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# THE FUTURE OF Computing Science

**Gérard Férey**
Recipient of the CNRS 2010 Gold Medal

advancing the frontiers


2011
JACQUES-MONOD CONFERENCES
Evolution of plant developmental regulatory mechanisms
Roscoff (Bretagne) April 30 - May 4, 2011
Deadline for application: January 15, 2011
New and Emerging Fungal Diseases of Animals and Plants: evolutionary aspects in the context of global changes
Roscoff (Bretagne) June 25-29, 2011
Deadline for application: March 15, 2011
Coevolutionary arms race between parasite virulence and host immune defence: challenges from state of the art research
Roscoff (Bretagne) September 3-7, 2011
Deadline for application: May 5, 2011
Molecular basis for membrane remodelling and organization
Roscoff (Bretagne) September 24-28, 2011
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# Editorial


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**BY** PHILIPPE BAPTISTE,
SCIENTIFIC DIRECTOR OF THE CNRS INSTITUTE FOR COMPUTER SCIENCES (INS2I)

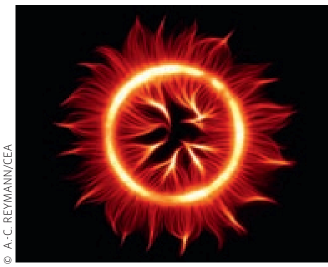
**Recent advances in computer and information sciences have triggered a revolution** whose spectacular developments have radically transformed our daily lives. Today, CNRS faces new challenges in digital technology, especially in the health and environmental protection sectors.

By founding the Institute for Computer Sciences (INS2I),[1] our national research center has strengthened its position in this highly competitive area. With the primary goal of pushing the boundaries of computer science and information technology, the INS2I is also actively involved in research at the interface of software and hardware, like automatic control, signals, imaging, robotics, and systems-on-chip. This interdisciplinarity, which makes new tools and concepts available in all disciplines, is at the heart of CNRS's agenda. What's more, CNRS welcomes all current and future debates raised by such novel scientific and social practices.

Through the INS2I, CNRS intends to pursue a policy of excellence for the benefit of the scientific community, while encouraging knowledge transfer and enhancement through partnerships with industry. It also intends to develop international collaborations through new international joint laboratories like the Japanese-French Laboratory for Informatics (JFLI), created in 2009 in Tokyo.[2] Similar structures are being developed with Argentina and Canada, both in areas related to the foundations of computer science. They should be operational by 2011.

01. Institut des sciences informatiques et de leurs interactions.
02. With the University of Tokyo, Keio University, and the National Institute of Informatics (NII) of Japan.

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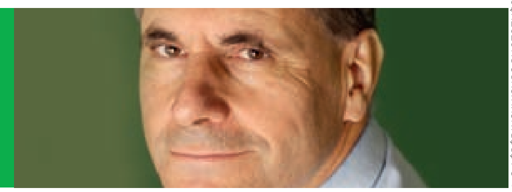
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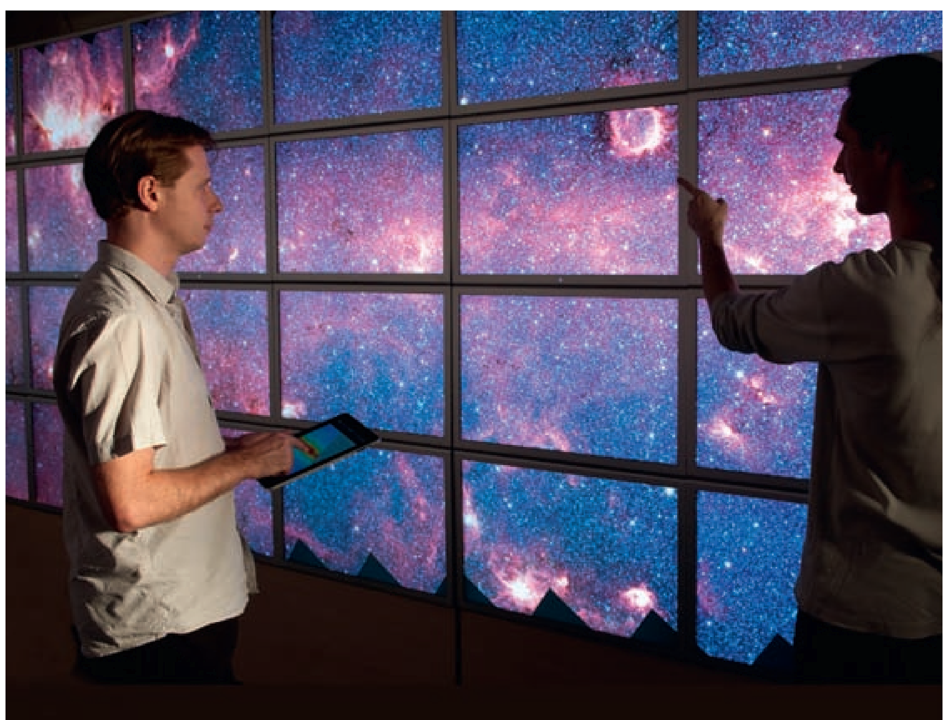
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## 2010 International Year of Biodiversity

# A Positive Outlook




→ The COP 10 was held in Nagoya (Japan) on October 18-29, 2010.

**Good news finally came on October 29, the last day of the international Conference of the Parties to the Convention on Biological Diversity (COP 10)** held in Nagoya (Japan). The 193 participating nations agreed to a treaty that lays down basic rules on how nations should access genetic resources from plants, animals, and fungi, and how benefits linked to their use should be shared. The Nagoya commitments should ensure the fair and equitable sharing of biological resources between the Northern and Southern Hemispheres.

The signatory countries agreed to implement a strategy whose main goals will be to increase protection of existing natural environments. For example, land-based protected areas and national parks should be extended from 12.5% of the Earth's surface to 17% by 2020. Similarly, the global percentage of protected marine areas should be raised to 10%. All parties agreed to intensify their efforts to back up this biodiversity protection plan through new financial mechanisms.

France is highly committed to the fight for biodiversity preservation. As a first step, the French government has promised to double public funds allocated to the development of biodiversity by 2012. This will be followed by a regular increase to reach the global target of €500 million per year by 2014.

A second encouraging factor came on December 21 from the United Nations' 65th General Assembly (UNGA). Following up on Nagoya's conference agreement, the UNGA adopted a resolution for the creation of the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES). Its mission is to provide governments with scientific expertise and knowledge assessment to help them make the right decisions in terms of environmental and biodiversity protection.

Such important measures taken at the close of the International Year of Biodiversity bode well for the 2011 International Year of Forests.

2010 International Year of Biodiversity

Life in harmony, into the future
COP10/MOP5
AICHI-NAGOYA
JAPAN 2010

## Innovation

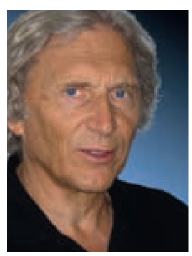
→ **Almost 80% of all innovation in clean energy technologies results from patents filed by six countries, including France. This was revealed by an international study[1] based on the examination of some 400,000 patent documents in the field of clean energy technology, including solar photovoltaics, wind power, biofuels, or carbon sequestration. Japan tops the ranking, followed by the US, Germany, South Korea, France, and the UK.**

1. Conducted by the European Patent Office (EPO), the United Nations Environment Programme (UNEP), and the International Centre for Trade and Sustainable Development (ICTSD).

# ERC STARTING GRANTS:
## CNRS, European Leader once again

→ **The European Research Council's third Starting Grant competition for young researchers** has approved 427 proposals. Among the 72 projects based in France, 55 originate from CNRS or associated laboratories, making the French research organization first single ERC grant recipient once again. Physical sciences and engineering account for 32 grants, followed by humanities and social sciences (10), and life sciences (13). The competition subsidizes innovative projects by researchers who have completed their PhDs within the past 2 to 12 years and who need funding to set up or consolidate a research team. The budget for this year's Starting Grants exceeds €580 million, which represents a 40% increase over last year's. A total of 2873 applications from candidates of 39 nationalities were registered, up by 14%. With 72 selected projects out of 269 applications, France ranks second behind the UK (79 projects) and ahead of Germany (66 projects).

# Ernst Jung Gold Medal

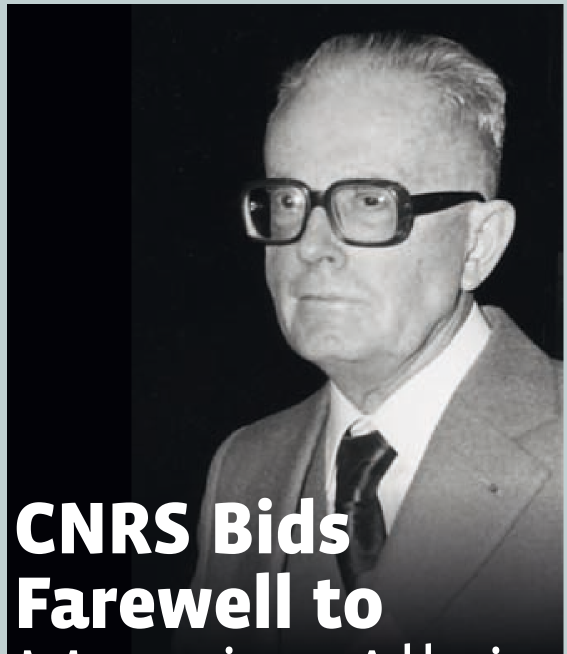




→ **Michel Lazdunski was awarded the Ernst Jung Medal for Medicine in Gold 2011** for his lifetime achievement in medical science. Professor at the Medical School of the University of Nice-Sophia Antipolis in southern France, and director of the IPMC[1] Institute in Sophia Antipolis, Lazdunski is a world-renowned expert on ion channels. Lazdunski and his team have made internationally-recognized contributions to both basic and applied research in pharmacology (antihypertensives, antidiabetics, and inhalational anesthetics) and pathology (pain perception, cardiac arrhythmia, and cerebral ischemia). His work was rewarded with a CNRS Silver Medal in 1976, and with the CNRS Gold Medal in 2000.

The Ernst Jung Foundation, funded by Hamburg merchant Ernst Jung in 1967, launched the Ernst Jung Prize in Medicine in 1976 and the Ernst Jung Gold Medal for Medicine rewarding lifetime achievements in 1990. The award ceremony will be held in Hamburg on May 6, 2011.

01. Institut de pharmacologie moléculaire et cellulaire (CNRS / Université de Nice Sophia Antipolis).





# CNRS Bids Farewell to Maurice Allais

→ **Maurice Allais, laureate of the 1978 CNRS Gold Medal and 1988 Nobel Prize in Economics, passed away on October 9, 2010. Born in Paris in 1911, he graduated from the École Polytechnique in 1933. Deeply concerned by the Great Depression of the 1930s and its disastrous social consequences, he studied economics in the hope of finding solutions to the major challenges of his time. His work, in particular on capital theory, the optimal allocation of resources and the "overlapping generations" model, which he introduced in 1947, has had a lasting influence in macroeconomics. Self-declared as a "free-market socialist," Allais often voiced his opinion on French national politics. He was a senior researcher at CNRS from 1946 until his retirement in 1980.**




**CNRS MAKES THE HEADLINES**

# Snapshots of Viral Infection

→ **The Chikungunya virus is a mosquito-borne alphavirus** which has caused widespread outbreaks in the last five years. The virus has glycoprotein spikes on its surface that are formed and maintained at neutral pH. In the acidic conditions encountered in target cells, these spikes dissociate and fuse with host endosomal membranes, thus infecting the cell.

An international team including CNRS researchers has revealed the crystal structure of Chikungunya's envelop glycoproteins at neutral pH,[1] while an American team has uncovered the crystal structure of surface glycoproteins at acidic pH of the Sindbis virus,[2] another alphavirus pathogen that can cause fever in humans. Both reports made the cover of *Nature* last December. Comparison of the two structures should help understand the infection process and provide potential targets for vaccines.

01. J. E. Voss et al., "Glycoprotein organization of Chikungunya virus particles revealed by X-ray crystallography," *Nature*, 2010. 468: 709-12.
02. L. Li et al., "Structural changes of envelope proteins during alphavirus fusion," *Nature*, 2010. 468: 705-8.514.

Transportation The Vipa, an autonomous driverless electric vehicle designed in partnership with CNRS, was one of the attractions at the 2010 Paris Motor Show.

# Driving to the Future



© AUTOMOBILES LIGIER

01 This driverless vehicle can accommodate four to six passengers. In late 2008, four prototypes were tested at the Airbus assembly site in Toulouse. For two weeks, they provided transportation for no fewer than 1500 people.

**AT A GLANCE**

| | |
|---|---|
| **NAME:** | VIPA, for "Véhicule Individuel Public Autonome" (Autonomous Public Individual Vehicle) |
| **TECHNICAL FEATURES:** | Capacity: 4 to 6 passengers<br>Autonomy: 8 hours<br>Maximum speed: 20 km/h |
| **DEVELOPERS:** | LASMEA (CNRS laboratory)<br>Ligier (car manufacturer)<br>Apojee (engineering firm) |

**BY** VAHÉ TER MINASSIAN

**This is no standard passenger car.** This machine, the result of a collaboration between researchers and industrials, could one day entirely transform urban transportation. The Vipa (an acronym for "Véhicule Individuel Public Autonome," or autonomous public individual vehicle) is the fruit of a cooperative effort between a laboratory specialized in electronics and automation (LASMEA),[1] the French car manufacturer Ligier, and the Apojee engineering firm. This driverless electric vehicle—straight out of a science fiction novel—was unveiled to the public at the 2010 Paris Motor Show this past October.

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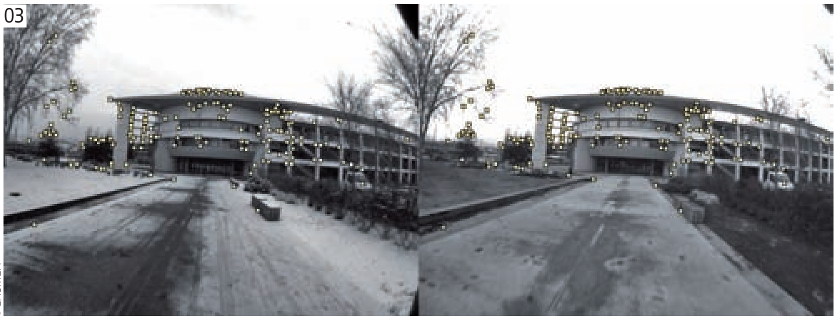

© LASMEA

02 The Vipa navigation system, developed by researchers at the LASMEA in Clermont-Ferrand, requires only a computer and a front-end camera.
03 The images recorded during the preliminary drive with a human operator (left) enable the Vipa computer to identify reference points (in yellow) that it then compares with the images captured while driving in automatic mode (right).

