must be done before reaching a conclusion on that matter." Moreover, the importance of environmental risks also needs to be evaluated.

SEEKING PROTECTION

Do we know how to protect ourselves from nanoparticles when they are sprayed as aerosols? Current systems such as fiber filters placed in ventilation systems or in the respiratory masks worn by operators are very efficient. The most effective filters manage to trap over 99.99% of 4 nm-sized particles. Particles of 100-500 nm are not as easy to stop, which refutes the widespread idea that the effectiveness of filters depends solely on the size of its pores. But there has been progress: "By using electrically charged fiber filters and playing on electrostatic effects to modify the path of particles and facilitate their capture, we are already able to neutralize between 95% and 99% of large nanoparticles," says Dominique Thomas, of LSGC.[12]

Finally, do scientists spend enough time thinking about the ethical and societal impact of their research? Not for philosopher and science historian Bernadette Bensaude-Vincent, from CNRS' Ethics Committee (COMETS). "French researchers recognize the need to assess the possible toxicity of nanotechnology," she says. "But most of them are still reluctant to explore any long-term effect it may have." Bensaude-Vincent regrets the fact that "save for a few laboratories, there is no place where researchers can talk about their doubts and concerns." Jacques Bordé, of COMETS, thinks that promoting direct dialog between scientists and the public is another necessity. "This implies training scientists to not simply consider their research from the viewpoint of the scientific challenge, but also in regards to ethical issues. Thinking about ethical issues doesn't prevent creativity, it may even stimulate it."

1. Commission nationale du débat public.
2. Institut d'électronique fondamentale (CNRS / Université Paris-XI).
3. Laboratoire de Physique de la matière condensée (CNRS/ École polytechnique).
4. Centre d'élaboration des matériaux et d'études structurales (CNRS).
5. The scanning tunneling microscope uses an extremely fine metal needle, which is moved over the surface to be studied at a distance of just a few atoms. This makes it possible to locate and manipulate the atoms on the sample's surface. The atomic force microscope works according to the same principle, but is used to explore non-conducting samples and especially biological material.
6. Laboratoire d'analyse et d'architecture des systèmes (CNRS).
7. Institut des sciences de l'ingénierie et des systèmes.
8. Centre d'études sur la coopération juridique internationale (CNRS / Université de Poitiers).
9. Research group belonging to the Institut de recherche sur les archéomatériaux (CNRS / Université de technologie de Belfort-Montbéliard / Université Bordeaux-III / Université d'Orléans).
10. Centre Européen de Recherche et d'Enseignement des Géosciences de l'Environnement (CNRS / IRD / Université de Provence / Université Paul-Cézanne / Collège de France).
11. The report, entitled "Nanomatériaux et sécurité au travail" (Nanomaterials and Occupational Safety), is available at the Documentation française website. (www.ladocumentationfrancaise.fr)
12. Laboratoire des sciences du génie chimique (CNRS).

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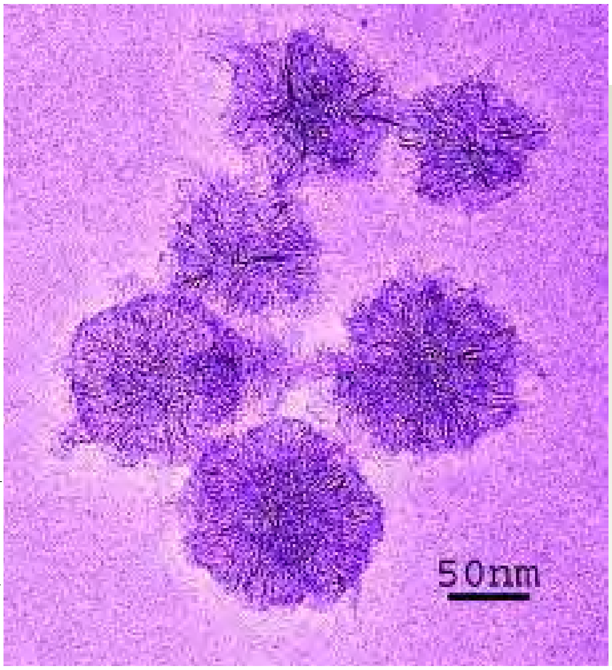

NANOHORNS for Storing

The definitive answer to vehicle pollution could well be the fuel cell, which uses pure hydrogen and produces no harmful emissions. But a number of problems need to be solved before this technology can see the light of day. Nanotechnology may help solve one of them: the storage and availability of hydrogen.

So far, the most reliable and economical means suggested to store hydrogen is to use porous materials. This would make it possible, on the one hand to confine the hydrogen, and on the other to release it easily so that it can combine with oxygen in the air. Among such materials, carbon nanoforms, in other words all carbon structures, "turn out to be very serious contenders because of their low mass and high absorption capacity," explains CRMD[1] director Marie-Louise Saboungi. "Work is currently focusing on carbon nanohorns, which were discovered in the 1990s. These are materials two to three nanometers long that assemble to form dahlia-shaped structures 80 to 100 nanometers in diameter. Hydrogen's interaction with nanohorns is much

Dahlia-shaped carbon structures called nanohorns are promising candidates for the storage of hydrogen.

NANO-BIOLOGICAL Probes

© S. Godefroy/CNRS Photothèque

A fluorescence microscope is used to follow the movement of molecules inside cells.

Biology is another field where nanotechnology has real and exciting applications. Biologists are particularly interested in semiconducting nanocrystals (or "quantum dots") devised in the past few years by physical chemists, which they would like to use as probes to explore biological processes at the molecular scale. These objects are made up of several tens or hundreds of thousands of atoms arranged in a crystal lattice structure, with an overall size of approximately 2-8 nm. When excited by light—a laser, for example—they become fluorescent.

The trick is to attach the quantum dots to biological molecules such as proteins (enzymes, antibodies) or nucleic acids (DNA, RNA). The light emission wavelength can then be chosen by varying their size (the smaller the nanoparticles, the more the emission is shifted towards blue), which would make it possible to distinguish biological processes from one another. "In fact, the nanoparticles behave like tiny light bulbs that can be tracked for several tens of minutes using a microscope," explains Maxime Dahan, of the Kastler-Brossel Laboratory (LKB).[1] "They tell us in real time about the motion and position of the biological players to which they are attached." Such imaging techniques at the level of individual nanoparticles, which were only just beginning to emerge five years ago, have since been vastly improved and are finding a greater number of applications.

They let us "see" beyond the cell membrane what occurs inside the cell, a region which until now was extremely hard to access. Eventually, by attaching probes of different colors to different proteins, it will be possible to record the motion of all these players simultaneously and study their interactions *in vivo*." This will improve our understanding of the complexity of the innermost mechanisms of living organisms. So far, this technology has only been applied to cultured cells, but researchers hope to eventually use it *in vivo*, which should lead to major improvements in medicine. In particular, by making biological imaging ultrasensitive, it should help both physicians and surgeons identify the smallest tumors and metastasis, on the scale of a hundred thousand rather than a billion cells.

1. Laboratoire Kastler Brossel (CNRS / École normale supérieure / Université Pierre-et-Marie-Curie).

➔ **Maxime Dahan**
maxime.dahan@lkb.ens.fr

Hydrogen

stronger than with carbon nanotubes. So these tiny horns trap hydrogen more easily than their close relatives." Moreover, nanohorns retain most of the adsorbed hydrogen at temperatures as high as 20°C, contrary to carbon nanotubes which need low temperatures for hydrogen storage (below -200°C). Along with these many advantages, one snag remains: their relatively high manufacturing cost.

1. Centre de recherche sur la matière divisée (CNRS / Université d'Orléans).

➔ **Marie-Louise Saboungi,**
saboungi@cnrs-orleans.fr

FOR FURTHER INFORMATION

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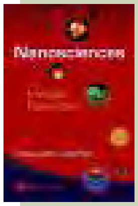

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http://videotheque.cnrs.fr/index.php?urlaction=doc&id_doc=1909&rang=1

1

PHOTOGRAPHY

SHEDDING light on the Autochrome

2

The Lumière family was not only innovative in cinema, but also in photography, where its inventions made a considerable mark. At the start of the 20th century, the Lumière brothers marketed the Autochrome plate, the first industrial color photography process based, surprisingly, on potato starch. Two French researchers recently revisited the Autochrome, conceived not without difficulty and protected by secrecy for many years.

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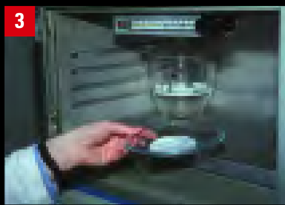

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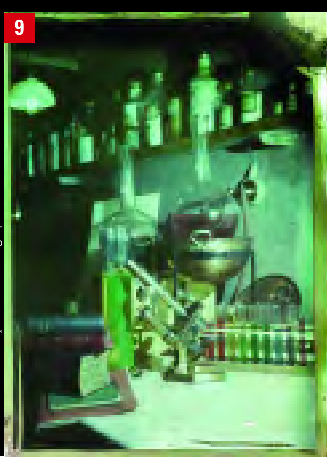

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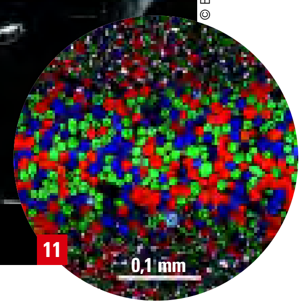


1 Autochrome self-portrait of Édouard Blanc, a chemist at the Lumière factory in Monplaisir (Lyon), around 1907.

2 Auguste and Louis Lumière, inventors and industrialists, 1895.

3 4 5 6 7 Several steps in the reconstitution of an Autochrome: drying then sorting the starch, coloring solutions for dyeing, sprinkling lampblack, and coating the second varnish.