It can accommodate four to six passengers, seated or standing, and automatically adjusts its speed to the obstacles encountered on the road. Capable of negotiating narrow city streets over several kilometers with no outside help (GPS navigation, for example), the Vipa could eventually become to the city what the elevator is to the skyscraper. It could also prove very useful in large public places like airports, train stations, or hospitals, and "could be used to transport goods in large manufacturing sites," explains Thomas Leblanc, who headed the project at Ligier and is currently seeking to get the Vipa approved for city use. Last but not least, it could be used by persons with reduced mobility.

## FROM FICTION TO REALITY

The car industry has for years dedicated research to autonomous vehicle navigation systems. In some airports, driverless electric buses are already shuttling passengers between terminals, guided by magnetic studs on the ground. "Yet this technology is expensive to install and permanently fixes the vehicle's course," LASMEA director Michel Dhome points out. In parallel, researchers have been working on prototypes that can track their own location and movement to the nearest centimeter using something called differential GPS, an enhanced version of the commonly-used GPS. However, "this technology is not exactly suitable to city streets, where satellite navigation signals are frequently disrupted by interference," Dhome explains. "This limits the system's use to open spaces. The Vulcania amusement park (in central France), for example, has several machines of this type in regular use."

## VISUAL MEMORY

The Vipa has no such problems, thanks to its "visual memory" that makes it both adaptable (it can be deployed on a new site in just a few minutes) and reliable (it remains operational inside buildings). The development of this innovative navigation device started in 2002 at the LASMEA, first in the form of students' theses and then as a project on land transport research and innovation (PREDIT)[2] in association with the ViaMéca Competitiveness Cluster. The vehicle requires nothing more than a computer and a video camera equipped with a wide-angle lens. It works in three phases. First, a human operator drives the vehicle while the onboard camera records the route. In the second phase, the computer analyzes the images, identifying visual points of reference (the corner of a building, a window, etc.) and matching them from one frame to the next in order to calculate their positions in space. In the third phase, which takes only a few minutes, the Vipa's "brain" compiles a 3D map of the reference points along the route. These are then compared with the images captured by the camera during the automated drive, enabling the vehicle to track its own 3D position in real time, according to the "learned" route.

Using mobile robots, LASMEA researchers have shown that the Vipa can automatically and reliably reproduce a path with a precision of less than a decimeter. Developed by Ligier, which also designed the chassis and body, its electric motor runs on four lead storage batteries of 8.5 kWh each, offering eight hours of autonomy at speeds deliberately limited to 20 km/h. Apojee, which created the architecture of the electrical and IT system, developed the Vipa's safety device based on "a triple protective barrier using sensors," explains Jean-Denys Canal, the firm's managing director. In addition to rubber bumpers and ultrasound devices to stop the vehicle in an emergency, a laser rangefinder at the front constantly scans the road ahead at a 25-meter distance, enabling the Vipa to stop or adjust its speed to stationary or moving obstacles.

## TOWARD MASS PRODUCTION

A consortium with financial backing of €4 million will now be in charge of producing this car for a wide market. Composed of the LASMEA, Ligier, and Apojee, the consortium was set up in 2009 for three years. Half of its funding comes from the Clermont urban area, the Auvergne regional council, and the European Regional Development Fund (FEDER). The Vipa shown at the 2010 Paris Motor Show is the first of a fleet of a dozen to be manufactured by Ligier in early 2011. Intended for show, they could soon be followed by mass-produced vehicles if the commercial launch is a success.

Meanwhile, the LASMEA will soon be equipped with a new, smaller prototype with the same functions. Called Vipalab, it will be used to test new video equipment that LASMEA researchers plan to develop and integrate in the Vipa. One of these promising features is the ability to drive around an obstacle or stop at a simple hand signal to pick up a passenger.

01. Laboratoire des sciences et matériaux pour l'électronique et d'automatique (CNRS / Université Blaise-Pascal).
02. Programme de recherche et d'innovation dans les transports terrestres.

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Environment

# The Water Cycle Runs Off Course

BY FUI LEE LUK

**→ Life on Earth relies on the water cycle, whereby $H_2O$ from evapotranspiration (EVT)** returns to the planet's surface as precipitation. The recycling of water does not, however, mean that EVT levels are stable. Scientists from the LSCE,[1] a laboratory specialized in environmental research, have taken part in a global study[2] exposing a recent decline in EVT.

EVT levels were gauged by merging satellite and meteorological observations with *in situ* data gathered by FLUXNET, a global network that measures $CO_2$, water vapor, and energy exchanges between ecosystems and the atmosphere. The team expected global warming to cause more $H_2O$ to evaporate, bringing up EVT levels. Indeed, EVT rose by around 7.1 mm per decade between the satellite measurements in 1982 and 1997. But to the team's surprise, EVT then fell markedly between 1998 and 2008, by about 8 mm per decade.

**EVAPOTRANSPIRATION** The sum of plant transpiration and evaporation of water from soil and water bodies such as oceans.

Researchers believe this recent drop in EVT can be explained by drier soil making less water available for evaporation. While the dip is more drastic in the Southern Hemisphere—chiefly drought-prone Africa and Australia—what is "even more surprising," remarks Nicolas Viovy of the LSCE, is that a similar pattern is observed in Europe and the US, where the team did not think water availability could become a limiting factor for EVT. Again, global warming may influence this shift: since more vapor can be held by a warmer atmosphere, less moisture remains in the ground.

Further monitoring is needed to verify whether this trend is part of a mere variation or a longer-term tendency. "We will now aim at improving models to reduce subsisting uncertainty, and also to understand the retroactions of this type of phenomenon on climate," Viovy adds. If the wane in EVT is here to stay, already fragile ecosystems face an ongoing decline in precipitation, bringing greater water stress on vegetation and hence lower terrestrial productivity, less carbon absorption, and more temperature fluctuations.

01. Laboratoire sciences du climat et de l'environnement (CNRS / CEA / Université de Versailles Saint-Quentin-en-Yvelines).
02. M. Jung et al., "Recent decline in the global land evapotranspiration trend due to limited moisture supply," *Nature*, 2010. 467: 951-4.
1049090.


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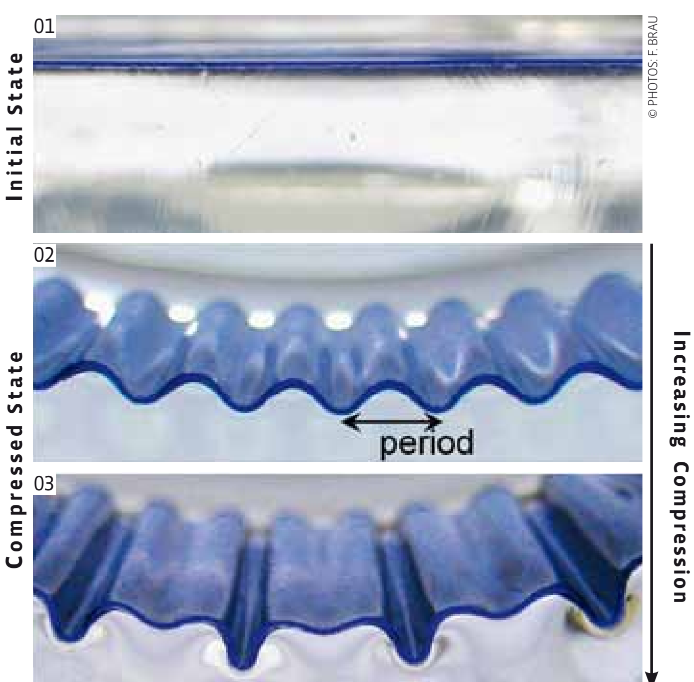


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→ 01 A thin film (in blue) is bound to a soft elastomeric substrate. 02 A moderate horizontal compression of the sample yields a sinusoidal folded surface. 03 Further compression leads to altered shallow and deep folds.

## WRINKLES UNDER STRESS

BY ELIAS AWAD

**→ From the small crevices on our skin to the large mountain ridges on the Earth's surface,** all wrinkles result from a similar process: the compression of a rigid membrane.

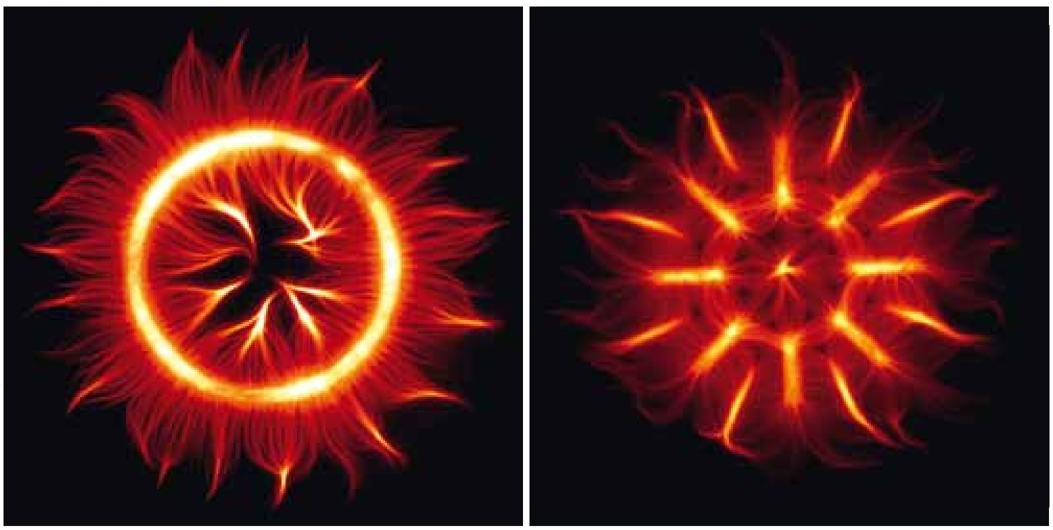
**PERIOD** The period of a sinusoid is the distance between two peaks of the curve.

Similarly, when an apple dries up, its skin shrinks to adapt to the smaller volume, hence the wrinkling. Physics labs study this wrinkling process with thin elastic membranes placed on soft, thick substrates, mimicking the skin and flesh. Recent work on such a model by a Franco-Belgian research team partly unveiled the physical mechanisms that determine how this type of material reacts to compression.[1]

"When undergoing compression, a membrane resting on a soft substrate begins to form a regular pattern of sinusoidal wrinkles, with an up-down symmetry," explains Arezki Boudaoud,[2] who co-headed the study. The team wanted to investigate what happens when such material is subjected to high compression levels. "Beyond a certain threshold, the wrinkles suddenly lose their symmetric profile above and below the horizontal axis," explains Boudaoud. One ripple dips deeper, while the next becomes shallower. As compression further

Cell Biology New research shows that the spatial organization of actin, key to a cell's shape, is directed by mathematical rules in addition to biochemical reactions.

# Natural **Mathematics**



Self-assembled networks of actin filaments. Filaments interact with one another and reproducibly form specific architectures when nucleation is induced on micropatterns with circle or eight-branch star shapes.

BY MARK REYNOLDS

**In the human body, very little happens by accident: from the color of our eyes to the shape of our skull,** everything is mediated by protein signaling. Hence the assumption that actin—a protein that essentially acts as the skeleton of our cells—takes its various forms through a similar process.

Not so, says Laurent Blanchoin, who with his colleagues from LPCV[1] showed that actin's spatial organization within the cell is governed as much by geometry as it is by biology.[2] This discovery has important implications for nanotechnology. "What it means is that, with the exact same biochemistry, with the right geometry, you can generate the forms that you need [at the nanoscale]," explains Blanchoin.

Actin is a series of filaments, which together take a number of forms within a cell: parallel bundles, tangled stalks, or elegant lattices rising from multiple bases to a common point—not unlike the Eiffel Tower. The form and density of these various combinations help different cells take different shapes—from stars in neurons to rods and cones in the retina.

Blanchoin explains that actin nucleation—its growth and location within a cell—is controlled by protein signaling. It was commonly believed that its shape and density were similarly controlled. To test such theory, the LPCV team designed a micropatterning method that allowed them to grow actin fibers on specific geometric forms—rings and angles—in a solution. They then observed the shapes the actin filaments took as they grew.

All the forms that actin took in solution—whether rigid and densely interwoven or elastic and thinly spread—are very similar to patterns found within living cells. Because the solution did not contain protein signals that could have directed the shape of the actin, the researchers were able to prove that it is the geometry of the actin's environment rather than biological signaling, that determines its form.

Previous research carried out in the US had already shown it was possible to use actin to construct simple nanoscale structures like gold wires. Blanchoin explains that his results and the subsequent mathematical models of actin behavior indicate that it should be possible to precisely build more complex nanoscale structures using actin's predictable growth patterns as a frame.

01. Laboratoire de physiologie cellulaire végétale (CNRS / CEA / INRA / Université Grenoble-I).
02. A.-C. Reymann et al., "Nucleation geometry governs ordered actin networks structures," *Nature Materials*, 2010. 9: 827-32.

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increases, so does the period of the dipping ripples until it becomes twice that of the original sinusoid. And it keeps doubling as compression intensifies.

To explain this behavior, the researchers derived a universal mathematical model that describes the formation of folded patterns induced by mechanical instability. This should help to understand the morphogenesis of a number of living tissues like wrinkled skin, cerebral convolutions, or fingerprints. The model should also make it possible to improve the micro-manufacturing of structures with specific topography, especially in microbiology and optics.

01. F. Brau et al., "Multiple-length-scale elastic instability mimics parametric resonance of nonlinear oscillators," *Nature Physics*, 2010. doi:10.1038/nphys1806.
02. Laboratoire de physique statistique (CNRS / Ecole normale supérieure / Universités Paris-VI and -VII) in France and Laboratoire Interfaces & fluides complexes (Université de Mons) in Belgium.

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Biochemistry

# New Hope in Fighting Depression

**BY** ELAINE COBBE


→ **Chronic pain sufferers often develop depressive disorders.** This is why scientists are keeping a close eye on new results that suggest a recently-discovered molecule may be effective in treating both pain and depression—with fewer side effects than current treatments.

Catherine Rougeot and her team at the Institut Pasteur in Paris,[1] in cooperation with neuropsychopharmacology specialists from ETAP,[2] first discovered the molecule sialorphin in rats. Given its strong analgesic capacity, the team tried to locate the equivalent molecule in humans and identified it as opiorphin.