8 9 Autochrome tests, around 1902-1905, with a negative plate (8) and a positive plate (9), in the laboratory of Louis Lumière.

10 A press used for flattening the starch grains has been restored and is now classified as a historic monument.

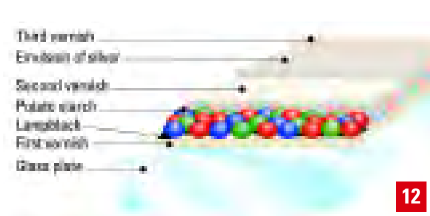
11 Starch lamination. Louis Lumière discovered the advantage of lamination accidentally, by scratching the network of starch with his fingernail. This resulted in better transparency.

12 Diagram of an Autochrome plate. "The plate prepared in this way is exposed through its back and then developed. Once reversed, the resulting image reproduces, through transparency, the colors of the photographed original," explained Louis Lumière in 1904.

Soon the whole world will run wild with color, and the Lumière brothers will be responsible," intuitively proclaimed the American photographer Alfred Stieglitz when the Autochrome plate was first put on sale in 1907. And this industrial color photography process enjoyed considerable success, as the Lumière brothers went on to sell millions of Autochrome plates over the following decades. To better understand the technology behind the Autochrome, researchers Bertrand Lavédrine, director of the CRCC,[1] and Jean-Paul Gandolfo, professor at the film school ENS Louis-Lumière, decided to revive it, more than half a century after it went out of production.

Painstakingly recreating the steps involved in making Autochromes, they began by selecting minuscule grains of potato starch, dyeing them violet, green, or orange, and mixing them. They then sprinkled millions of these grains onto a varnished glass plate and added lampblack—soot from oil lamps—to fill the gaps between the grains. This was followed by lamination—pressing the plate—and a second application of varnish. The final step—the most difficult to recreate by hand on small plates in a dark room—was the application of the final layer of the Autochrome, a black and white emulsion of gelatino silver bromide, a light-sensitive substance which requires particular care.

The device works on the basis of "additive color synthesis," the principle that enables all color hues to be created from only three primary colors (red, green, and blue) and which was later to be used in television screens. In Autochromes, the photosensitive layer is exposed to light rays, which are filtered beforehand by the dyed grains of starch. After taking the picture and developing it, the silver grains in the photosensitive layer mask certain colored grains of starch to a greater or lesser extent, thus recreating the colors of the original image photographed. The image appears by viewing the transparent positive print in a special device or by projecting it as a slide. "The grains are extremely >



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13 **Paris, 1918. The author, Auguste Léon, worked for the "Archives de la Planète," an immense photo- and cinematographic record of the epoch, founded by the banker Albert Kahn. Today, the Albert-Kahn Museum archives some 72,000 Autochromes.**

14 **Children dressed up as small soldiers. Autochrome by Léon Gimpel, press correspondent, 1915.**

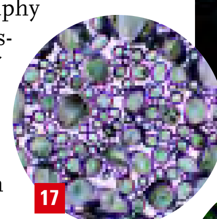
15 **In this Autochrome by Édouard Blanc (1908), fields and forest contrast with poppies.**

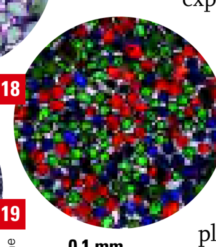
16 **Gabriel Doublier, the manager of a factory in Paris, poses in front of machines used for mixing starch, 1931.**

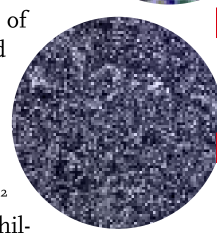
17 **18** **19** **Unsorted (17) or sorted and dyed (18) potato starch, and unsorted rice starch (19).**

> small, invisible to the naked eye. An optical mixture of the different starch colors is then created within the eye... resulting in the palette of colors visible in the Autochrome," explains Lavédrine.

If the underlying principle of the Autochrome (first formulated by French inventor Louis Ducos du Hauron) is sound, it nevertheless took seven years for the mighty Lumière family business, already specialized in photography and cinema, to launch its industrial production. The choice of starch for example, a key aspect of the invention, required months of head scratching. Potato grains were preferred to rice grains, which take on colors less easily.







For this in-depth study of Autochromes, Lavédrine and Gandolfo also struggled for many years. Not only did they try to produce them but, as they explain in their book *L'Autochrome Lumière*,[2] they also interviewed the children of eyewitnesses from the period, dissected laboratory notebooks, and analyzed the dyes in old plates. They also closely examined a lamination press, which the Lumière brothers chose not to patent, probably to keep it unique. Lamination—a crucial phase which, by squashing the grains against each other, enhanced the transparency of the granular network—was indeed alluded to in a patent, but only in an elusive manner. Competitors were thus kept at bay. And they needed to be: at the turn of the 20th century, photography, which was invented in 1839, was thriving. Creating photographs in color was a major challenge, and the object of much research and experimentation which benefited from the scientific progress on light phenomena and color recombination.

With the Autochrome, photography finally adopted color. But the process proved fragile and the production of Autochrome plates difficult. The exposure time, approximately one second, virtually precluded instantaneity. Despite both this weakness and their high price, millions of Autochrome plates were sold throughout the world in 30 years. In 1931, the glass plates were replaced by a flexible substrate, but it was only in the mid-1950s, two decades after the introduction of the more popular Kodachrome, that the invention fell into obsolescence, and that the Lumière factory ceased production of its Alticolor films, direct descendants of the Autochrome plate. Beside its obvious historical interest, a more in-depth understanding of this technology should no doubt help us better preserve the existing samples.

Mathieu Hautemulle

1. Centre de recherche sur la conservation des collections (CNRS / Ministère de la culture et de la communication / Muséum national d'histoire naturelle).
2. Bertrand Lavédrine and Jean-Paul Gandolfo, *L'Autochrome Lumière* (Paris: Editions du CTHS, 2009).

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NANOBIOSCIENCE

France and Israel Join Forces in Nanobioscience

For the past two years, CNRS and the Weizmann Institute, a prestigious Israeli research institution, have joined forces to explore the rapidly-growing field of nanobioscience, at the interface between nanoscience and biology.

Set up in January 2008 by CNRS and the Weizmann Institute, the European Associated Laboratory Nano Bioscience (LEA NaBi) is the successful combination of both scientific and human elements. On the one hand, its creation is motivated by the shared need to move forward in this new field which applies the methods of nanoscience to biological systems and structures. And on the other hand, it acknowledges the longstanding bond that has developed between French and Israeli researchers.

Joseph Zyss, who, along with his Israeli counterpart Ron Naaman, is the technical and scientific co-director of the LEA, was the initiator of this project. "In 1990, I launched a series of biennial Franco-Israeli conferences in physical optics, the FRISNO series, which continue to this day. To a large extent, these conferences provided a framework for the development of the LEA. The project now offers an opportunity for greater understanding and appreciation between our two countries in the field of photonics and beyond."

Little negotiation was therefore necessary before the two institutions signed a preliminary agreement in 2007, which led to an initial four-year renewable joint research program. This agreement covers a dozen or so projects that are all related to nanobioscience with a photonics component. For example, teams are working on the design and production of biochips for biological analyses, as well as on the development of systems for the control of cell differentiation, which could both be of value to cancer research.


The Weizman Institute's particle accelerator.
© N. Singer

The LEA NaBi was officially inaugurated in March 2009 at the Weizmann Institute in Rehovot (south of Tel Aviv). But it is also active on three sites in France: the Institut d'Alembert[1] in Cachan near Paris, the French "bridgehead" headed by Zyss; the laboratory of statistical physics (LPS)[2] and the PASTEUR chemistry laboratory,[3] both at the ENS in Paris; and the Institut Fresnel[4] in Marseille.

Yet this geographical distance does not affect the cohesion of the teams involved: "We host Israeli researchers for several months, and vice versa," explains Zyss. "The projects we are working on provide a daily framework for the activities of the different teams."

A total of 40 people, divided equally between the two partners, now work for the LEA. Postdoctoral fellows form the backbone of the program. "We have seen a growing, spontaneous flow of requests from potential partners who want to be part of the LEA," stresses Zyss, who admits he is often approached by students eager to join such a prestigious laboratory. And prestige does play its part, at both an individual and institutional level.

Francesca Grassia, who contributed to setting up the LEA at the CNRS Office of European Affairs, recalls the importance of this partnership: "The Weizmann Institute is one of the best-performing research institutions in the world, both in terms of scientific results and technology transfer." Similarly, CNRS is perceived in Rehovot as a European partner of choice.

As for the LEA NaBi, its future depends on three major factors. The first is to obtain results that will enhance the reputation of nanobioscience and its applications. The second is the hope that the advances achieved by the laboratory will result in industrial exploitation. "In this respect, the Weizmann Institute and CNRS have all the expertise necessary," notes Grassia. Finally, perhaps one day the LEA NaBi could have its own site. It would then become the first CNRS International Joint Research Unit in Israel.

Stéphan Julienne

THE WEIZMANN INSTITUTE

Founded in 1934 as the Daniel Sieff Research Institute, it was renamed Weizmann Institute in 1949 and has since been distinguished on several occasions. Its scientists were responsible for developing the RSA cryptography algorithm that is today used for the security of bank credit cards or for online transactions. One of its 2600 members, Ada Yonath, received the 2009 Nobel Prize for chemistry. The Institute's participation in the LEA NaBi allows Israel, an associate country in EU programs since the end of the 1990s, to reinforce its position in the European Research Area. There is one noteworthy precedent: the Pasteur-Weizmann Foundation has for the past 35 years involved scientists from both institutions.

1. Institut fédératif de recherche (CNRS/ ENS Cachan).
2. Laboratoire de physique statistique (CNRS/ ENS Paris/ Universités Paris-VI and -VII).
3. Processus d'activation sélectif par transfert d'énergie uniélectronique ou radiatif (CNRS/ ENS Paris/ Université Paris-VI).
4. CNRS / Universités Aix-Marseille -I and -III / Centrale Marseille.

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Chretien Moonen
All-out War on Cancer

Open-minded and curious about everything, Chretien "Chrit" Moonen is the opposite of an ivory tower scientist. The Dutch researcher, now 53, is a polyglot who speaks Dutch, French, English, and German. Born in the Maastricht region (Netherlands), Moonen grew up on a farm. He admits that this is maybe what subconsciously drew him to an agricultural university for his early studies. But the biggest draw was his desire to study the three subjects that fascinated him the most: chemistry, physics, and biology.

© F. Vrignaud/CNRS Photothèque

And though science is undoubtedly his realm, Moonen, unlike many other researchers, has an almost visceral need to see the results of his research put into practice. "Fundamental research is all very well, but what matters are its clinical applications," he says. Indeed, this explains why he has always sought to involve doctors in his work on magnetic resonance imaging (MRI), like Hervé Trillaud, who has been working with Moonen for the past ten years on real-time control by MRI of several non-invasive technologies aimed at fighting cancer. A radiologist at the Saint-André hospital in Bordeaux, Trillaud even says that Moonen is "unhappy when he doesn't see doctors in his lab on a regular basis."

After a memorable year at the Federal Polytechnic School in Zürich, where he studied in the laboratories of future Nobel Prize winners Richard Ernst[1] and Kurt Wüthrich,[2] it was in 1983, the year of his PhD on the structure of proteins, that Moonen steered his research toward medical applications.

At the time, one of the main methods to study protein structure involved nuclear magnetic resonance. So when magnetic resonance imaging, which was to completely transform radiology, was developed, Moonen became enthralled. A few years later, at the age of only 31, he became director of the MRI research center at the National Institute of Health (NIH) in Washington. He has fond memories of his long stay in the US. "Very little paperwork, no need to apply for funding, and cutting-edge lab equipment... It was heaven for a researcher," he recalls. But Moonen and his French wife decided to return to Europe. "We didn't want our kids to have to move constantly during their adolescence. As we are nonetheless culturally more European, we decided to move back here."

Moonen arrived in Bordeaux in 1996 and joined CNRS, which presented an advantage of great value: it offered jobs that were "entirely dedicated to research." He was therefore able to devote all his time to developing a mini-invasive therapy that uses focused ultrasound guided by MRI. His interdisciplinary laboratory, which brings together physicists, computer scientists, and biologists, received the 2006 Antony-Bernard Oise Award for their painstaking work in fighting cancer, a work that has been backed for the last ten years by the National Anti-Cancer League.

The device co-developed by Moonen's lab and produced by the company Philips is undergoing clinical trials at the Saint-André hospital in Bordeaux, in the department run by Trillaud. "The machine has been under a clinical research protocol since June 2008. We have treated around ten patients for uterine fibroma," Trillaud explains. This is just a first step before treating cancers of the breast, kidney, and possibly liver, the real-world applications so close to Moonen's heart.

Dominique Salomon

1. Nobel Prize for chemistry in 1991 for his contribution to the development of multidimensional nuclear magnetic resonance spectroscopy.
2. Nobel Prize for chemistry in 2002 for his work on the use of multidimensional nuclear magnetic resonance for the study of protein structure.

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GRANTS/FELLOWSHIPS

ÉGIDE
Égide is a non-profit organization that manages French government international mobility programs. Many funding opportunities are listed on the website, and most content is in English.
→ **www.egide.asso.fr**

EURAXESS
This portal provides information on grants, fellowships, or positions available throughout Europe as well as practical information (accommodation, childcare and schools, healthcare...) for each country.
→ **http://ec.europa.eu/euraxess/**

EUROPEAN RESEARCH COUNCIL
This entails a number of calls for proposals by the European Research Council (ERC) for both starting and advanced grants in Physical Sciences and Engineering, Life Sciences, and Social Sciences and Humanities.
→ **Deadline:** April 7, 2010.
→ **http://erc.europa.eu (grant section)**

ECOS PROGRAMS
ECOS are scientific cooperation programs between France and South American countries, divided in ECOS-Nord (Colombia, Mexico, Venezuela) and ECOS-Sud (Argentina, Chile, Uruguay). Calls for applications are open in basic research in all scientific fields for selected countries.
→ **Deadline:** Mexico: Feb. 26, 2010.
Chile: March 31, 2010.
Argentina: April 15, 2010.
→ **www.univ-paris13.fr/cofecub-ecos**

5TH STIC-AMSUD CALL
The STIC-AmSud program calls for research-development projects in all topics related to ICT. Projects must include at least two participating South American countries, and one team of French scientists.
→ **Deadline:** May 15, 2010.
→ **www.sticamsud.org**

Michael Detlefsen
Questioning Truth


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The American Michael Detlefsen is a humanist in search of truth. Yet at the same time, he questions the very existence of truth: can several truths, and thus several proofs, co-exist at one and the same time? Surprisingly, or not, Detlefsen tackles these complex questions through mathematics. The philosopher and mathematician from Notre Dame University (Indiana, US) has set up camp in France until 2011 in CNRS-affiliated laboratories, where he heads a program called "Ideals of proof."

The program explores what are known as "imaginary" numbers, which can result in surprising outcomes. With imaginary numbers, the square of a number (the multiplication of a number by itself) can become negative. "The very existence of these numbers is a totally irrational concept for many people untrained in mathematics." And yet, this concept is a mathematical truth for those who deal with these numbers on a daily basis.

This questioning of truth has its origins in Detlefsen's own roots, and in the incredible epic of his great-grandfather and great great uncle who decided, at ages 9 and 11, to leave Denmark and their family on their own to embrace the American Dream. "A long and trying adventure then ensued which led them, by boat, train, and then finally on foot, to the town of Dannebrog in Nebraska," explains Detlefsen. "There, the government gave them land on the condition that they cultivate it for at least five years. The dream became reality." Detlefsen, who knows the story by heart, can himself raise a number of questions: Why did these children really decide to leave their family? Is the truth, as told to him by his older brother, the real truth? Does a single truth ever exist, or is truth affected by our own history? And what about our own history in relation to History?

When he started his undergraduate studies, Detlefsen turned towards the sciences, mathematics, physics, as well as towards philosophy. Eventually he obtained a PhD in logic. After a dissertation on Gödel's second incompleteness theorem—which shows that certain sentences expressing the consistency of systems are impossible to demonstrate in those systems—the scientist's first position was as professor of philosophy in Minnesota followed by a second at the University of Notre Dame in Indiana. "Do mathematical concepts really exist in nature, or are they only a creation of the mind, which tends to rationalize the order of the world in this manner and project its truth?" That was the starting point of a thought process that Detlefsen has followed throughout his career in the US and across the world.

Croatia, Germany, Switzerland, Australia, Japan, Spain, and many other countries have hosted Detlefsen over the last 25 years. It is now France's turn, where Detlefsen, as a world specialist in the foundations of mathematics, has been awarded the 2007-2011 Senior Chair of Excellence.[1] At the end of 2007, he joined a Nancy-based laboratory specialized in the history of sciences and philosophy.[2] This year, he signed on with the History and philosophy of science department of Paris-VII University[3] for a duration of two years. He will then return to Nancy for a final year before heading back to Notre Dame. Will this take him closer to the truth? That's another question entirely.

Séverine Duparcq

1. With the support of CNRS, Paris-VII and Nancy-II Universities, the Collège de France, and Notre Dame University.
2. Laboratoire d'histoire des sciences et de philosophie-Archives Henri-Poincaré (CNRS / INPL Nancy / Universités Nancy-I and -II).
3. Département d'histoire et philosophie des sciences (Université Paris-VII). This includes three structures, two of which are joint research units linked to CNRS.

TS'AI YÜAN-P'EI PROGRAM WITH CHINA

This program is open to students, post-doctoral fellows, and confirmed scientists in all scientific fields to develop scientific exchanges between France and China. The initial one year funding can be renewed for a second year.

➔ **Deadline:** March 20, 2010.
➔ **Contact Information:**
science1@ambafrance-cn.org
universitaire@ambafrance-cn.org

WORKING IN A FRENCH LAB, PRACTICAL INFORMATION:

The Kastler Foundation (FNAK): Helps foreign researchers settle in France and maintains contact after their departure.
➔ www.fnak.fr

Foreign embassies and consulates in France:
➔ www.diplomatie.gouv.fr/annuaire/

French embassies and consulates abroad:
➔ www.expatries.diplomatie.gouv.fr/annuaires/annuaires.htm

Association Bernard Gregory: This association helps young PhDs from any discipline make the transition into business.
➔ www.abg.asso.fr

France Contact will help you plan and arrange your stay in France:
➔ www.francecontact.net

Edufrance: Information on France's higher education programs–course enlistment, grant and fellowship applications.
➔ www.edufrance.fr

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IMMUPHARMA

Therapeutic Peptides

Immupharma France, in Mulhouse, is developing several drugs based on peptides–protein fragments–discovered by researchers at CNRS. Company president and managing director Robert Zimmer tells us about the company's most promising treatments.