Rougeot describes human opiorphin as a "regulator of regulators," involved in the enkephalin neurotransmission pathway. Enkephalins suppress the transmission of pain messages, and opiorphin seems to strengthen the action of enkephalins, thus increasing their pain-killing effectiveness. A series of tests on laboratory rats showed that opiorphin also influenced emotional states, thus inducing antidepressant-like effects.[3]

Those tests demonstrated that, for the same doses, opiorphin's analgesic potency is comparable to morphine, but without the known side effects such as induced tolerance and strong addiction, thus making it particularly interesting in long-term pain management. Nor does it produce many of the side effects often associated with antidepressants, which can include sedation or hyperactivity.

Rougeot stresses that the tests are at an early stage and clinical trials on humans are still a long way off. "The next step is to carry out further toxicity tests on rats." Researchers place great hopes in this new molecule that could prove as effective as morphine and be of value in the very specific field of combined anti-depression treatment and pain relief.

01. Biochimie structurale et cellulaire (CNRS / Institut Pasteur).
02. Ethologie appliquée - Technopôle de Nancy-Brabois, Vandoeuvre-lès-Nancy.
03. H. Javelot et al., "Human Opiorphin is a naturally occurring antidepressant acting selectively on enkephalin-dependent delta-opioid pathways," *Journal of Physiology and Pharmacology*, 2010. 61: 355-62.

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Astronomy

# *A Small Bang*

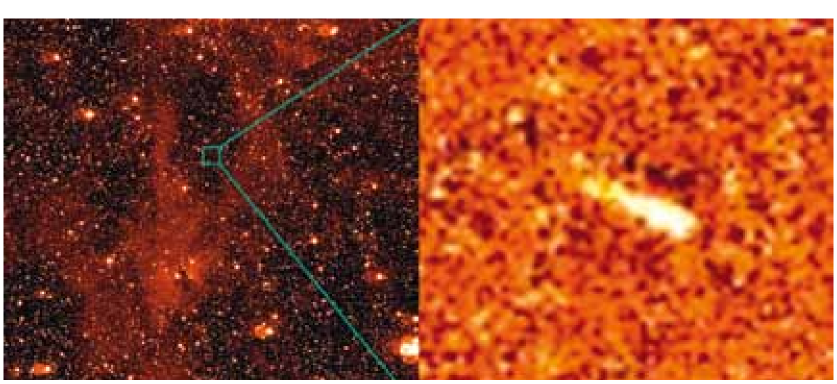
**BY** TOM RIDGWAY

→ **In February 2009, a trail of debris appeared in the asteroid belt between Mars and Jupiter.** It was initially thought to be a comet and consequently named P/2010 A2 (comets' names begin with P/). Yet closer study by a European team[1] over the following months revealed the trail to be the result of a collision between an asteroid and a small rock a few meters in diameter.[2]

While collisions between asteroids are relatively frequent—in terms of space-time—the sheer size of the asteroid belt means that they are rarely seen until long after they have occurred. However, the 2009 collision was remarkable in that it allowed researchers to study a recent event, as if paleontologists had unearthed a "fresh" dinosaur body.

"To interpret the trail as the result of a collision, it was essential to understand its shape and evolution," says Philippe Lamy from the LAM in Marseille. This meant using a variety of observation tools. "Given the fact that the Earth's orbit and that of the asteroid are practically in the same plane," explains Lamy, "it wasn't possible to observe the trail of debris in all its detail from the Earth or from the Hubble Space Telescope, which orbits the Earth." So the researchers turned to the OSIRIS camera aboard the European Space Agency's "comet-chasing" probe, Rosetta. The resulting high-resolution images taken beyond Mars' orbit were then combined with later data collected by Hubble and ground-based telescopes to reconstruct the trail's evolution.

The simulation revealed that the collision took place between February 1 and 20, 2009, and that the pieces of debris measured at least 1 millimeter on average. "It has given us new insight into asteroid debris trails," says Lamy, "and beyond that, a snapshot of what has been going on for millions of years in the Solar System."



→ The colliding asteroid P/2010 A2 as seen by Rosetta.

01. Including researchers from the Laboratoire d'astrophysique de Marseille (LAM) (CNRS / Université de Provence) and the Laboratoire d'études spatiales et d'instrumentation en astrophysique (Observatoire de Paris / CNRS /Universités Paris-VI and Paris-VII).
02. C. Snodgrass et al., "A collision in 2009 as the origin of the debris trail of asteroid P/2010 A2,"*Nature*, 2010. 467: 814-6.

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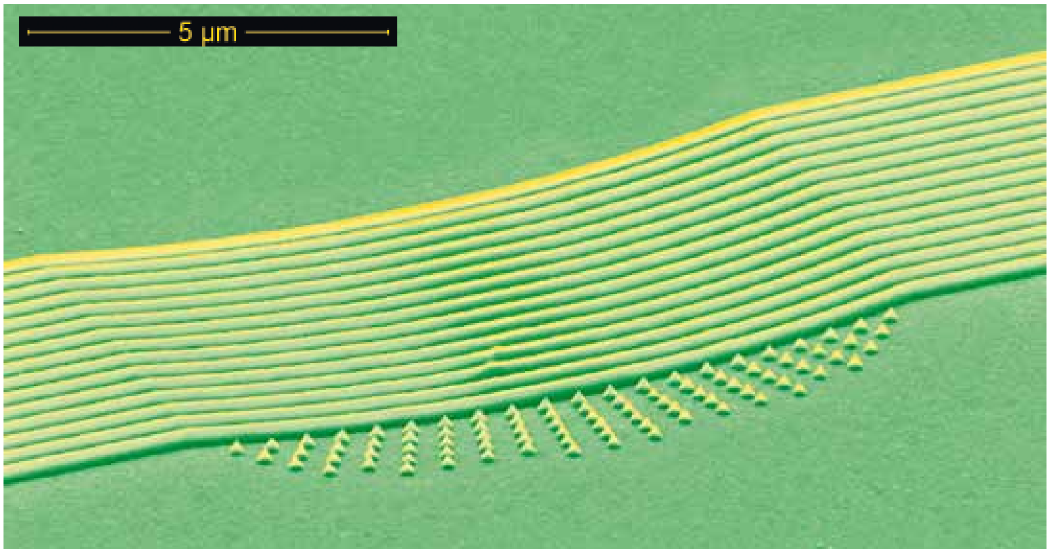
Engineering Scientists are taking a keen interest in the controlled generation of surface plasmons, due to their many potential applications.

# Towards Controlling Surface Plasmons

**BY** SEBASTIÁN ESCALÓN

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→ Electron microscopy image of plots of titanium dioxide nanoparticles curving the trajectory of surface plasmons on a gold surface.

**Who will finally succeed in taming surface plasmons,** the odd electromagnetic waves that propagate along the surface of metals? Produced when a beam of light hits a properly patterned metal surface for instance, plasmons behave both as photons and electrons. They are the subject of much research, as their properties are likely to produce a variety of applications. But to make this possible, they first need to be produced and controlled. Two recent studies involving CNRS teams have achieved significant progress in the field.

The reason why so much effort is being devoted to surface plasmons is that they present a fundamental advantage over light. Guiding light requires relatively bulky optical waveguides or fibers. Yet using surface plasmons, the energy contained in a beam of light can be confined on a metal surface, within a minute space much smaller than the wavelength of the light beam itself. As a result, surface plasmons could be used to transmit information at a far higher frequency than that of an electric current.

"Plasmons could soon make the dream of combining electronics and optics in the same circuit come true," says Stefan Enoch, researcher at the Institut Fresnel.[1] Many other technologies could benefit from plasmon research, such as photovoltaic cells, chemical compound sensors, or near-field microscopy.

## TWO MAJOR DISCOVERIES

A first team,[2] led by Raffaele Colombelli from the IEF[3] has made great headway by creating an ultra-compact plasmon source of very small size (1 millimeter long by 20 micrometers wide).[4] This ultra-compact system is made up of three components: a semiconductor laser whose light travels through a material that amplifies its intensity; a device called a "coupler" that injects the plasmons into the waveguide; and the waveguide itself. "Until now, we had to rely on a bulky and impractical system to generate surface plasmons and inject them into the metal waveguide designed to carry them," explains Colombelli.

Although more fundamental, the work carried out by Enoch's team, together with the Institut de Ciències Fotòniques in Barcelona, also holds great promise.[5] "We have obtained the first experimental proof that plasmon propagation can be controlled using metamaterials," Enoch explains. The metamaterial developed by the team is made up of a gold surface studded with an array of titanium dioxide nanoparticles. Plasmons normally travel along a surface in a straight line. However, these nanoparticles force them to move along a curved path. This means that the plasmons can travel around an obstacle placed between the source and the observer. And this obstacle becomes completely invisible to the observer on the receiving end of the plasmons. This remarkable feat ushers plasmons into the field of transformation optics, a method that makes it possible to control the propagation of light. We are bound to hear a lot more about these very unusual waves in the years to come.


**METAMATERIAL**
A metamaterial is an artificial composite material that has electromagnetic properties unknown in natural materials.

01. CNRS / Université de Provence / Université Paul-Cézanne / Centrale Marseille.
02. In collaboration with the Institut Langevin (CNRS / ESPCI ParisTech / UPMC / Université Paris Diderot), the Laboratoire de photonique et de nanostructures (CNRS) and the laboratoire Matériaux et phénomènes quantiques (CNRS / Université Paris Diderot).
03. Institut d'électronique fondamentale (CNRS / Université Paris-Sud-XI).
04. A. Babuty et al., "Semiconductor Surface Plasmon Sources," *Phys. Rev. Lett.,* 2010. 104: 226806.
05. J. Renger et al., "Hidden progress: broadband plasmonic invisibility," *Optics Express,* 2010. 18: 15757-68.

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Geology Geophysicists have recently discovered the presence of two layers of partially molten rocks inside the Earth's mantle.

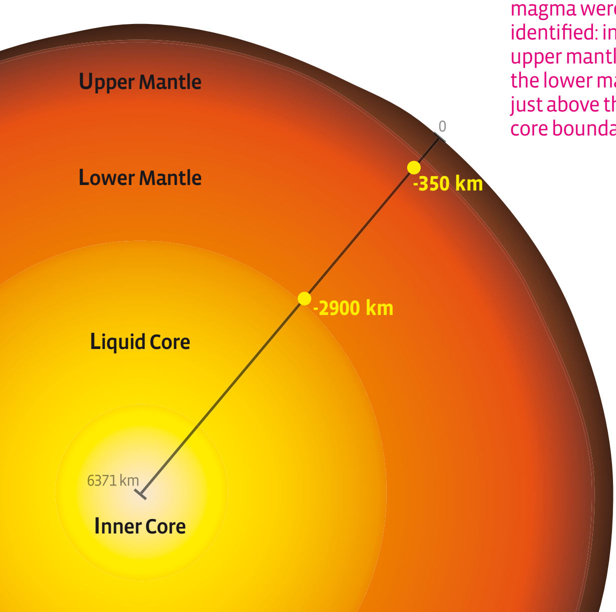
# **Unearthing** Oceans of Magma

**BY** CLÉMENTINE WALLACE

**The Earth is made up of several layers, which geophysicists have been able to delimit** using seismic tomography—the geological equivalent of a medical scanner. This technique consists in recording the velocity of seismic waves as they spread through the Earth's structures. "For example, higher temperatures generally reduce the speed of seismic waves," explains geologist Eric Debayle, researcher at the LST[1] in Lyon. "And these seismic velocities can also provide information on the composition and the relative liquid or solid state at specific locations."


Making our way down to the center of the Earth, our first stop is 400 km below the surface. We are inside the Earth's upper mantle, right above what is known as the mantle transition zone. At this depth, researchers have at times identified the presence of isolated areas where seismic waves are slowed down.

Now, new findings[2] by an international collaboration including researchers from Utrecht University (Netherlands), the LST, and the EOST[3] suggest these pockets could actually be part of a previously unnoticed layer of magma around the globe, composed of rocks in solid or liquid state—depending on their fusion temperature.




→ Two layers of magma were newly identified: in the upper mantle, and in the lower mantle, just above the liquid core boundary.

For this study, the researchers recorded seismic waves traveling vertically under 152 stations around the globe. They were able to place this intermittent low-velocity layer some 350 km under 89 of the stations. "Since our method is not sensitive enough to detect changes in structures that are less than 30 km thick, we believe that our data actually images the thickest parts of a continuous global layer that shows steep lateral variations in thickness," says Debayle, describing a layer that, in some areas, could be as thick as 100 km.

## DEEPER MYSTERIES

Traveling deeper inside the Earth, an important boundary lies 2900 km deep, where the mantle meets the core. Right above this boundary, researchers have suspected the presence of partially molten rocks, forming a sort of magma ocean.

About 15 years ago, seismologists had identified the presence of an abrupt reduction in seismic wave speeds (10 to 30%) in several locations inside the lower mantle, just above the core-mantle boundary. They named these zones the Ultra Low Velocity Zones (ULVZs). Several hypotheses were put forward to explain ULVZs. One, in particular, suggested that some of the mantle's rocks inside that zone are molten, while others, whose points of fusion are higher, remain solid.

To test this hypothesis, a team of mineral physicists from the IMPMC,[4] a mineralogy institute in Paris, carried out laboratory experiments on a rock called peridotite, which is a good proxy for the mantle's mineral composition. "Previous studies used rocks that corresponded to one or the other components of the mantle, but the mantle is a complex structure," explains Guillaume Fiquet, from the IMPMC. "Peridotite, when subjected to those lower mantle pressures, is transformed into an assemblage of specific minerals or phases, typical of what we find in the lower mantle."

As described in their study,[5] the team used diamond anvil cells and infrared laser beams to recreate the pressure and temperature conditions found at such depths. Using X-ray diffraction at the European Synchrotron Radiation Facility, they were able to determine which mineral phases melt first. "We established, without extrapolation, the fusion curves of the deep Earth mantle," says Fiquet. "Our results show that at such pressures and temperature, we could have a layer of partially molten rocks lying at the base of the mantle, and whose vertical extension could possibly reach 50 km," he adds. "This more or less coincides with the ULVZ seismic observations."

This layer, the authors stipulate, could correspond to the relics of the early magmatic ocean that probably existed within the Earth when it was formed, about 4.5 billion years ago.

01. Laboratoire de sciences de la terre (Université de Lyon-I / CNRS-INSU / Ecole Normale Supérieure de Lyon).
02. B. Tauzin et al., "Seismic evidence for a global low-velocity layer within the Earth's upper mantle," *Nature Geoscience*, 2010. 3: 718-21.
03. Ecole et observatoire des sciences de la Terre (CNRS / Institut de physique du globe de Strasbourg / Université de Strasbourg).
04. Institut de minéralogie et de physique des milieux condensés (CNRS / UPMC / Université Paris Diderot / Institut de Physique du Globe / IRD).
05. G. Fiquet et al., "Melting of Peridotite to 140 Gigapascals," *Science*, 2010. 329: 1516-8.