Which treatment, out of all those developed in collaboration with CNRS, is the most far advanced?

Robert Zimmer: Definitely Lupuzor, a drug candidate for treating systemic lupus erythematosus, a chronic autoimmune inflammatory disease in which the patient's immune system produces auto-antibodies that can result in serious symptoms (rheumatological, neurological, dermatological and renal). By floating the company on the British stock market in 2006, we raised €15 million, enough to perform the full development up to phase II clinical trials. The results are very promising. In fact, Lupuzor is one of the first anti-lupus treatments tested at this stage which has performed significantly better than the placebo. The company that has been entrusted with the development of Lupuzor will start phase III clinical trials in the near future. If all goes well, the drug could be on the market by 2013. This is a real hope for people afflicted with this disease—1.4 million in G8 countries, 90% of which are women between the ages of 18 and 50. Current drugs on the market are neither curative, nor specific to this disease and may cause serious adverse effects.

But what is the specificity of this 'anti-lupus' drug?

R.Z.: Lupuzor is a peptide, in other words a part of a protein, and is made up of a particular sequence of amino acids. Unlike certain immunosuppressive drugs that affect the entire immune system, this peptide only targets the precise category of immune cells involved in the disease. It was discovered in 2001 at CNRS' ICT laboratory[1] in Strasbourg, a laboratory we cooperate with via a framework partnership agreement signed with CNRS in February 2002. Our strong ties to the ICT lab led us to exploit the existing CNRS patent and, together with CNRS, to extend its protection. Since 2002, four ICT researchers have become shareholders in our company, and Immupharma France has also recently funded a technician position at the ICT laboratory.

Do you collaborate with CNRS on other projects?

R.Z.: We are currently working on an anticancer drug also discovered by the ICT lab, together with two other CNRS laboratories.[2] The therapeutic molecule, called HB19, is also a peptide. It binds nucleolin, a protein abundant at the surface of tumor cells and related blood vessels, and inhibits both blood vessels and tumor growth in mice. HB19 could also be used to treat psoriasis, diabetic retinopathy, and to heal wounds. We intend to test this candidate drug next year in a clinical trial. Immupharma France has just funded two positions at CRRT[2] for a PhD student and a technician to work on this project. The initial patent was filed by CNRS, and a second one, co-owned with Immupharma, has been filed to protect the method of production of this peptide and to cover the more potent next generation peptide which will be tested in humans early this year.

© L. Weigel/Horschamps

"For the first time in phase II clinical trials, an anti-lupus drug has performed significantly better than the placebo."

What other diseases are you targeting?

R.Z.: With the ICT, we are also developing an antibiotic to fight nosocomial infections due to bacteria resistant to common antibiotics. The way it works is quite innovative, as it destroys the bacterial membrane. It is presently at the stage of preclinical development and is also protected by a CNRS patent and joint-patents. Immupharma is also working on a painkiller for severe post-operative and cancer pain. This compound, Cin-met-enkephalin, derived from a natural analgesic, would have fewer side effects, and would last longer than morphine derivatives. Our company also holds a chemical library of almost 300,000 molecules jointly-patented with CNRS. Some of these seem to be active against inflammation, allergies, and malaria.

Interview by Jean-Philippe Braly

1. Immunologie et chimie thérapeutiques. (CNRS)
2. CRRT: Croissance, réparation et régénération tissulaires (CNRS / Université Paris-XII), and Régulation de la transcription et maladies génétiques (CNRS).

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PHARMASEA

A Cure from the Depths

Chemical warfare waged between marine organisms could save human lives. This is what the Pharmasea project hopes to achieve by fighting Alzheimer's disease using marine molecules.

Pharmasea partners—two SMEs and four academic research centers, including CNRS[1]—are definitely not starting from scratch. The project is led by the ManRos Therapeutics company,[2] co-founded in 2007 by biologist Laurent Meijer, who works on protein phosphorylation at the Roscoff biology station,[3] and chemist Hervé Galons, currently at Paris-V University.

Laurent Meijer's CNRS team has been studying the anti-tumor and anti-neurodegenerative properties of certain molecules secreted by marine invertebrates—sponges and ascidians—which may be synthesized to deter their predators. In humans, these molecules are capable of acting on protein kinases, essential regulators in many processes of cellular life and death. This research has led to the discovery of Roscovitine, a molecule now patented by CNRS and undergoing phase II clinical trials against lung and nasopharyngal cancers, as well as against glaucoma—an ocular illness that can cause blindness.

ManRos Therapeutics intends to overcome, with "speed and flexibility," as Meijer puts it, all administrative and financial obstacles that plague pharmaceutical research. For the moment, ManRos Therapeutics is testing four families of marine molecules at the preclinical stage against Alzheimer's disease but also against cancers, leukemias, and polycystic kidney disease. Human trials will follow as soon as possible.

The Axinella sponge, off the coast of Brittany, is a potential source of bioactive molecules.

The company has eight employees, all biologists and chemists. ManRos, the name of which is a contraction of Manhattan and Roscoff, hopes to develop on both sides of the Atlantic, and has already found numerous investors in the US. Its many awards and constant media attention (it was recently included in a French financial magazine's top 100 "most promising" start-ups in France[4]) should make it easier to find funding, especially for ambitious projects like Pharmasea.

Mathieu Hautemulle

1. ManRos Therapeutics, C.RIS Pharma, CNRS, CEA, and Rennes-I and Paris-V Universities.
2. www.manros-therapeutics.com
3. Laboratoire Phosphorylation de protéines et pathologies humaines (CNRS research and service unit).
4. *Capital*, August 2009.

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ALYXAN

Tracking Down Gases

Air often contains traces of pollutant gases and other substances in addition to its common constituents, namely nitrogen, oxygen, and carbon dioxide. The ultra-rapid and transportable B-Trap analyzer, which is protected by a double patent,[1] can detect such substances in a flash. "We live in a world with increasing safety concerns. We therefore need to be able to detect toxic substances on the spot and in real time, to alert the surrounding population, for example," explains Michel Heninger, a researcher in the team behind B-Trap, at Orsay's LCP.[2]

Until now, this type of precise analysis was costly and time-consuming. A sample had to be taken and transferred to a laboratory to be analyzed by a mass spectrometer that required a skilled operator. Mass spectrometry involves the separation of substances according to the mass of their constituent molecules, as this mass is unique to each type of molecule. So far, the only instruments capable of high mass accuracy measurements were designed for the large molecules found in the petroleum and pharmaceutical industries, and therefore not adapted to the small molecules that make up the air. Furthermore, their size—that of a small apartment—meant transporting them was impossible.

The LCP team has succeeded in miniaturizing and adapting this mass spectrometry technique. The B-Trap analyzer, which is very simple to use, is the size of a small refrigerator and only costs around €150,000. It can detect a given molecule out of a million or even a billion in real time. "And we can obtain up to one measurement every second," adds Heninger. The results are so encouraging that the project won a French national competition to promote innovative technologies[3] twice—in 2003 and 2004—leading to the creation of the start-up AlyXan in 2005.

AlyXan has already won several contracts with France's Ministry of Defense for the continuous measurement of atmospheres in submarines, where the confined environment makes any toxic leak life-threatening. "A collaboration is also underway with the French petroleum institute (IFP) to study gas emissions produced by cars," adds Heninger. "And we are also collaborating with the Occupational Medicine Department of the Paris-Sud University to monitor workplace air quality, a technology that could be extended to private homes." Given the present concerns regarding questions of public health, AlyXan should have a very promising future.

Charline Zeitoun

1. CNRS / Universités Paris-XI and -VI.
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3. Concours national d'aide à la création d'entreprises de technologies innovantes.

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THE EUROPEAN SOUTHERN OBSERVATORY

Space Seen from Earth

Laurent Vigroux, the current director of the Astrophysics Institute of Paris,[1] has also been president of the Council of the European Southern Observatory (ESO) since January 2009. He explains the role of this organization and its future projects.

The ALMA project aims to build a giant interferometer by 2013 at an altitude of 5104 meters in northern Chile.

The Very Large Telescope (VLT) is today considered the best observatory in the world.

© F. Kamphues/ESO

Tell us about the European Southern Observatory.

Laurent Vigroux: It is an intergovernmental organization which was set up in 1962 to develop modern astronomy in Europe. At the time, the main objective of the five founding countries (Germany, France, the Netherlands, Belgium, and Sweden) was to build a 4-meter telescope at La Silla in Chile that would be dedicated to studying three objects that are hard to observe from the Northern Hemisphere: the Magellanic Clouds, which are the two galaxies closest to our own, and our galaxy, the Milky Way—especially its center. Because this first instrument and those that were added during the 1970s produced excellent results, other countries decided to join ESO, making even more ambitious projects possible. The best-known example was the construction in the 1990s of the four 8-meter telescopes of the Very Large Telescope (VLT) on Mount Paranal in Chile. Today, this observatory is considered the best in the world. ESO now has 14 Member States and owns some 20 instruments at the La Silla and Paranal sites, which enable observations of the sky at almost all wavelengths.

© D. Jarnet/CNES

What role does ESO play in world astronomy?

L.V.: ESO occupies a unique place in the discipline as it is currently the largest organization responsible for ground-based instruments: all major European countries are now members. No region of the world has an equivalent structure—namely an organization capable of playing a federative role at the scale of an entire continent, with an annual budget and qualified in-house personnel—not even the US, where telescopes generally belong to universities or private consortia. Furthermore, unlike the European Space Agency which devotes a large share of its activities to space launches and Earth observations, ESO only concerns itself with astronomy. This gives it a much more significant mandate in the eyes of the scientific community.

The latest call for proposals for observations received more than 1200 requests for the use of the ESO telescopes—unfortunately seven times more than available. Every year, 400 scientific articles are published on studies performed using the VLT, i.e., more than one a day. To this figure should be added the 25 to 30 yearly publications that focus on discoveries made using the VLTI (Very Large Telescope Interferometer: the interferometric mode of VLT[2]) and the telescopes at La Silla.

ESO is today a real science-generating machine to which we owe results as spectacular as the assessment, last year, of the mass of the black hole that lies at the center of our galaxy, or in 2005, the production of the first image of an exoplanet.

To what degree is CNRS involved?

L.V.: Although indirect, CNRS' involvement in ESO is considerable since most French astronomers work in CNRS laboratories. They also make important contributions to the design of instruments. Out of the 15 instruments of the VLT and VLTI, 7 were designed with the assistance of French teams, 6 of these being from CNRS. Besides, most of the 100 or so French articles based on ESO observations involve CNRS.

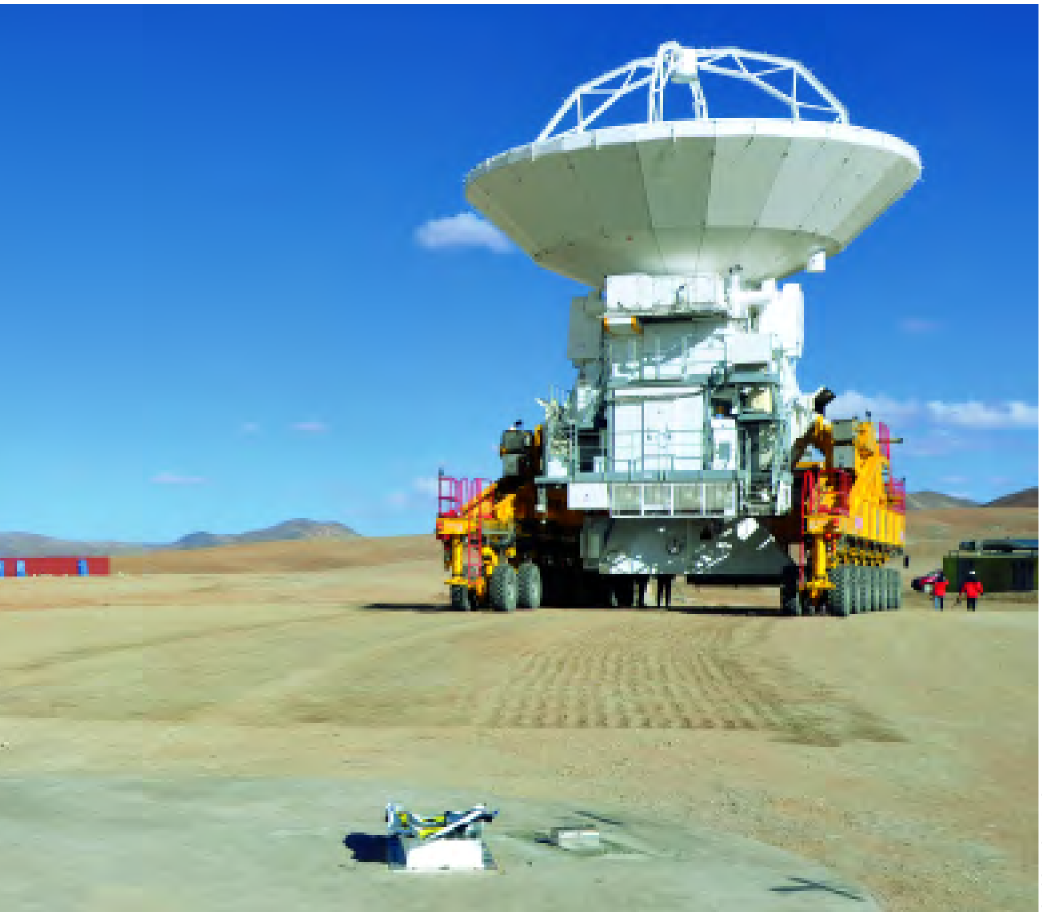
What is the relationship between ESO and the various space agencies? Is there competition between space- and land-based astronomy?

L.V.: Not at all, these two branches of astronomy are complementary. To obtain images of exoplanets, for example, a ground-based 40-meter telescope is essential. But determining where to point it still requires a space-based telescope of the CoRot type.[3]

Similarly, observing the sky at certain wavelengths—X-ray, gamma-ray, or far-infrared—is not possible from Earth. For this reason, some initiatives have to be taken outside ESO, especially since all terrestrial observation resources are not represented in our organization. ESO does not carry out radioastronomy and does not participate in high-energy astrophysics instruments like HESS or Auger.

How is ESO organized?

L.V.: The observatory is managed by a Council where each Member State has two representatives. This Council, of which I have been the president since January 2009, is responsible for appointing the director general, approving the budget, and determining our principal policy orientations. ESO's annual budget is just over €130 million, which mainly comes from the con-



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tributions of each Member State proportionally to its GDP. Roughly 40% makes up the operational budget, which also includes industrial contracts for the building and instrumentation of the telescopes. The remainder is spent on the 650 or so staff, spread between the ESO head office near Munich (Germany) and the observatories in Chile. It should be noted that in most cases, ESO does not build the instruments that equip its telescopes. It issues calls for proposals that are answered by laboratories in the Member States in exchange for observation time. France is one of the leading countries in this area, and has become renowned for its novel ideas in adaptive optics, the technique that uses a deformable mirror to enable the real-time correction of disturbances caused by the atmosphere. The country boasts several specialized teams, based in science observatories in Marseille, Toulouse, Bordeaux, Grenoble, Nice, and Lyon, and at the French Atomic Energy Commission (CEA).

How will ESO instruments evolve over the next few years?

L.V.: The VLT is currently equipped with 12 instruments. These will gradually be replaced by new, second-generation systems, two of which are currently being developed in France. Dedicated to research on exoplanets and to the visible and infrared spectroscopy of distant galaxies, these systems, called SPHERE, MUSE, and KMOS, should be operational by 2012 or 2013. The VLTI also has a second-generation instrumentation plan, in which CNRS will play a major role.
In parallel, ESO represents Europe in a vast international program called ALMA, in which the US, Canada, Japan, and Taiwan also participate. Endowed with a budget of €800 million—half of which comes from ESO as the European contribution—this project aims to build a giant radio interferometer at an altitude of more than 5000 meters at the Llano de Chajnantor, Northern Chile. When it becomes operational in 2013, this network of antennae will be dedicated to studying the composition of interstellar clouds, the clouds of gas and dust from which the first galaxies probably emerged.
As for the post-VLT period, we are currently studying the concept of a 42-meter telescope, the European Extremely Large Telescope (E-ELT), whose main objective will be to obtain images of exoplanets. The ESO Council should decide on its construction by the end of 2010 or mid-2011. It could become fully operational by 2017-18.
But this all depends on the political decisions taken by the different Member States. Supporting this project, which will cost approximately €1 billion, means accepting a substantial increase in their financial contributions.

Interview by Vahé Ter Minassian

1. Institut d'astrophysique de Paris (CNRS / Université Paris-VI).
2. Interferometry produces images of a cosmic object by operating several telescopes in concert.
3. COnvection, ROtation and planetary Transit.

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A CAMERA TO FILM THE UNIVERSE

OCam, an ultrafast and ultra-sensitive camera for adaptive optics, able to capture 1500 images per second in almost complete darkness, has just been completed. It took five years for a consortium of three French laboratories[1] from CNRS-INSU to develop this camera, jointly funded by the European Commission, ESO, and INSU, in the context of the European Opticon project.
It was especially designed to be used on one of the VLT's second-generation instruments, called SPHERE, but will also be used on all VLT adaptive optics systems to come. This ultrafast camera will allow astronomers to measure and then correct for in real-time—and with hitherto unequaled accuracy—the atmospheric turbulence that interferes with the astronomical images captured by large ground-based telescopes.

1. Laboratoire d'astrophysique de Grenoble (CNRS / Université Grenoble-I, Observatoire des sciences de l'Univers de Grenoble (CNRS / Université Grenoble-I / Institut polytechnique Grenoble)), Laboratoire d'astrophysique de Marseille (CNRS / Université Aix-Marseille-I / Observatoire astronomique de Marseille-Provence) and Observatoire de Haute-Provence (CNRS).

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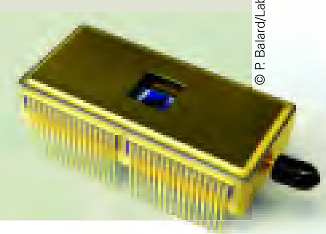

The detection system of the OCam camera for VLT adaptive optics. It can capture 1500 images per second in almost complete darkness.