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# Tracking the Black Death

BY CLÉMENTINE WALLACE

**→ Researchers have reconstructed the evolutionary history of plague—the pandemic that eradicated** over half of Europe's population during the 14th century.

"To understand where a disease originates from, how it propagates, and at what speed, a good variety of samples are needed. We received over 300 conserved isolates of *Y. pestis*—the bacterium causing plague—from various countries," explains evolutionist Thierry Wirth, researcher from the OSEB laboratory[1] at the French Natural History Museum. By analyzing and comparing the samples' genomes, his team located the molecular origins of the disease in China, at least 2600 years ago.[2]

The authors used a technique called "Denaturing High Performance Liquid Chromatography" to screen DNA samples for single-nucleotide polymorphisms—DNA sequence variations that occur when a single nucleotide in a gene differs between strains. "The genetic information is quite homogenous despite the variety of strains, so visualizing punctual mutations was relatively easy," says Wirth. "When a population divides into two groups following different migration routes, each group carries common ancestor mutations to which are added new mutations of its own."

Biocomputing algorithms were used to calculate the mutation rate and determine how the disease spread over time. The researchers traced the successive epidemics that ravaged Europe and Africa over 600 years ago. "The disease was probably carried by rats, which are a natural reservoir for *Y. pestis*," notes Wirth. "These rodents travelled in merchant caravans along the Silk Road and in Chinese explorers' vessels heading West."

The detailed molecular findings also show that during the 19th century, after spreading from China to India and Hawaii, the plague finally reached the American ports of San Francisco and Los Angeles, before disseminating inland.

This study will serve as a paradigm to trace the origins and understand the evolution of other major diseases like anthrax and tuberculosis.

01. Origine, structure et evolution de la biodiversité (CNRS / MNHN).
02. G. Morelli et al., "*Yersinia pestis* genome sequencing identifies patterns of global phylogenetic diversity," *Nature Genetics*, 2010. 42:1140-3.




→ According to a Chinese legend, the hero's magic fan reduces plague-disseminating umbrellas to dust.

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Chemistry

# Man-made Metalloenzyme


BY MARK REYNOLDS

**→ There is no better producer of chemical catalysts than nature.** Enzymes perfected over millions of years of evolution can perform chemical reactions both precisely and very efficiently. Chemists hoping to mimic nature's skill have largely been confined to trial and error, but no longer. Researchers from the LCBM[1] and the IBS[2] in Grenoble have now created an artificial metalloenzyme and observed it activate dioxygen using X-ray crystallography.[3]

The researchers attached an iron complex containing an aromatic compound to a protein that normally transports nickel in common bacteria. The resulting metalloenzyme was crystallized, and its dioxygen activation followed by X-ray crystallography. By slowing down the reaction, Stéphane Ménage, from the LCBM, and his collaborators from the IBS, managed to take images of the artificial enzyme before, during, and after it performed its enzymatic reaction. "For the first time, we were able to follow the reaction step by step and in real time," comments Ménage.

This unique observation of an enzymatic synthetic active site paves the way for engineering enzymes that can efficiently produce custom-made molecules—a breakthrough that may revolutionize the way we produce medicines, clean fuels, or chemical components.

"Natural enzymes are designed to do one thing perfectly. With artificial metalloenzymes, we will be able to create a lot of different reactions, and therefore new products," concludes Ménage.

**METALLOENZYME**
A metalloenzyme is an enzymatic protein that, in the active state, contains one or more metal ions which are essential for its biological function.

01. Laboratoire de chimie et biologie des métaux (CNRS / CEA / Université Grenoble-I).
02. Institut de biologie structurale (CNRS / CEA / Université Grenoble-I).
03. C. Cavazza et al., "Crystallographic snapshots of the reaction of an aromatic C-H with $O_2$ catalysed by a protein-bound iron complex," *Nature Chemistry*, 2010. 2: 1069-76.

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Biology Whether it be in the area of adjuvant therapies to boost standard anti-cancer treatments or limit recurrence rates, in the development of more personalized medical approaches, or in finding ways to alleviate side effects, oncology research is constantly breaking new ground. **BY** CLÉMENTINE WALLACE

# Improving Cancer **Treatments**

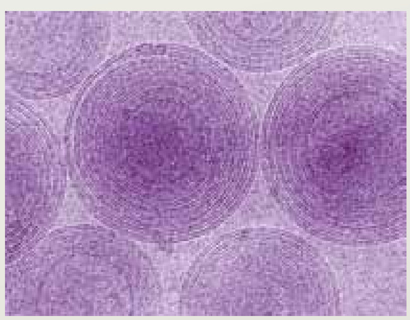

## *Synthetic Vectors Boost Immune Response*

**A recent study[1] suggests a possible new therapeutic approach could boost current treatments to fight hepatocellular carcinoma (HCC),** a severe form of liver cancer with high recurrence rates. HCC has a very poor prognosis, with recurrence rates reaching 65% at five years, and strategies to treat recurrences are not effective.

Researchers have recently started to explore immunotherapy approaches—where a patient's immune responses against tumors are stimulated by injecting tumor-specific antigens. "Until now clinical trials failed, mostly because the vectors used were viruses," says CNRS researcher Bruno Pitard.[2] "Virus vectors come with their own sets of antigens that also stimulate the immune system, thus diluting the anti-tumor response.

But Pitard's team discovered "nanospheres," a class of synthetic non-viral vectors that are not recognized by the immune system. "Nanospheres are a very simple molecular taxi, easy to produce industrially," says Pitard. Inside these nanospheres, the researchers inserted a tumor antigen expressed in 70% of HCC tumor cells, called alpha-fetoprotein (AFP). "Because nanospheres do not trigger an immune response, the immune system is entirely dedicated to eliminating the antigen they carry."

The team administered to newborn mice a chemical known to trigger the appearance of HCC tumor nodules expressing AFP. Before the nodules were visible, the scientists injected AFP-loaded nanospheres inside the mice's muscles. "We boosted the immune system's sensitivity to AFP so that when the tumor nodules expressing the antigen appeared, the immune response would rise quickly," says Pitard. This treatment led to a 65% reduction in tumor size as compared to non-treated animals.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→ AFP-loaded nanospheres.

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02. Institut du Thorax (CNRS / Inserm / Université de Nantes).

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## *Immune Defenses*

**Researchers led by Sébastien Maury, David Klatzmann, and José Cohen, from the I3 laboratory,[1] have tested a new therapy** that consists in muffling one set of lymphocytes during the immune response to a tumor.[2]

When the immune system reacts to a tumor, two types of lymphocytes are mobilized: effector T cells and regulatory T cells. Effector T cells specifically recognize "abnormal" components of tumor cells to destroy them; regulatory T cells, whose main job is to protect our own tissue from immune attack, recognize the "normal" components of the cancer cells and thus protect the tumor.

"From an immunological standpoint, tumor cells are over 99% normal. So the body engages in protecting the tumor during the immune attack. It's a mixed message that's sent: protect and attack," says David Klatzmann, director of the I3 laboratory. He notes that when the tumor emerges, protective regulatory T cells are mobilized much more rapidly than destructive effector T cells, thus preventing tumor destruction.

"Tests have shown that if regulatory T cells are absent during this first encounter between the immune system and a tumor, the destruction takes place efficiently," notes Klatzmann. "So the ideal

# Personalized Analysis on Chip

**A simple, fast and highly specific approach has been developed to detect and analyze tumor cells** in microbiopsies of patients' lymph nodes.

A team of researchers led by Jean-Louis Viovy, from the MMBM laboratory[1] at the Institut Curie in Paris have developed a technique named Ephesia. It is composed of a "cell screen" consisting of a network of pillars made of magnetic microbeads bearing antibodies directed against tumor cells' surface proteins.[2] Tumor cells, if present, are thus "caught" by the antibodies acting as hooks. This system belongs to a new generation of instruments called "lab on a chip," applying technologies inspired from electronic "chips" to biochemical analysis.

Viovy's team compared their system to flow cytometry on various types of samples: blood, pleural effusion, and fine needle aspirates from healthy donors and patients with leukemia and lymphoma. "We obtained 100% agreement on the diagnosis, from a number of cells ten to one hundred times smaller," explains Viovy.

This new technique should improve the reliability of microbiopsies, and constitute an additional step towards more personalized medical treatment, in which each patient is given a drug targeting the molecular characteristics of his or her own tumor.

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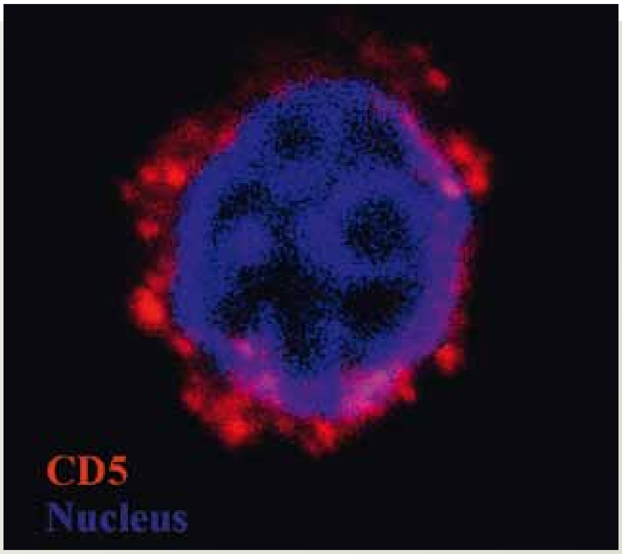
02. A.-E. Saliba et al., "Microfluidic Sorting and High Content Multimodal Typing of Cancer Cells in Self-Assembled Magnetic Arrays," *PNAS*, 2010. 107: 14524-29.






→ A lymphocyte B cell from a patient with a mantle lymphoma, trapped and imaged in Ephesia lab-on-chip.

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# Re-engineered

approach would be to administer a drug that would control regulatory T cells. Unfortunately, this drug doesn't exist yet."

Researchers therefore imagined a protocol to specifically destroy regulatory T cells. They take a large blood sample from a patient and treat it to destroy all regulatory T cells. The patient is then administered a lymphocyte-depleting treatment before the regulatory T cell depleted blood is re-injected. "This way, you create an environment where the individual has very few regulatory T cells, which should allow the effector T cells to be more efficient at attacking the tumor cells."

The team tested this approach in adults with leukemia relapse after bone marrow transplantation. "Four out of four patients who received the full treatment responded, and two are today in long-term remission," Klatzmann concludes.

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02. S. Maury et al., "CD4+CD25+ regulatory T cell depletion improves the graft-versus-tumor effect of donor lymphocytes after allogeneic hematopoietic stem cell transplantation," *Sci Transl Med*, 2010. 2: 41ra52.

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# Explaining Cisplatin's Notorious Side Effects

**When infused with cisplatin, a platinum-based chemotherapy drug, 30 to 50% of patients experience** quasi-instantaneous neurological side effects such as shaking, asthenia, hearing defects, etc. "Many of them find it unbearable and ask to change treatments, even if the medication is working," says lead researcher Laurent Counillon, from the IPMC.[1]

Counillon's team, who studies the biology of cell transporters and channels, investigated the effects of cisplatin on cell membranes.[2] Using scanning electron microscopy and atomic force microscopy on model cell lines, they observed that cisplatin triggers a rapid change in membrane architecture. "This coincides with the rapid side effects observed in patients," notes Counillon.

Using patch clamp and transport measurements, they further observed that the change in architecture is linked to the blockage of certain proteins involved in pressure sensitivity and neuronal excitability. This is a first step towards understanding cisplatin's side effects.

01. Institut de pharmacologie moléculaire et cellulaire (CNRS / Université de Nice / Sophia Antipolis).
02. N. Milosavljevic, "Nongenomic Effects of Cisplatin: Acute Inhibition of Mechanosensitive Transporters and Channels Q2 without Actin Remodeling," *Cancer Research*, 2010. 146: 2219-27.

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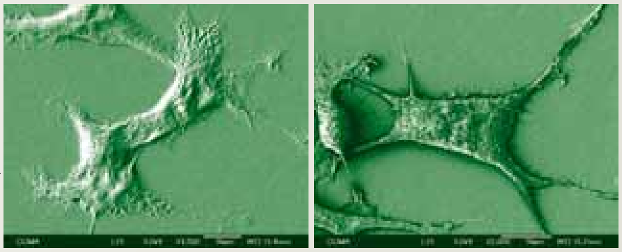
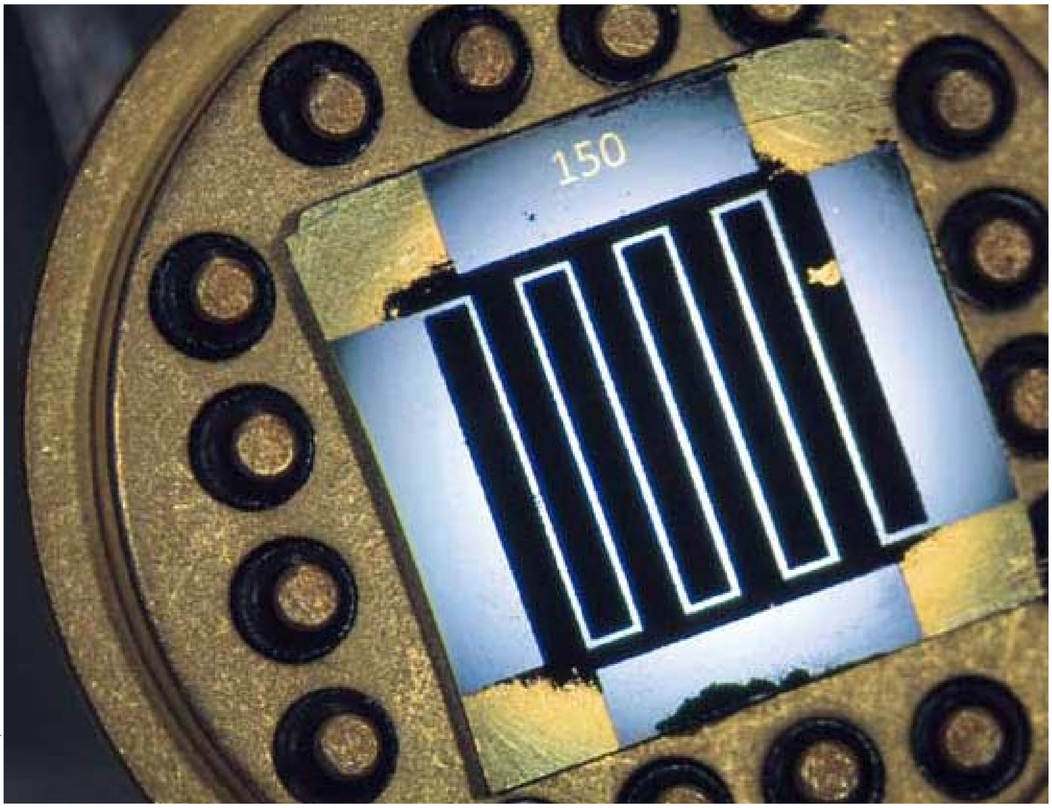


→ Electron microscopy showing the difference in membrane morphology between a control fibroblast (left) and a fibroblast treated for 10 minutes with Cisplatin (60µg/ml).







Electronics A Franco-American team has developed a new type of capacitor that pushes back the boundaries of miniaturization for energy storage systems.

# **An Ultra-Powerful** Micro-Supercapacitor

**BY** SEBASTIÁN ESCALÓN

**Lightweight and compact portable communication devices is what today's microelectronics researchers are aiming to achieve.** A key challenge in this ongoing revolution is to improve energy storage capacity. In this very competitive field, a Franco-American team of researchers from the LAAS,[1] the CIRIMAT,[2] and Drexel University in Philadelphia (Pennsylvania, US), has reached an impressive milestone. They were able to design a micro-supercapacitor the size of a fingernail with a power density (charge or discharge rate) 4000 times greater than that of the miniature batteries currently on the market.

→ A micro-supercapacitor on a support device (optical microscopy).

**SUPERCAPACITOR** A supercapacitor is a device capable of storing and then releasing electrical energy.

This project, featured in the September 2010 issue of *Nature Nanotechnology*, was commissioned by Airbus, a subsidiary of the European aerospace company EADS. The aircraft manufacturer wanted to equip its planes with sensors to monitor their structural integrity. Airbus expected these sensors to be self-contained—powered by microsystems (transducers) capable of transforming fuselage vibrations or ground/sky temperature variations into electricity. But these energy sources are not continuous, whereas the sensors—working non-stop—require an uninterrupted supply of electrical power. Temperature differences, for example, are only significant during takeoff and landing. To meet this challenge, the researchers created micro-supercapacitors capable of storing the electricity supplied by the transducers during energy-producing flight periods, and delivering it as a constant flow to the sensors—all this at temperatures as low as -50°C.

In principle, the micro-supercapacitor is similar to a classical supercapacitor. It consists of electrodes made of a carbon-based porous material and separated by an ionic liquid. When voltage is applied, the charge accumulates on the electrodes, where it is stored. Reversing the voltage releases the charge, delivering electrical current. The porous material makes it possible to increase the supercapacitor's storage surface and hence its capacity.

## SMALLER AND FASTER

To achieve such extreme power density, the LAAS micro-supercapacitor exhibits several improvements. First, it is built in a planar way on a silicon substrate, instead of the conventional wound or stack technologies. The electrodes' current collectors, which are made of gold, are only 100 microns apart. "This reduces the distance traveled by the ions in the liquid, allowing the supercapacitor to charge and discharge more rapidly," explains LAAS researcher Magali Brunet. Furthermore, the electrodes were coated with a new material developed at Drexel University, instead of the usual activated carbon. This new material contains nanoparticles made of graphitic layers arranged in an onion-like structure. Such nanoparticles are easily accessible to the ions, making it possible to drastically reduce the time required for accumulating energy. The result is a micro-supercapacitor that charges in less than one millisecond, well below today's commercial devices, which require about one second. One more year of research will be needed to produce a complete and functional prototype.

01. Laboratoire d'Analyse et d'architecture des systèmes (CNRS).
02. Centre interuniversitaire de recherche et d'ingénierie des matériaux (CNRS / INP Toulouse / Université Paul-Sabatier).

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Paleoentomology Last summer, a French research team set off to a small island beyond the Arctic Circle to search for the fossilized remains of the world's first insects.

# Tracking the World's **First Insects**

**BY** MARIE LESCROART

**When hunting for fossils, rifles can come in handy.** "There are polar bears in the region," explains Romain Garrouste, a paleoentomologist and entomologist at the French National Museum of Natural History.[1] One of five scientists who traveled to Spitsbergen—part of the Norwegian archipelago of Svalbard, beyond the Arctic Circle—last summer, Garrouste recalls their search for the remains of the world's earliest insect species. "We were based at Pyramiden, a Russian coal-mining concession abandoned in 1998. Every day we would walk some 25 kilometers exploring the surrounding area. We also rummaged through the coal tips. They are made of carboniferous rocks that have already been brought up to the surface, and are a real treasure trove for what we are looking for."

"The major advantage of this site is that you can find continuous outcrops of every geological formation in a coastal environment, all the way from the Lower Devonian, dating back 400 million years, up to the Mississippian, a sub-period of the Lower Carboniferous going back some 340 million years," explains paleoentomologist and project leader André Nel. "These are key periods and environments for understanding how certain crustaceans adapted to life out of the water before evolving into winged insects." Although fossils of a wide variety of insects have already been found in more recent geological formations, there are virtually no traces of such organisms in the Devonian and Carboniferous, a gap that researchers are keen to fill.

Finding the insects, especially in the very dark rocks of the Mississippian, will require detailed examination of the material. However, the 400 kilograms of samples collected look promising.

## ROCK-SOLID EVIDENCE

"In the Lower Carboniferous we found very fine-grained clayey rocks, which facilitate the preservation of small anatomical details. What's more, they're rich in plant fossils, and plants are known to attract insects," says Nel. Fossil tree trunks from the Upper Devonian, evidence of one of the world's oldest known forests, were discovered in the Archipelago's Munindalen valley. Many fish fossils from the same period were also found. "These will enable us to date the strata precisely, and reconstruct the environment of the time," Nel explains. The expedition also uncovered slabs of rock showing traces of trilobites, which were marine arthropods from the Devonian. "This discovery considerably increases the volume of known deposits of such fossils," Garrouste points out. Enthusiastic about these first results, the team plans to return to the site next summer.

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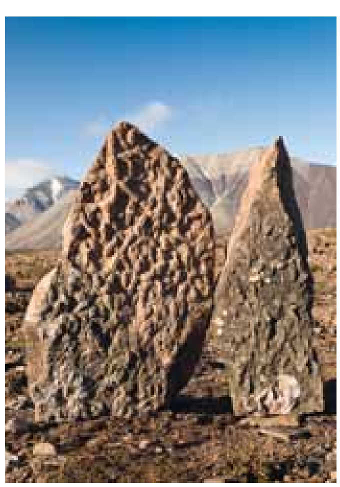
## AMBER IN THE ARCTIC

**It was on their way back, near Svalbard's "capital" Longyearbyen, that the team came across the northernmost amber deposit ever discovered, in a Paleocene[1] fossil site popular with tourists. "It's very interesting, even if we've found only a few droplets for the moment," explains Romain Garrouste. Amber—the fossilized resin of ancient trees—traps and preserves remarkably well the organisms that lived in the forest at the time it was formed. "In the Paleocene, Spitsbergen was at the same latitude as it is today, which meant several months of darkness a year," Garrouste explains. "Yet the region, which enjoyed a warm temperate climate, was covered with lush forests. If plants, insects, or bacteria are trapped in the amber, they could give us information about the Arctic environment during this climatic optimum."**

01. 40-50 million years old.





→ Detail (right) of the rocks (left) where trace fossils (ichnofossils) of marine arthropods from the Upper Devonian were found in the Mimerdalen Valley.

CNRS 2010 Gold Medal A world-renowned chemist and specialist in porous solids gets France's top scientific prize.

# Gérard Férey, Materials Architect

**BY** ÉMILIE BADIN

**ORGANIC** chemistry covers carbon, hydrogen, oxygen, nitrogen, phosphorus, and sulfur. Chemistry involving other elements is termed inorganic chemistry.

**"What do I do for a living?" Gérard Férey asks.** "I create organic and inorganic hybrid porous solids—'Swiss cheese' materials with regular pore patterns on the atomic scale. I make the pores as large as possible. Since nature abhors a vacuum, these pores act as traps able to store $CO_2$, for example." Working with his team at the Institut Lavoisier in Versailles,[1] Férey can also predict these materials' structure. "We have filed about a dozen patents," he reports. In recognition of the international impact of his work, and of his long and brilliant career, Férey has been awarded the 2010 CNRS Gold Medal, France's highest distinction in scientific research.

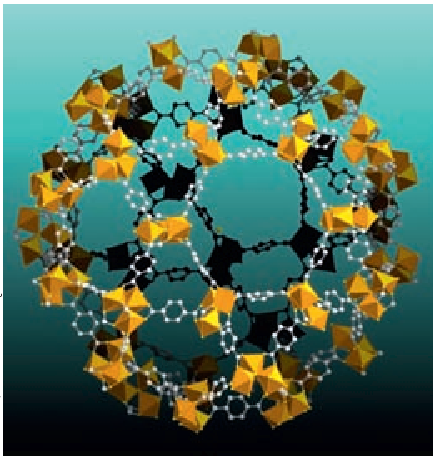
## CHEMISTRY REVEALED

Now 69, Férey became a top-level chemist through a series of twists of fate. At the age of 19, following in his family's footsteps, he became a teacher and founded a secondary school in his native Normandy. But a book by Linus Pauling (American chemist and physicist, 1901-1994) changed everything. "That's him over there," Férey says, pointing to a photo of himself standing alongside the famous scientist. Three years later, in 1963, Férey left the school he had founded to pursue his studies at the University of Caen. "There, two professors—Maurice Bernard and Alfred Deschanvres—made a lasting impression on me and sealed my fate in chemistry."

After completing his thesis, Férey worked as an assistant in the chemistry department of a technological institute in Le Mans (western France). There, he learned the basics of the chemistry of solids, a new discipline focusing on reactions within solids, rather than within solutions as in conventional chemistry.

Determined to unravel the secrets of matter, to understand how its "building blocks" are assembled, Férey studied crystallography, the science of locating atoms in space and observing how they arrange to form solids. Working with Félix Bertaut in Grenoble, he also investigated magnetism and neutron diffraction. His knowledge of these tools later enabled him to become an "architect" of matter.

"I don't like to spend more than ten years on the same





→ Cage-like structure of MIL-101, the porous material developed by the team of Gérard Férey. This material can trap 400 times its weight in gas.

### POROUS SOLIDS: 250 YEARS OF SCIENCE

**It was in 1756 that Swedish scientist Axel Fredrik Crönstedt first discovered porous materials. "He was heating stilbite, a natural mineral, and noticed that bubbles formed on its surface when the material reached 150°C," Férey explains. But it wasn't until 1930, with the work of Linus Pauling, that chemists began to understand the crystalline structure of these strange minerals called zeolites (a Greek term meaning "boiling stone"). In these solids, the atomic structure forms regular pore patterns—or cages—a few angstroms ($10^{-10}$ meter) in diameter. These cages absorb molecules of other substances, like water, which explains the appearance of bubbles during heating. Manufacturers and researchers immediately saw potential applications, especially for gas absorption. But such solids are often costly to manufacture and their cages are too small to store significant quantities. Férey was a pioneer in the development of hybrid porous solids, whose backbone consists of both organic and inorganic elements. This breakthrough made it possible to change the size of the cages without compromising the stability of the material as a whole. The solids thus obtained are non-toxic, biodegradable, and easy to synthesize in large quantities, therefore cheaper to produce. Férey's team has created computer programs for selecting the most stable atomic arrangements. This allowed the development of the famous MIL-101: capable of absorbing 400 times its own volume of $CO_2$, it is currently the material with the highest gas storage capacity.**

© F. PLAS/CNRS PHOTOTHÈQUE

**GÉRARD FÉREY: 5 KEY DATES**

| | |
|---|---|
| 1941 | Born in Bréhal, Normandy (France) |
| 1968 | Doctorate in chemistry from the University of Caen |
| 1996 | Founding of the Institut Lavoisier in Versailles |
| 2005 | Development of MIL-101 |
| 2010 | CNRS Gold Medal recipient |

subject or in the same job," Férey comments. Hence his decision, in 1988, to accept the position of deputy director of the CNRS's chemistry department, "a wonderfully formative, beneficial, and humbling experience. I was in charge of laboratory funding," he explains. "Instead of asking for grants—something I was used to—I was now responsible for their distribution. And to do so in all fairness, I had to understand every branch of chemistry."

At the end of his mission in 1992, Férey went back to research. He tackled a subject that had fascinated him for years: porous solids. He began developing a number of *in situ* spectroscopic methods to supplement the techniques of crystallography to observe in real time the formation of crystals—the building blocks of solids. "I was able to play with them, predict their structure, and explore hundreds of possibilities for synthesizing the desired type of pores," he recalls. Well ahead of his competitors, Férey started to imagine a host of applications for these innovative "Swiss cheese" materials.

## MATERIAL REVOLUTION

In 1996 the president of the newly-founded University of Versailles asked Férey to create a research center devoted to solid state chemistry and physics, which was to become the famous Institut Lavoisier.

It was there in 2005—after 10 years of research—that he and his team developed the famous MIL-101 (Materials of the Institut Lavoisier n°101). This "miracle material" is a hybrid structure with cages four nanometers (4 x $10^{-9}$ meter) in diameter—a vast expanse on the atomic scale—that enable the material to absorb and store 400 times its own volume in gas. The industrial process behind it is protected by a number of patents. "As soon as the results were published, I got a phone call from Nissan, soon followed by other manufacturers," adds Férey. It was ultimately BASF, the largest chemical company in the world, that undertook the manufacturing of MIL-101. The group's pilot factory can now produce one ton per day, and the final production unit could have a daily output of several hundred tons.

MIL-101 has many potential applications from trapping $CO_2$ to encapsulating drugs. "The trials on medicines have been excellent," Férey reports. Now perfected and patented, this revolutionary method can provide the targeted and continuous release of a drug in the bloodstream of mice for two to three weeks, while preserving intact 75 to 100% of the active ingredients injected. Detectable by medical imaging devices, this new type of nanovector can be tracked from the intravenous injection to the target. "This new technology, which *in vivo* tests have shown to be non-toxic, could be used to treat a number of diseases, including juvenile leukemia, breast cancer, and AIDS."

Though Férey officially retired in September 2009, he keeps a busy schedule. A member of the French Académie des Sciences and of France's ethics advisory committee, Férey participates in restructuring France's Chemical Society, a non-profit organization for the promotion of chemistry, and is very active in organizing the International Year of Chemistry to be held in 2011. "Being bored shows a great lack of imagination," he concludes.