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SESAR

Modernizing Air Traffic in Europe

A threefold increase in air traffic capacity in European skies, management costs halved, safety improved tenfold, and the environmental impact of each flight cut by 10%: just some of the objectives of the European SESAR program, to which CNRS is actively participating.

With nearly 30,000 flights a day during peak travel periods and more than 10 million flights a year (set to increase to 17 million by 2020 and 20.4 million by 2030), European air traffic risks paralysis if its management and control are not rapidly modernized.

For this reason, in 2007 the European Commission launched the SESAR (Single European Sky Air traffic management and Research) program, the technological side of the "Single European Sky" initiative, which aims to restructure air traffic management in Europe, currently split into 27 different national systems.[1] "Air traffic control has evolved very little since communication by radio and radar became the norm," explains Philippe Baptiste, one of the 12 members of the SESAR scientific committee and director of the LIX.[2] "To a large extent, it is still fairly low-tech, with very little automation, and continues to rely on the individual capacity of controllers to manage ever increasing traffic levels."

A member of the SESAR scientific committee and senior researcher at PREG,[3] Alain Jeunemaître points out that "the economic losses linked to the system's lack of efficiency are estimated to be between €3-5 billion a year, one billion of which is due to system fragmentation. Air traffic control costs two times more in Europe than in the US, mainly due to this segmentation problem."

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To optimize air traffic control, various technologies will be implemented like an intranet connecting all the players involved, digital links with airplanes, or new turbulence detection systems.

DEFINING OPTIMAL FLIGHT PATHS

"At present, the flight paths set by air traffic controllers are far from optimal. They are overly dependent on the geographic segmentation of national management systems and military training spaces," explains Patrick Ky, SESAR's executive director. "For instance, it is estimated that current flight paths deviate from optimal paths by 3 to 5%, which results in excessive fuel consumption, pollution, lost time, and wasted money."

SESAR is therefore now working on optimizing flight paths. For any given flight, an optimal path will be jointly defined by controllers, airline companies, and other users of airspace (airports, business jets, private and military aviation, etc.). To do so, a number of technologies are being developed such as an intranet that links every player involved in air traffic control or direct data transfer between the ground and airplanes by digital link, to complement the current radio link. Other solutions involve the first satellite navigation tests using the European Galileo system planned in 2010-2011, controller and pilot assistance via new automatic functions, and new turbulence detection systems. Once fully developed, these technologies will first be deployed on the ground, then in airplanes by 2014.

LONG TERM RESEARCH

In parallel with the technological developments currently underway, SESAR's scientific committee is setting up academic research networks on various topics like modeling and optimization of air traffic, the controller/computer interface, and improving the system's economic performance.

In France, several CNRS laboratories are conducting research in these fields. PREG, for example, has been examining ways of restructuring European air traffic control to reduce its cost, while the LIX has been working on traffic modeling aspects. The modernization of European air traffic control is essential, since failures come at a high price, like the 2002 mid-air collision above Lake Constance in Switzerland which resulted in 71 fatalities.

Jean-Philippe Braly

1. Its present budget stands at €2.1 billion, divided between the European Commission, Eurocontrol (European Organization for the Safety of Air Navigation) and 15 industrial partners.
2. Laboratoire d'informatique de l'école polytechnique (CNRS / École Polytechnique).
3. Pôle de recherche en économie et gestion de l'école polytechnique (CNRS / École Polytechnique).

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With its 69 antennae mounted on its three arms, the SMOS satellite will analyze the oceans' salinity and the soil's moisture.

© ESA

SMOS

Tracking the World's Water

After more than 20 years of research and development, the SMOS (Soil Moisture and Ocean Salinity) satellite was finally launched from Plesetsk, in northern Russia, on November 2nd, 2009. It will spend at least the next three years in orbit, monitoring the Earth's water.

The SMOS project, which originated at the Center for the Study of the Biosphere from Space (CESBIO)[1] in Toulouse, aims to provide the first global maps of soil moisture and ocean salinity, two key indicators of the state of the Earth's climate.

"Getting the satellite into orbit has been the work of an international team," says Yann Kerr, CESBIO's director and SMOS PI.

The SMOS satellite acts as a giant radio-thermometer picking up the Earth's microwave radiation, which is reduced by soil moisture and salinity. The 69 antennae mounted on the satellite's three "arms" pick up radiation from large pseudo-hexagons approximately 1000 kilometers wide. "It lets researchers compile maps of our planet's surface water every three days with a resolution of 40 kilometers or better," adds Kerr.

Since water levels, whether as soil moisture or in the oceans, are seen as "a tracer or an indicator of climate change," the SMOS mission—a joint French, Spanish, and European Space Agency project—will not only let researchers track long-term climate change, but also predict it with greater accuracy in the short term.

This also means scientists can follow ocean currents as they move around the globe, and thus "better understand and model thermohaline circulation," in other words, the way temperature and salinity interact.

Since its launch last November, SMOS has already started sending back data, which is promising for meteorologists, hydrologists, and agronomists. "All the first stages have gone marvellously well and we have received the first images earlier than anticipated," Kerr says. "We're extremely satisfied."

Tom Ridgway

1. Centre d'études spatiales de la biosphère (CNRS / Université Paul Sabatier / CNES / IRD).

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ASSOCIATED LABORATORIES

Uruguay

The Franco-Uruguayan Institute of Mathematics (IFUM), which was created on December 10th, 2009, associates a number of French laboratories in Paris, Montpellier, and Toulouse, with the University of the Republic and the Program for the Development of Basic Sciences (PEDECIBA) in Montevideo (Uruguay). Following a long-standing cooperation in mathematics between the two countries, this International Associated Laboratory (LIA) will coordinate research in three mathematical fields: algebra and geometric algebra; dynamic systems; and statistics and probability.

http://www.math.univ-montp2.fr/~cibils/IFUM/

Argentina

The International Franco-Argentinian Nanociences Laboratory (LIFAN), associating two laboratories in France,[1] and two in Argentina,[2] was created last December. Mainly geared towards research on hybrid systems in spintronics, metal-oxide interfaces, and nanophonics, this International Associated Laboratory is expected to boost the existing collaboration, over ten years long, between the founding laboratories.

1. Institut des nanosciences de Paris (CNRS / UPMC); Laboratoire des collisions atomiques et moléculaires (CNRS / Université Paris-XI).
2. From the "Comisión Nacional de Energía Atómica," and from the "Ministerio de Ciencia, Tecnología e Innovación Productiva," in Buenos Aires and Bariloche.

Greece / Romania

Dubbed SmartMEMS, a new European Associated Laboratory (LEA) was created between CNRS, the Greek Foundation for Research and Technology (FORTH) in Heraklion (Greece), and the National Institute for Research and Development in Microtechnologies in Bucharest (Romania). Its objective: to advance the knowledge on materials and their electromagnetic properties, and to exploit such properties in the development of novel components for communications and instrumentation. The first LEA created with Greece, SmartMEMS associates for four years some 40 researchers from CNRS' Laboratory for Analysis and Architecture of Systems (LAAS), the Microelectrics Research Group in Greece, and the Laboratory of Micromachined Structures, Microwave Circuits and Devices (RF MEMS) in Romania.

PHYSICS

Most Powerful NMR Spectrometer Now Operational

The most powerful nuclear magnetic resonance spectrometer in the world was recently inaugurated at Lyon's European Nuclear Magnetic Resonance Center (CRMN).[1] Gilberte Chambaud, director of CNRS' Institute of Chemistry, tells us about this exceptional instrument and how collective efforts and ambitious policies have made the project possible.

Can you tell us more about this newly inaugurated instrument?

Gilberte Chambaud: It is a nuclear magnetic resonance (NMR) spectrometer (*see box*) of unrivalled power. It was funded—to an amount of €11 million—by French national and regional institutions.[2] This large apparatus, which weighs 12 tons and stands 5.2 meters high, will certainly allow significant advances in the structural analyses of molecules of interest for medicine, biology, or materials science. Its magnet can generate a magnetic field of 23.5 Teslas,[3] i.e., about 500,000 times the magnetic field of Earth. This will make it possible to reach a "resonance frequency" of 1 Gigahertz (1000 MHz) for hydrogen atoms. Until now, the most powerful spectrometers in the world were limited to a frequency of 950 MHz. During the past 30 years, successive improvements in NMR techniques have led to new discoveries, and it is expected that this new step in technology will further advance the field.

What will be the specific use of this instrument ?

G.C.: The teams with access to this machine are working on a large number of fundamental issues. For example, NMR spectroscopy can help detect structural alterations of molecules associated to cancer. Determining proteins' architectures and their dynamics could lead to the development of novel therapeutic compounds. The instrument can also be used to analyze the structure of materials like wood, glass, or concrete, or to improve the design of polymers. At least 70% of the projects are in chemistry and the life sciences.

This machine belongs to the ultra-high field NMR network.[4] What is this network?

G.C.: It is a large and unique research infrastructure spread on six sites throughout France, each combining a specific scientific expertise and a specific NMR spectrometer. The strength of this network stems from the excellence of its expert teams (45 researchers and engineers), internationally recognized in the field of solid inorganic or bioorganic NMR as well as in liquid NMR. Through this network, French, but also European scientists can have access to these ultra-high field spectrometers in an environment of competent technical and scientific support. In addition to their own research activity, the network's scientists also host and help other researchers carrying out studies requiring the use of the NMR spectrometers. The new 1 GHz NMR spectrometer is the centerpiece of the network.

Is there a project for an even more powerful apparatus ?