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# The Future of Computing Science



Information technology has revolutionized all facets of communications, from the personal computer to the latest and trendiest smart phones. Yet it has also given a radical boost to research, lending scientists enormous amounts of computing power to locate distant galaxies, devise climate models, sequence the human genome, or model our organs. And this is still only the beginning. Research laboratories around the world are busy developing a new Internet that will also connect billions of objects together, inventing powerful data processing technologies, and edging closer to the much-awaited quantum computers. CNRS International Magazine reports on the latest bytes, bits, and qubits that make up the bright future of one of the fastest growing fields in science.

**A SURVEY BY** MATHIEU GROUSSON AND VAHÉ TER MINASSIAN

# The Digital **Revolution**

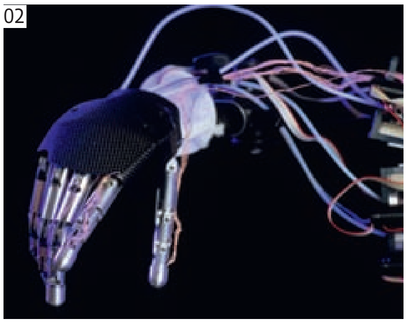
“**It is a fundamental and inevitable revolution,** comparable to the invention of the steam engine, which marked the beginning of the industrial age,[1]” says Gérard Berry, member of the French Academy of Sciences and 2009-2010 Chair of Computing and Digital Sciences at the Collège de France. “Our civilization is going digital. Traditional industries, such as telecommunications, and the dissemination of culture are undergoing drastic changes. Others, such as IT and associated services, are expanding at lightning speed. The Internet has revolutionized communications by eliminating such constraints as distance, time, and volume. In science, computer modeling of any phenomena has become standard.” Twenty-one years after the invention of the World Wide Web—the Internet’s main application—it would be both tedious and futile to attempt to list the countless upheavals generated by recent progress in computing. Yet they are comparatively few considering what the future has in store.

01 The 32 high-definition screens of the Wild platform can display extremely large images. Featured here is one of the most detailed photographs of our galaxy taken to date, 450,000 pixels wide.



## FAST EXPANSION

What will this digital world of the future be like? Difficult to say. New applications shake up the IT industry every week. Nevertheless, specialists predict a spec-



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02 In the future, electronic prostheses such as that of the Cyberhand project will be directly connected to the nervous system.

tacular expansion of the Internet, which will eventually connect not only people, but also objects near and even inside us. “Today, autonomous computers worldwide are 15 to 20 times more numerous than computers that interact with humans,” explains Berry. For example, the latest car models feature more than 80 microprocessors that control everything from braking to combustion. “Currently, these hundreds of billions of processors scattered all around us are not interconnected. Tomorrow, with the advent of this ‘Internet of Things,’ all these machines will communicate with one another to collectively produce new applications. The road itself will communicate with our vehicles to inform on speed limits, warn about traffic jams, or monitor trajectories to avoid accidents.”

Electronic prostheses will be directly connected to our nervous system, and circuits in patients’ bodies will send information on their health to a hospital’s IT system. Ultimately, it is the physicians who will call their patients in case of remotely detected problems, and not the other way around.

Meanwhile, the way we control the machines designed to receive our instructions will also radically change. Touch screens and motion detectors could soon replace keyboards and mice on desktop computers. Furthermore, progress in the semantic Web will provide intelligent search engines able to find information on the Web based on the meaning of a question rather than on its syntax. “Finally, applications such as Twitter and Facebook, as well as the commercial success of smartphones, have changed the core utility of the Web. It is no longer just

© KAKSONEN/INRIA

03

a giant repository of information, but also an interactive space where people communicate with one another,” notes Serge Abiteboul, scientist at the LSV[2] and at INRIA[3] Saclay. “In fact, some people are permanently connected to this space via their cell phones,” adds this specialist in the management of the highly disseminated data and knowledge of the present-day Web—where information is accessed via numerous channels (computers, cell phones, websites, social networks, etc.).

## ADAPTING TO THE FUTURE

Such upheavals require major adjustments. “Despite the Internet’s ability to integrate new technologies and applications—a key factor in its success—this evolution also makes it vulnerable,” explains Serge Fdida, professor at the LIP6[4] and coordinator of the European platform OneLab,[5] a European project tackling the future Internet. “Although its basic principle is not threatened, the Internet was not designed to handle demands like mobility, security, and platform diversity on a large scale: the combination of these factors disrupts its current structure. One must remember that the Internet was initially designed for clearly-identified, trustworthy individuals using static devices. This is certainly not the case today. Furthermore, the system has gradually changed to provide numerous services, leading to the development of ad hoc solutions such as security management, mobility, or content distribution using overlays. Yet most of these solutions are poorly integrated, making it very complex to manage the network and ensure its efficiency.”

A selection of **pictures** from the traveling exhibit **A Digital World** can be viewed on the online version of CNRS Magazine
> http://www2.cnrs.fr/en/384.htm

03 Multipoint touch screens used by the iPARLA team at Labri make it possible to manipulate 3-D objects. 04 The proliferation of mobile terminals requires new network architectures, tested here on high-mobility small objects wirelessly connected to one another.

Four or five years ago, this situation prompted several countries including the US, Germany, and Japan to launch ambitious research programs intended to lay the foundations of a more modular Internet for the future. In Europe, the Fire project aims in particular to set up by 2015 an experimental platform for scientists, industry, and small and medium businesses to securely design, deploy, and test new tools and Web services. The OneLab platform is the first step—a test phase of sorts—for this giant undertaking. This prototype, which has been operational for three years, provides access to a restricted network of 1000 interconnected computers worldwide and to other research platforms. It has already made it possible to test several applications in a variety of fields like Internet content distribution (videos, eBooks, music), and allowed the geolocation of IP addresses (the number used to identify every computer connected to the Internet).

Another challenge brought on by the increasing mobility of users is the limits of radio technologies for mobile IT services. "Second-generation mobile phone networks such as GSM were designed to transmit voice, not to send images or videos, or connect to digital television or the Internet," notes Pierre Duhamel, senior researcher at the L2S.[6] As a result, these networks are often close to saturation in large cities. "Several solutions are being investigated, including network coding—where data is sent over a network made up of other cell phones that may act as transmitters, receivers, relays, or routers. In any event, our research teams are allocating most of their time and effort to meet this challenge," he adds. Indeed, since September 2010, Duhamel is coordinating the first major project dedicated to this innovative field of network cooperation, as part of the Digiteo Advanced Thematic Research Networks[7] in the Paris region.

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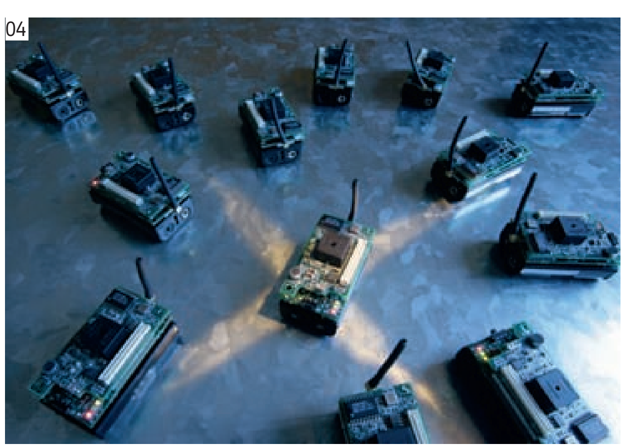

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## SYSTEMS SECURITY

Security—first and foremost that of people—is also a major concern. The plethora of embedded processors performing a wide variety of functions in our environment, without human intervention, already offer appreciable guarantees in terms of responsiveness, availability, and autonomy. Now engineers no longer hesitate to entrust "mission-critical" processors with tasks where human lives are at risk, such as the control of nuclear power plants, aircraft operation, or computer-assisted surgery. Yet "these systems are very expensive to design," says Joseph Sifakis, CNRS researcher at the Verimag laboratory[8] and 2007 winner of the prestigious Turing Award—the IT equivalent of the Nobel prize. "Writing mission-critical software requires specific development methodologies. This type of program is 1000 times more expensive than regular software, and must be submitted to an international certification authority." And while industrial methods for verifying such embedded systems do exist—current methods involve a type of model checking co-invented by Sifakis—they remain ineffective beyond a certain level of complexity. "This prevents the roll-out of several technologies requiring high availability or responsiveness. This includes medical or vehicle-operation software, but also applications relating to the 'Internet of Things' where an additional step is necessary to enable the cooperation of numerous embedded systems in a non-critical Internet environment, i.e., that offers little security."

Faced with these challenges, some scientists, following Sifakis' example, have revisited the theory, hoping to find solutions that would avoid a posteriori verification. "When engineers build a bridge, they use mathematical equations that guarantee that the structure will not collapse," he says. "No such tools are available to programmers: they must build systems first and check operation afterwards. My colleagues and I are trying to identify the theoretical basis that would guarantee that a computer system built from basic components would function properly."

## THE HACKING PROBLEM

Finally, the increase in communicating objects makes IT security breaches a growing challenge. Users are often unaware that their computers have been hacked. Mobile phones, credit cards, game consoles, as well as electronic keys or pay TV sets are all potential areas of study for the cryptographers who design security mechanisms, and the cryptanalysts who try to break them. "Today we are sharing more and more personal information, with little or no control over where it ends up. That is why identity theft and the protection of our private lives are among today's biggest concerns," says Phong Nguyen, researcher at the LIENS laboratory[9] in Paris. Some researchers on the Crypto team at ENS are working on provable security, i.e., ways to improve security guarantees on cryptographic programs. Others are testing the limits of existing security systems by devising the best types of attack against a given cryptographic scheme. This can go as far as trying to recover data from a smart card by observing its electrical consumption or its electromagnetic radiation... For Nguyen, this cat and mouse game will eventually apply to tomorrow's technologies such as quantum computers, although "if such a technology sees the light of day, we will have to transform much of today's cryptography."

**CRYPTOGRAPHY** All relevant techniques that ensure the secure transmission of data.

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01. Gérard Berry, *Pourquoi et comment le monde devient numérique,* coll. "Leçons inaugurales du Collège de France" (Paris: Collège de France / Fayard, 2008).
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04. Laboratoire d'informatique de Paris-6 (CNRS / UPMC).
05. www.onelab.eu
06. Laboratoire des signaux et systèmes (CNRS / Supélec / Université Paris-Sud-XI).
07. Digiteo is a research platform dedicated to science and technology. With a staff of 1200 researchers from six institutes, the platform collaborates on a number of projects.
08. CNRS / Université Joseph-Fourier / Grenoble INP.
09. Laboratoire d'informatique de l'ENS (CNRS / ENS Paris / INRIA).

05 In cryptography, data is frequently condensed (or "hashed"). The resulting condensed file makes it possible to generate a digital signature used to authenticate a message sender.

# Navigating the Datasphere

**"Whether you're a tourist looking for the cheapest airline ticket,** a physicist analyzing data from a particle accelerator, or an employee at a temp agency sifting through applications, you all have something in common," says Amedeo Napoli from the IT specialized LORIA[1] laboratory in Vandœuvre-lès-Nancy. "You are trying to extract specific information from a huge amount of data." In principle, solving this problem couldn't be simpler: prepare the initial data, feed it to a data mining algorithm, and wait for the system to provide the results in the required format. But in a world where that volume of data is increasing relentlessly, extracting pertinent knowledge becomes a seemingly impossible task.

Looking for a holiday flight, hotel, and rental car, all at the lowest possible price, is a good example. As Michel Beaudouin-Lafon, from the LRI in Orsay[2] puts it: "Mathematically, we know that the complexity of this type of problem makes it impossible to find an exact solution in reasonable time, given the massive amount of input data." Therefore, in practice, programmers must find clever ways of obtaining the most accurate result within reasonable time. In fact, the burgeoning field of data mining brings together specialists from fields as different as computer science, of course, but also machine architecture, linguistics, and mathematics. These specialists use artificial intelligence, databases, learning techniques, and statistical methods.

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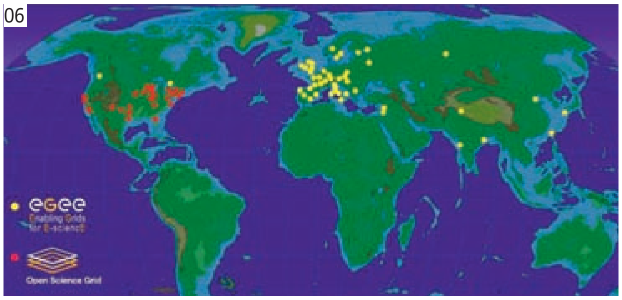


© CERN

06 Location of sites involved in the world's two largest grid infrastructures: Egee in Europe (in yellow) and OSG in the US (in red).

### OPTIMIZING DATA SIFTING

One thing is certain: every field needs to develop efficient methods to avoid being flooded with unusable data often impossible to store. Take the French Midas project,[3] for example. It brings together, among others, CNRS labs and companies that have to deal with complex sets of data, like the telecommunications company Orange or the French energy provider EDF. Its goal is to develop an algorithm able to condense a large amount of data generated in real time so that it can be stored in a limited central memory for later use. "This is typically the type of situation that France Télécom, EDF, or the French national railway company SNCF have to deal with every day," says Pascal Poncelet of the LIRMM,[4] in Montpellier. "For example, a TGV high-speed train records 250 data points per carriage every five minutes to anticipate maintenance operations. But such a huge amount of data is impossible to store. Events must therefore be sorted by order of importance, which changes over time."

Scientists themselves are heavy users of data mining techniques. The LHC, CERN'S giant particle collider in Geneva, is a prime example. When it reaches its full capacity, 40 million proton collisions will occur every second. Yet physicists estimate that just 100 of those will be of interest and will need to be recorded. Such events will have to be selected in real time using specialized algorithms. "These are typically learning algorithms where the computer's performance improves as it processes the new data to be kept or rejected," explains Beaudouin-Lafon, whose laboratory is involved with the LAL,[5] to elaborate ways of analyzing the

## MAKING PICTURES TALK

**If you think sorting family pictures on your home computer is a hassle, imagine sifting through the largest image databases in existence, which contain millions. Luckily, tools like face recognition software are already available. Yet as Matthieu Cord of the LIP6[1] points out, "the success rate is only 50-60%." Typically, a specialized algorithm can perfectly handle so-called "low-level" information: color, contrast, or pixel movement vectors in a video stream, for example. It is somewhat trickier to transform this data into high-level information making it possible to positively identify a particular object or event. This has not prevented the emergence of increasingly powerful applications, like the one developed by Jenny Benois-Pineau's team at the LaBRI,[2] a laboratory near Bordeaux working in conjunction with the French national medical research center (Inserm). "We film Alzheimer patients at home with wearable cameras, and identify behaviors associated with the disease so that doctors can follow a patient's evolution," Benois-Pineau explains.**

**Cord is working on the iTowns project, a digital map of Paris elaborated from photographs, and modeled after Google Street View—but with an accuracy of just one centimeter. "We are developing tools to automatically detect people and cars in order to blur personal data," he explains. "But we are also working on the recognition of a multitude of objects more or less buried in these images, such as street signs, façades, or vegetation, in order to improve advanced navigation."**

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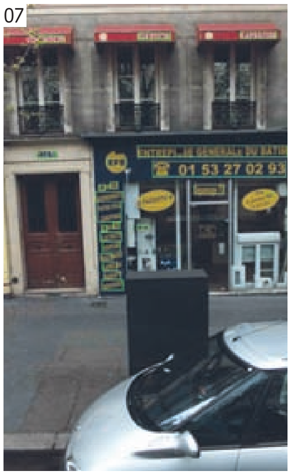

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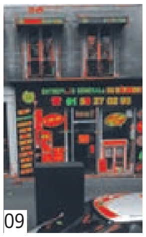

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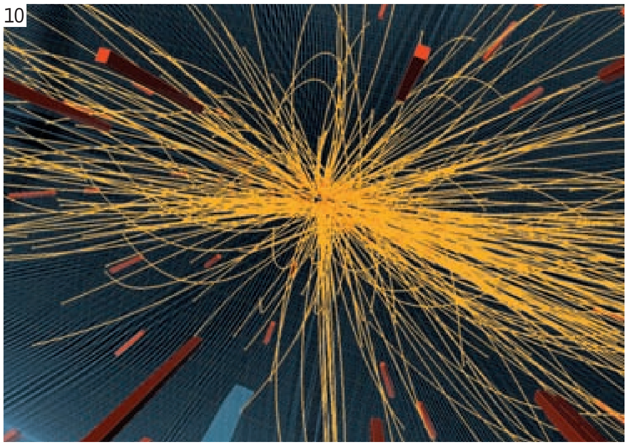
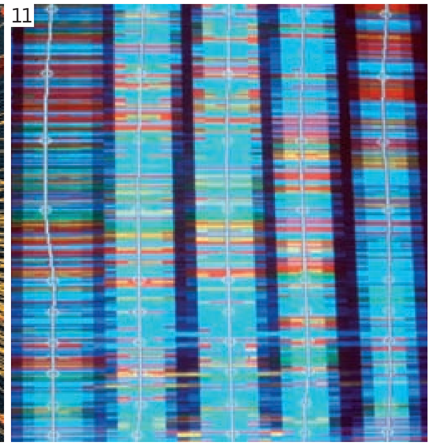
07 08 09 iTowns automatically extracts all types of information contained in an image.





10 11 Some experiments, such as particle collisions (left) or genome sequencing (right), generate large amounts of data that must be sorted and analyzed.
12 Analyzing scientific data sometimes requires extensive computing resources as well as interconnecting machines through networks, as shown here in the Grid 5000 project.

huge amount of data provided by particle accelerators.

## TRIAL AND ERROR

Particle physicists are far from being the only ones to handle large amounts of data. Pascal Poncelet's team, working in collaboration with researchers from the French medical research center Inserm, has developed an algorithm able to single out the genes involved in various types of breast cancer tumors, based on patient data (genetic information, age, weight and size of the tumor, treatment used, and results obtained). "It gives doctors information on the potential evolution of the tumor," the researcher explains.

In a different field, Amedeo Napoli's team has worked with astronomers to develop data mining software applied to information collected in astrophysics. Researchers hope this type of software will reveal particular characteristics or combinations that might have escaped a human operator.

Can data mining work miracles? Not exactly. It is a relatively new field, first explored at the end of the 1980s, and still in full expansion. For Beaudouin-Lafon, "most methods used today are empirical. Parameters are adjusted manually and when something works, it is not really clear why. In many cases, there are no quantitative criteria for judging the quality of information extracted from a database. That is left up to specialists in the field." Napoli adds: "much work still has to be done to handle very large amounts of data. At present, we can manage a few thousand objects with a few hundred attributes. Beyond that, the hardware's physical limits become apparent."

To overcome this obstacle, two complementary approaches are currently used. First, when a single machine does not have enough computing power for a specific task, several computers can be run in parallel. This is the principle of grid computing (*see box*), which LHC has pushed to the limit: it relies on 50,000 PCs located in various research centers worldwide to analyze the 15 millions Gigaoctets of scientific data (the equivalent of a

## GRID COMPUTING

**Grid computers are virtual infrastructures consisting of a set (or clusters) of computers, including home computers, that are geographically remote but working as a network. These systems, which emerged a few years ago to meet the demands of particle physics experiments, enable research scientists and industrialists to have access to extensive computing resources at lower cost, in sectors ranging from engineering to the study of neurodegenerative diseases or astrophysics. The CNRS's Grids Institute (Institut des grilles) managed by Vincent Breton, has been the leading research center in this field in France for the past three years. Along with Grid 5000, a tool specifically dedicated to grid research, it provides scientists and industry with a production grid comprising around 20,000 processors scattered over some 20 centers at CNRS, CEA,[1] and universities. Last September, this already sizeable system reached new heights with the creation of "France Grilles," involving several research organizations and universities. Its purpose is to coordinate the deployment of a nationwide grid infrastructure, which will eventually be integrated into a European grid. For Breton, who heads the program, its objective is clear-cut: "to double resources and users by 2015."**

01. French Atomic Energy and Alternative Energies Commission.

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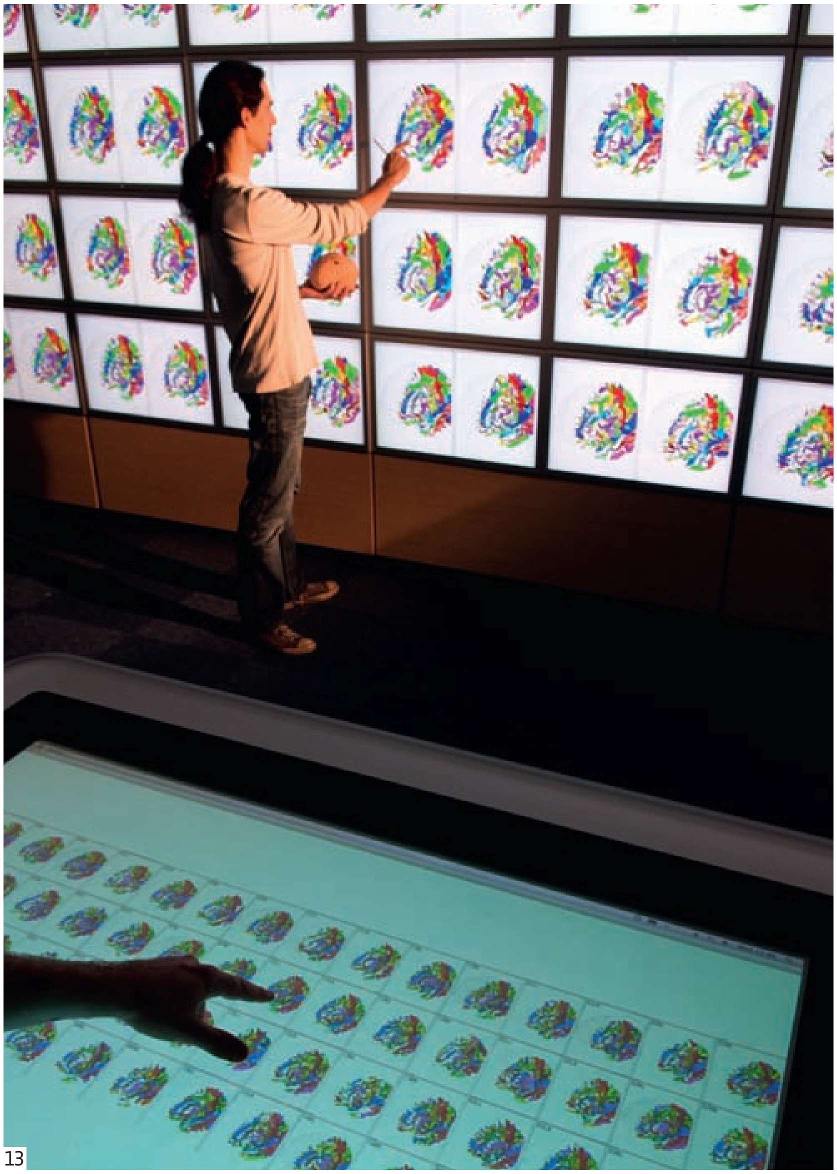
20km-long pile of CDs) that researchers will collect every year. The second approach is based on supercomputers, like the one used since 2008 at CNRS's IDRIS[6]—a monster capable of performing 207 thousand billion FLOPS. "In some cases, such as weather simulation, for which it is difficult to parcel out the data to a network of PCs, supercomputers remain the best solution," explains Beaudouin-Lafon.

**FLOPS**
FLOPS stands for floating-point operations per second. It is a measurement of a computer's performance. By comparison, an average handheld calculator can perform around 10 FLOPS.

## THE HUMAN FACTOR

But developing fast and high-performing computers is not enough. The data they have sorted still need to be understandable to human users. Take Google for example: the search engine can bring up several thousand addresses for a query, but can only display a dozen or so per page. "It is a shame to have sophisticated data retrieval algorithms and yet not be able to display the results comprehensively," says Beaudoin-Lafon. This raises the question of how search results can best be presented.

To answer this question, the LRI has developed a new type of platform called Wild: a wall of 32 computer screens—over 130 million pixels in total—allowing users to grasp a huge amount of information at a glance. "We are working with eight other laboratories from CNRS and the Saclay Campus, on this project," says Beaudouin-Lafon. For neuroscience specialists, Wild can display 64 brain MRIs, "which offers an indisputable advantage when trying to identify a pathology, considering there are significant variations even among healthy brains," he adds. Similarly, in astrophysics, certain observatories now compile images much too large to be displayed on single computer screens. To view an entire image at its highest resolution, Wild-like tools make all the difference. "I am convinced that this type of approach will expand in the future—not only for research, but also for industry," concludes Beaudoin-Lafon. "Indeed, the amount of data is constantly expanding, and the questions asked are both increasingly vague and complex." In other words, everything must be done to prevent today's information society from drowning in this massive quantity of data.



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13 The "Substance Grise" (Grey Matter) application used on the Wild platform allows users to simultaneously compare 3-D reconstructions of 64 patients' brains.

**800,000 petabytes***

***was the estimated amount of digital data in the world in 2009. This number was expected to rise to 1.2 million in 2010, and experts predict it to grow by 45% each year between now and 2020.***

* $10^{15}$ bytes.

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# Quantum Computers: The Ultimate Challenge

**It is every computer scientist's dream: a computer so fast that breaking a code,** making long-term weather predictions, or thrashing a chess grandmaster would only take a second. If this is still science-fiction today, it does not prevent mathematicians and physicists from sketching the outlines of how this extraordinary machine might work. Its name: quantum computer. Its underlying structure: to take advantage of the surprising laws of quantum mechanics, which allow a particle, an atom, or a molecule, to exist in two states at once. While today's computers store data as bits equal to either 0 or 1, quantum bits (or qubits) can simultaneously be equal to both 0 and 1. The advantage is the ability to store (in principle) information representing a large number of potential solutions to a given problem in the same memory, and, by applying suitable algorithms, to process all those solutions at once. This would turn today's most powerful computers into stone-age relics overnight.

**QUBIT**
A quantum bit is a unit of quantum information—the quantum analogue of the classical bit. A qubit has some similarities to a classical bit.

## THE LONG ROAD AHEAD

But will such a machine ever make it out of the laboratory? And if so, would it really be able to work wonders? Nothing is less certain. Quantum computers started as a simple idea floated in the 1980s by Richard Feynman, Nobel Prize Laureate in Physics. For Julia Kempe from the LRI[1]—elected Research Woman of the Year in 2010—"Feynman explained that quantum computers would be able to calculate the properties of quantum particles, such as electrons, much faster than a traditional computer. Each electron could be encoded in a qubit, whereas a large number of traditional bits are needed to encode the many states it may be in at the same time. But it was still all just an idea." And a very good one at that. In 1994, Peter Shor, then working at the AT&T Laboratories in the US, formally demonstrated that a quantum computer could factor a number—break it down into a product of prime numbers—in record time. Enough to make cryptographers nervous, since factoring, because it requires lots of computing time, is currently the key to all encrypted codes, whether for credit cards or top-secret documents. Likewise, in 1997, Lov Grover, then also at AT&T, demonstrated that a computer using qubits could considerably increase the effectiveness of algorithms aimed at finding information in databases. Unfortunately, despite mathematicians' and physicists' attempts to demonstrate the advantages of quantum computers at the time, these remained a pipe dream. In fact, to this day, no one knows exactly what a qubit will be made of: atoms, ions, molecules, electrons, superconductor circuits? What's more, the type of medium itself—solid, liquid, or gas—also remains a mystery.

**FACTORING** The decomposition of a mathematical object (for example, a number, a polynomial, or a matrix) into a product of other objects, or factors, which when multiplied together produce the original.

Several teams around the world are currently testing all types of materials that could potentially be used as basic components in future quantum processors. "We are studying qubits whose 0 and 1 states correspond to the spin states (a kind of rotation of the particle around itself) of molecules or ions of certain metals in solid matrices," explains Bernard Barbara, of the Institut Néel[2] in Grenoble.

## DECOHERENCE IS THE ENEMY

But physicists are far from proposing a turnkey computer. For now they are trying to understand and, insofar as possible, overcome the major pitfall in the path to quantum computers: something called decoherence. As Barbara points out, "any system in a quantum superposition of various states is extremely fragile. Through interactions with the environment, it can lose in a fraction of a second the properties required for any quantum calculation, and the more qubits it contains, the more unstable it is." At present, the best computing feat performed with qubits is that of Isaac Chuang at the Massachusetts Institute of Technology (US). In 2001, using the spin of molecules with seven effective nuclear spins, the researcher managed to factor 15, showing that the number could be broken down into 3 times 5. "But to be really effective," says Barbara, "a quantum computer needs to include a few thousand qubits, and be able to combine them in order to perform logical calculations."