G.C.: We are expecting a 1200 MHz machine by 2015-2020, though the technology needed to produce such an apparatus is still in progress and requires a strong collaboration between the researchers and the manufacturers.

Interview by Kheira Bettayeb

1. Centre Européen de résonance magnétique nucléaire (CNRS / Ecole normale supérieure de Lyon / Université Claude Bernard Lyon-I).
2. CNRS, the Rhône-Alpes Region, the urban community of Lyon, and Claude Bernard University.
3. The Tesla is a unit that characterizes the force of a magnetic field.
4. TGIR-RMN: www.tgir-rmn.org

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The new 1 GHz NMR spectrometer in Lyon can generate a magnetic field of 23.5 Teslas.

NMR SPECTROSCOPY

Discovered some 60 years ago, nuclear magnetic resonance (NMR) can precisely analyze the composition and structure of a sample of matter at the atomic scale. The technique consists in detecting variations in the internal magnetization (spin) of specific atomic nuclei—such as that of hydrogen—placed in a strong magnetic field. In practice, the nucleus absorbs an electromagnetic radiation at a given frequency—the resonance frequency—which modifies its internal magnetization. When the radiation is withdrawn, the nucleus returns to its fundamental state. This "relaxation" causes the emission of a characteristic electromagnetic wave that can be measured and analyzed. The higher the magnetic field, the larger the resonance frequency and the more detailed the spectrum obtained. Because variations in internal magnetization depend on the immediate environment of the nucleus, the technique allows for a detailed structural analysis of the matter studied.

FD

PALEOCLIMATOLOGY

Thawing Climate History

During the interglacial Eemian Period, which occured approximately between 130,000 and 115,000 years ago, polar temperatures were significantly warmer than at present, with sea levels 4-6 meters higher. This period offers a perfect benchmark for current global warming models, which predict a temperature rise of 2.4°C per century.

Yet little is known about Eemian evolution—including the sequence of changes in polar ice caps and ocean currents. Crucial evidence of this period and its transition into the last Ice Age is buried deep below the Greenland ice cap as thin layers of ice, each representing annual snowfall, compacted over tens of thousands of years. Each of these layers contains a trove of information about previous atmospheric and environmental conditions in polar regions.

To retrieve this evidence, the NEEM project (North Greenland EEMian Ice Drilling), led by the University of Copenhagen (Denmark), but made up of a team of scientists from 14 countries[1] including CNRS researchers,[2] is established at a remote base in northwestern Greenland. The site of this ambitious project, drilling to ice older than that of any previous study, was chosen by radar prospection for optimal conditions: it had to be above an ice divide, where the oldest ice is located, and on a flat bedrock to ensure the undisturbed preservation of the layers.

NEEM began deep drilling in June 2009, using its own non-polluting drill fluid developed with CNRS scientists. By the summer's end, NEEM had reached a depth of 1757.84 meters—establishing a new world record for single-season deep-ice core drilling. It now hopes to reach the annual Eemian ice layers by the end of summer 2010. Each of these layers is on average 7 mm thick and found close to the bedrock, 2542 meters below the surface.

The samples brought to the surface are analyzed by stable water isotope ratios, revealing the temperatures prevalent at the time in Greenland, and the regional sources of the precipitations.

Gases trapped between snow crystals and the particulates they contain tell us about atmospheric conditions, notably greenhouse gas levels. But more information can be obtained from chemical and biological material, like bacteria, or by measuring both ice crystal structures and bore-hole temperatures.

The ice reached last summer dates from 38,500 years ago. First analyses show the site at that time received the heaviest precipitations in the summer, and reveal the nature of climatic variations prevalent over the Labrador Sea and Baffin Bay.

Graham Tearse

1. The United States, Belgium, Canada, China, Denmark, France, Germany, Iceland, Japan, Korea, the Netherlands, Sweden, Switzerland, and the United Kingdom.
2. From INSU-CNRS, CEA, Versailles St. Quentin University, Joseph Fourier University (Grenoble), with the support of the French national research agency (ANR), and the French polar institute (IPEV).

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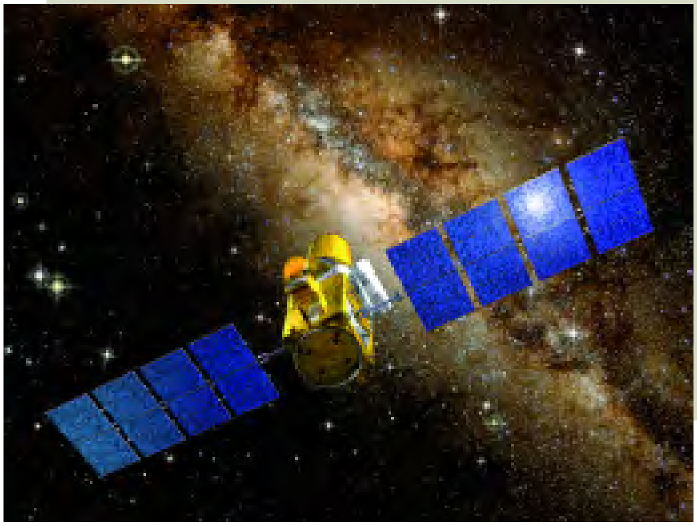
ASTRONOMY

CoRoT Mission Extended

The CoRoT satellite's mission has been extended for another three years. The satellite was launched in 2006 with two objectives: to scan the universe for exoplanets and to learn more about star structure (by measuring star oscillation). CoRoT was originally a three-year mission, but its mandate was renewed due to the overall high quality of data obtained—including some recent breakthroughs on both stars and exoplanets. The results of the mission were published in a special issue of *Astronomy & Astrophysics* in October 2009.[1] The mission's extension was granted by France's National center for space studies (CNES), together with its national and international partners (CNRS-INSU, the Paris Observatory, the European Space Agency (ESA), Austria, Belgium, Germany, Spain, and Brazil). During the next three years, researchers hope to acquire more information on new types of stars. They will also focus on finding "super hot earths," planets slightly more massive than the Earth that rotate much closer to their parent star.

1. "The CoRoT space mission: early results," *Astronomy & Astrophysics*, 2009. Vol. 506 / 1 - October IV.



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Artist's rendering of the CoRoT satellite.

Planck Keeps its Promise

The Planck satellite, launched in May 2009, gave its first reading of the sky, a narrow band across the entire celestial sphere, providing excellent quality data. This European mission is designed to measure cosmic microwave background radiation, the oldest radiation emitted in the Universe, showing us how it was 380,000 years after the Big Bang. The satellite will provide a complete map of the sky with unprecedented accuracy for the heterogeneity of the temperature and polarization of cosmic microwave background radiation, using the French High Frequency Instrument. CNRS laboratories from INSU and IN2P3 have played a crucial role in its conception, development, and implementation. Complete readings from Planck are expected by 2012.

CNRS in Brief

The **Centre National de la Recherche Scientifique** (National Center for Scientific Research) is a government-funded research organization under the administrative authority of France's Ministry of Research.

Facts...

Founded in 1939 by governmental decree, CNRS has the following missions:
- To evaluate and carry out all research capable of advancing knowledge and bringing social, cultural, and economic benefits to society
- To contribute to the application and promotion of research results
- To develop scientific communication
- To support research training
- To participate in the analysis of the national and international scientific climate and its potential for evolution in order to develop a national policy

CNRS research units are spread throughout France, and employ a large body of permanent researchers, engineers, technicians, and administrative staff. Laboratories are all on four-year, renewable contracts, with bi-annual evaluations. There are two types of labs:
- **CNRS labs:** fully funded and managed by CNRS
- **Joint labs:** partnered with universities, other research organizations, or industry

As the largest fundamental research organization in Europe, CNRS is involved in all scientific fields, organized into the following areas of research:
- Life sciences
- Physics
- Chemistry
- Mathematics
- Computer science
- Earth sciences and Astronomy
- Humanities and Social sciences
- Environmental sciences and Sustainable development
- Engineering

CNRS conducts some twenty interdisciplinary programs in order to promote exchange between fields, ensure economic and technological development, and solve complex societal problems.
- www.cnrs.fr/prg/PIR/liste.htm

The CNRS annual budget represents one-quarter of French public spending on civilian research. This funding comes from various sources:
- Government and public funding
- CNRS funds, primarily from industrial and EU research contracts and royalties on patents, licenses, and services provided

... And Figures

Budget for 2009
€3.36 billion of which €607 million comes from revenues generated by CNRS contracts

Personnel
32,000 employees: 11,600 researchers, 14,400 engineers and technical staff, and 6000 non-permanent employees

Organization
- 10 thematic institutes
- 19 regional offices, ensuring decentralized direct management of laboratories
- 1100 research units–90% are joint research laboratories with universities and industry

Industrial Relations (2007)
- 1680 contracts signed by CNRS with industry in 2007
- 30 current agreements with major internat-ional industrial groups
- 3103 patent families
- 729 licenses and other financially remune-rating active acts
- €58.2 million in royalties
- 394 companies created between 1999 and 2008

DAE AND DRI, TWO OFFICES DEVOTED TO INTERNATIONAL RELATIONS

CNRS carries out research activities throughout the world, in collaboration with local partners, thus pursuing an active international policy.

The Office of European Affairs (DAE) and the Office of International Relations (DRI) coordinate and implement the policies of CNRS in Europe and the rest of the world, and maintain direct relations with its institutional partners abroad. The DAE and the DRI promote cooperation between CNRS laboratories and foreign research teams through a set of structured collaborative instruments developed for this purpose. At the same time, they coordinate CNRS actions with those of other French and international research organizations as well as the activities of the Ministries of Research and Foreign Affairs. To carry out their mission, the DAE and the DRI–with head offices in Paris–rely on a network of eight representative offices abroad, as well as on the science and technology offices in French embassies around the world.

IN NUMBERS:

Exchange agreements: 85 (with 60 countries)

Foreign visiting scientists: 5000 (PhD students, post-docs, and visiting researchers)

Permanent foreign staff members:
- About 1700 researchers of whom more than 1200 come from Europe

- **International Programs for Scientific Cooperation (PICS):** 368
- **International Associated Laboratories (LEA + LIA):** 123
- **International Research Groups (GDRE + GDRI):** 90
- **International Joint Units (UMI):** 22

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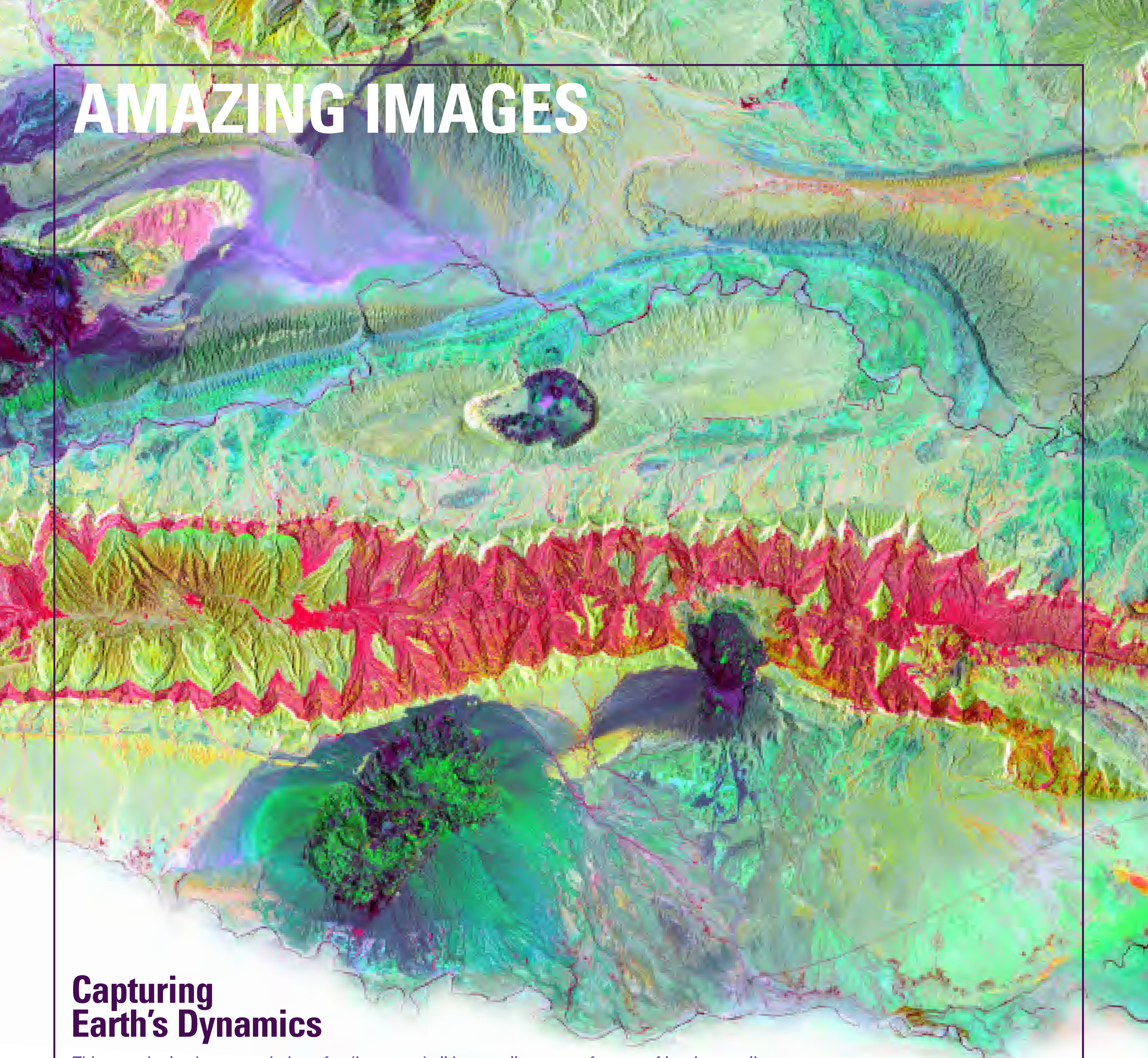
AMAZING IMAGES



Capturing Earth's Dynamics

This seemingly abstract painting of a dinosaur skull is actually a map of a part of Iran's coastline near Khamir, where the northward-moving Arabian tectonic plate and the Eurasian plate collide. The resulting folds are the Zagros Mountain Range.

The map was developed by researchers from the Geosciences Montpellier lab[1] using the Landsat 7etm+ satellite. Remote sensing was used to obtain digital photographs taken from space in which different components of the Earth's surface are captured at different wavelengths and then combined into a single false-color picture.

This technique lets researchers create evolving records of the Earth's surface. It is a particularly useful tool for surveying inaccessible areas, and furnishing dynamic data for patterns of erosion, sedimentation, the nature and age of rocks, and tectonic activity. Such information will help evaluate the global dynamics of the Earth's natural processes and the effects of human interventions.

Sarah MacKenzie

1. CNRS / Université Montpellier-II.

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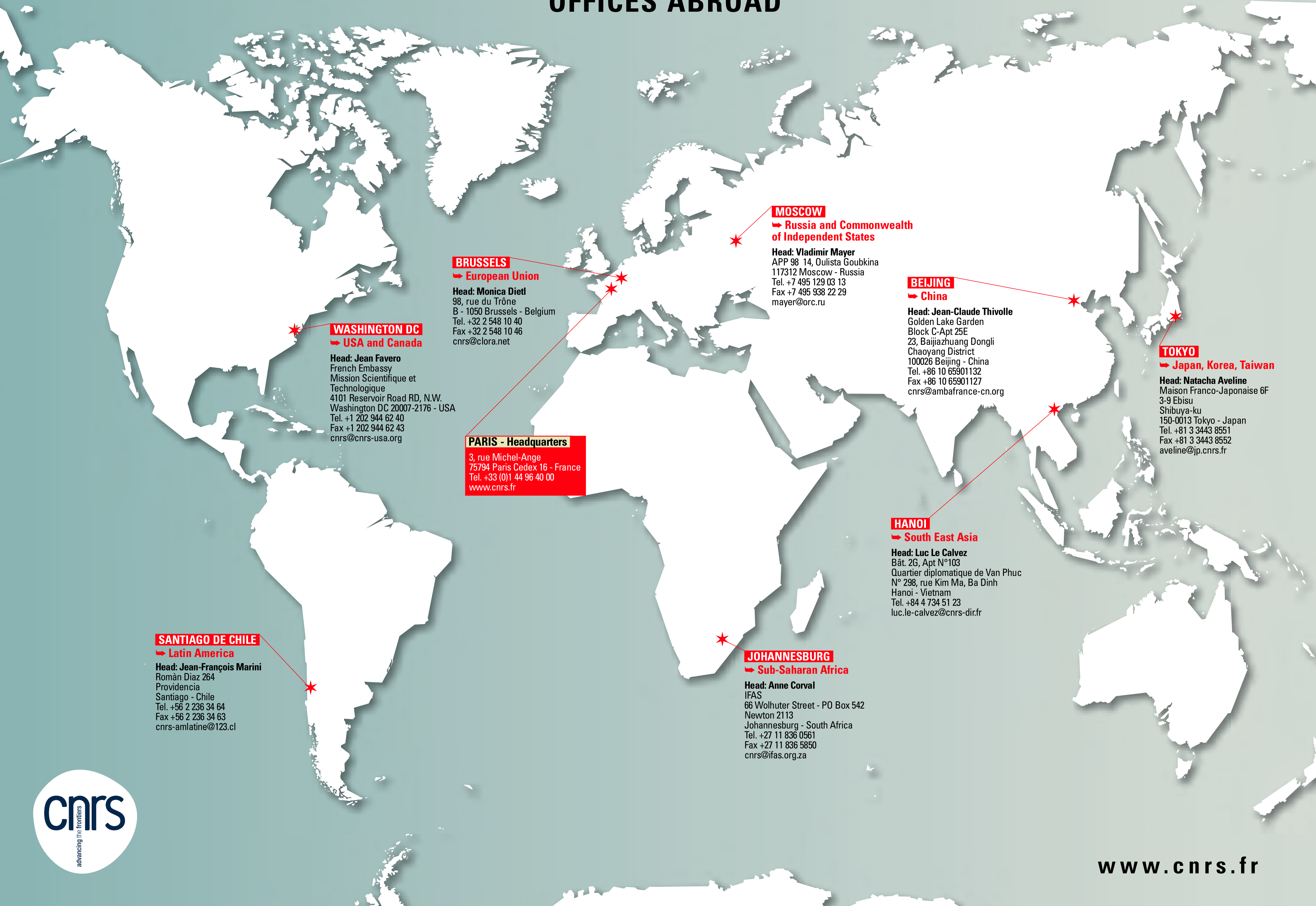

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