**DECOHERENCE** Time during which a quantum system is not corrupted by its external environment.

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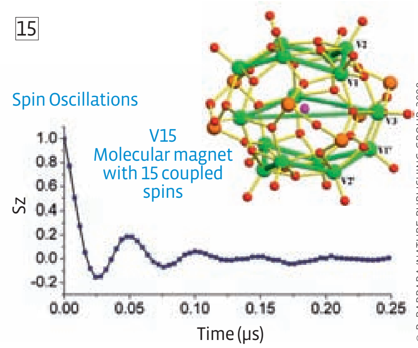




14 Quantum computers, like the one developed at MIT based on organic molecules, are still very much in the experimental stage.
15 A large molecule containing several hundred atoms, when interacting with its environment, slowly loses its quantum nature: a phenomenon known as decoherence.

For most scientists, two systems currently offer the most interesting perspectives. These include superconductor qubits, or microscopic electronic circuits allowing electric current to flow in both directions at the same time. "They are very easy to manufacture and duplicate and can be laid out in chips with several qubit superconductors," says Barbara. The second and most promising development relates to "gaseous ions trapped by powerful laser beams that provide several minutes of coherence, despite relatively restricted systems."

"Quantum computers are still a long way away," admits Barbara. "But I think they may become a reality within a few decades." Miklos Santha, also at the LRI, is less optimistic: "We might eventually find out that nature prohibits the very possibility of quantum computers..."

If quantum computers ever become a reality, they will still not be the ultimate computing machines, as their time-saving power could only be applied to solving specific problems. "While the benefit is considerable in the case of factoring, it is less obvious when searching through unsorted data, determining the shortest route on a map, or playing a game of chess or Go," notes Santha. "And quantum computers would provide little benefit put to other types of data, like sorted lists for example."

Does this mean research into quantum computers is pointless? Far from it. "Whether or not we build a quantum computer, our research helps us learn how to control quantum laws and understand the fundamentals better," explains Barbara. As for Kempe, she insists on the advantages of developing quantum algorithms: "They represent very powerful mathematical tools for addressing fundamental questions linked to complexity, and also for studying what a traditional computer can and cannot do. Finally, as quantum factoring algorithms threaten classical cryptography, it is essential to develop quantum cryptography, which is already used to exchange secret data." Nobody knows whether quantum computers will ever make it out of the laboratory. But it does not matter. Even if the concept proves unattainable, it remains an endless source of inspiration—and a genuine scientist's dream.

01. Laboratoire de recherche en informatique (CNRS / Paris-XI).
02. CNRS.

## RECENTLY PUBLISHED

***The LLL Algorithm, Survey and Applications. Series: Information Security and Cryptography.*** Phong Q. Nguyen and Brigitte Vallée, Eds. (Berlin: Springer, 2010).

***Joint Source-Channel Decoding. A Cross-Layer Perspective with Applications in Video Broadcasting over Mobile and Wireless Networks.*** Pierre Duhamel and Michel Kieffer (Amsterdam: Academic Press, 2009).

***Machine Learning Techniques for Multimedia: Case Studies on Organization and Retrieval.*** Matthieu Cord and Pádraig Cunningham, Eds. (Berlin: Springer, 2008).

***HCI Remixed, Reflections on Works That Have Influenced the HCI Community.*** Thomas Erickson and David W. McDonald, Eds. (Cambridge: MIT Press, 2008).

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Innoveox

# New Solution to Toxic Waste

**BY** CAROLINE DANGLÉANT


→**The technology developed by Innoveox is an alchemist's dream:** it can turn any toxic liquid waste into clean water and recyclable by-products, with the added bonus of creating energy at the same time.

Intended mainly for liquid industrial waste (used oils and solvents, pesticides, petroleum waste, etc.), this technology is the result of two decades of research at ICMCB,[1] that were led by Francis Cansell, now director of the Bordeaux Polytechnic Institute.

The process is based on a reaction called supercritical hydrothermal oxidation, a sort of cold combustion of organic matter. Upon entering the treatment unit, waste liquids are heated to 250°C and pressurized to 221 bars, i.e., nearly 220 times atmospheric pressure. They are then subjected to three injections of oxygen, leading to the gradual destruction of the molecules by oxidation while maintaining combustion, which can raise temperatures to 550°C.

These temperature and pressure conditions take the liquid's different components to their supercritical level. Put simply, this state allows oxygen to instantly dissolve in the liquid, where it can oxidize the different molecules. In only one minute and with an efficiency of 99.99%, the system releases water, carbon dioxide ($CO_2$), and oxidized metals and minerals in their purest form. As all these components are unmixed, they can be recycled. This technology is a major ecological leap forward, as toxic industrial waste is usually burned or buried. "This process makes it possible to recycle dangerous products such as explosives," marvels Jean-Christophe Lépine, president of Innoveox.

The company's secret lies in the three injections of oxygen, a process patented by CNRS. This process and the heat levels it generates provide the massive amounts of energy required to achieve the supercritical hydrothermal oxidation reaction.

So far, Innoveox is a cost-efficient alternative to current waste disposal methods. The equipment can be installed directly at the industrial plant, eliminating all financial and environmental costs linked to waste transportation. After two years of existence, Innoveox is preparing to set up its first treatment units. The hazardous industrial waste market is unlikely to resist this "miraculous transmutation" technique.

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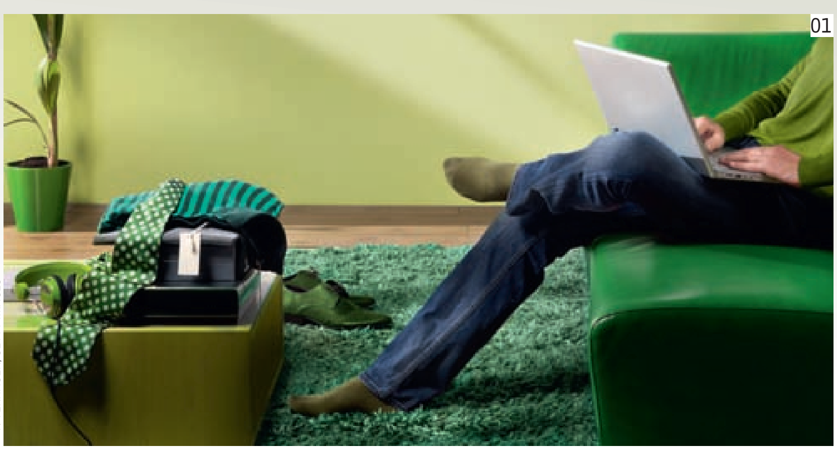
Ethera

# *Detecting Pollutants at Home*



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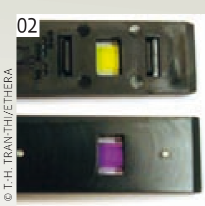

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01 Formaldehyde, chlorinated products, hydrocarbons... we might be breathing these at home. 02 The Ethera-developed captors change color when in contact with atmospheric pollutants.

**BY** DENIS DELBECQ

→ **How can traces of harmful airborne substances be detected without using cumbersome equipment?** Working on this particular problem, researchers at the Laboratoire Francis-Perrin[1] in Saclay have recently developed fast and easy-to-use sensors that could revolutionize current pollutant-detection techniques. Starting in 2012, they will market this product under the name Ethera, a newly-created company that won the French National 2010 awards for the support of innovative start-ups. Ethera's air pollution sensors change color in the presence of traces—a few micrograms per cubic meter of air—of molecules such as formaldehyde, which is released from glues, furniture, carpets, flooring and some cosmetics.

The sensors are made of materials that trap pollutants in nanometer-size pores. "We start with a liquid solution that contains silicon-based precursors," explains Thu-Hoa Tran-Thi, senior researcher at the Laboratoire Francis-Perrin and co-founder of Ethera. "By controlling the temperature, acidity, and type of precursors, we obtain a gel with countless pores of the required size, each containing probe molecules." For instance, in the presence of formaldehyde, a chemical reaction occurs with Fluoral-P molecules, causing a color change that can be quantified either with a color chart, or with an optical device for greater precision.

"Today, formaldehyde is detected by sampling the atmosphere and analyzing it in the laboratory using chromatography. With our porous gels, the results are directly obtained on site within a few

01 With the current method, it takes a few days to take this image of a breast tumor biopsy. 02 The LLTech system can take this image in just a few minutes. 03 The LLTech optical biopsy device is already being commercialized.

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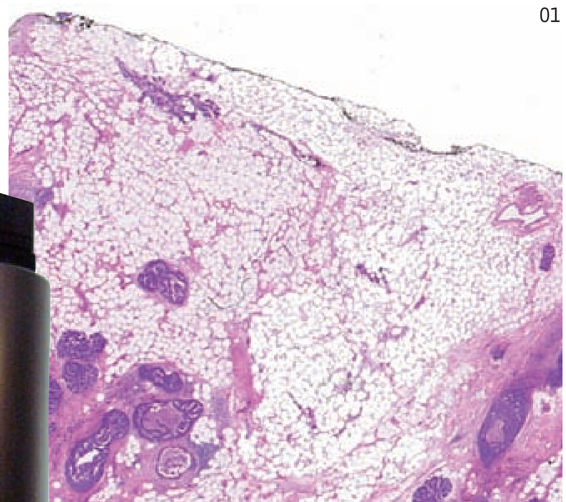

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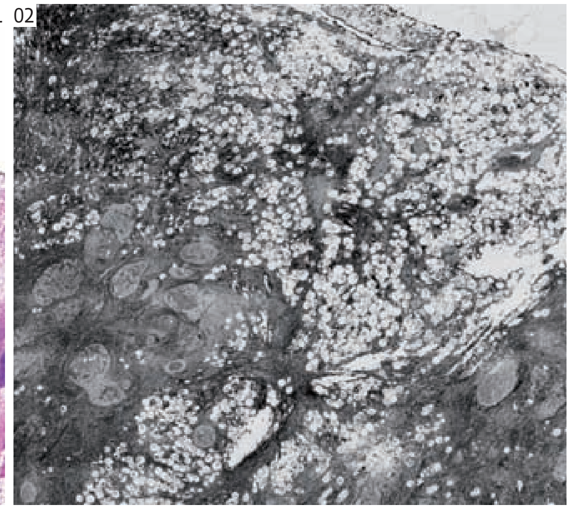

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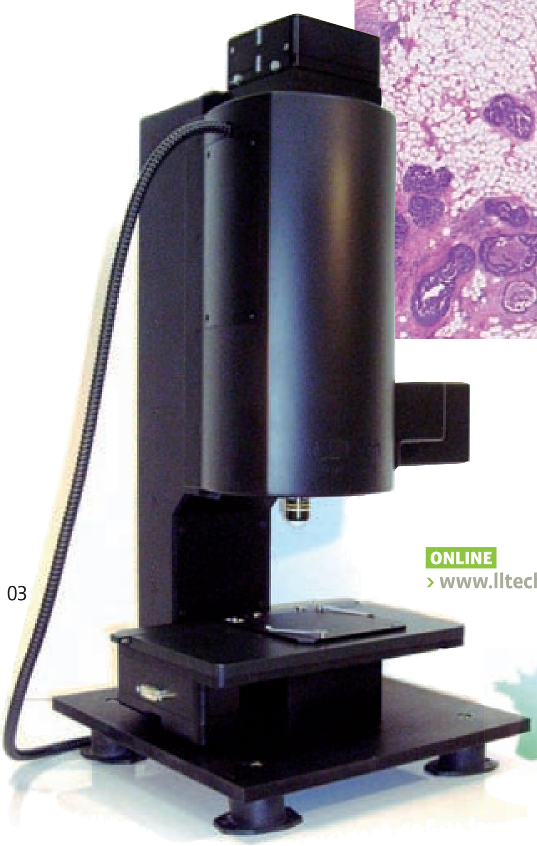

ONLINE
› www.lltech.fr


minutes," Tran-Thi points out. "In addition, the same device can be re-used dozens of times."

Besides calibrated systems for ultra-precise measurements, Ethera also produces kits for the general public. "We target the detection of formaldehyde, aromatic hydrocarbons (benzene, toluene, etc.), and chlorinated compounds," specifies Tran-Thi. "People will be able to determine concentrations of these chemicals in their homes by comparing the color of each sensor with color charts." The team is also investigating food freshness sensors that work by measuring the gases released by deteriorating flesh. These could be used for meat, fish, and seafood.

01. CNRS / CEA.


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LLTech A new invention could revolutionize current imaging techniques, by making them more precise, simple to use, and immediate.

# 3D in the Flesh

**BY** JEAN-PHILIPPE BRALY

**Three-dimensional non-destructive imaging of tissues at the cellular level is now possible in real time** —*in* or *ex vivo*—using the optical biopsy devices developed by French start-up LLTech. This company, created in 2007, has based its technology on two CNRS patents derived from research carried out at the Langevin Institute in Paris.[1] One of LLTech's founders was a researcher at the Institute.

LLTech technology, called full-field optical coherence tomography, uses light to make optical biopsies under the surface of the analyzed tissue, up to 1 mm in depth. It was co-developed by Claude Boccara, founder and scientific advisor of LLTech, and member of the Langevin Institute's scientific board. Equipped with sophisticated microscope objectives and one million-pixel resolution cameras that can capture over 100 pictures per second, the non-invasive instruments can eliminate any light reflected by the tissues under observation. "The resolution obtained is 10 times higher than with current techniques: around a micrometer in all three dimensions," explains Boccara. "The target tissue doesn't need sampling or preparation of any kind, viewing is possible within a few minutes, and the systems are easy to operate."

This technique could find applications in a number of fields. During breast cancer surgery, for instance, these instruments could allow real-time, ultra-precise viewing of the tumor to be removed. Dermatologists could immediately find out whether or not a black spot is a melanoma. Many other uses are being considered. These range from measuring drug efficiency during test phases, to determining cosmetic products' degree of skin penetration, or analyzing different stages of embryo development.

Five of these instruments are already in use in French and American laboratories and hospitals to build a database of reference images. A new injection of funds will enable LLTech to commercialize these systems on a large scale. The target market is expected to be worth $800 million by 2012.

01. Institut Langevin ondes et images (CNRS / ESPCI ParisTech / UPMC / Université Paris Diderot).

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Archeology In Turkey, French archeologists are busy excavating the remains of the city of Xanthos and its principal sanctuary, the Letoon. The 2010 campaign has been highly productive, with a number of discoveries confirming the prosperity of this iconic site of Lycian civilization.

# Unearthing Anatolia's **Ancient Civilization**

01

02 03



**BY** PHILIPPE TESTARD-VAILLANT

**Jacques des Courtils, from the Ausonius Institute[1] and director of the Xanthos-Letoon archeological mission,** has just returned from what was once ancient Lycia, on the southern coast of present-day Turkey. When asked how long excavations there will last, his answer says it all: "there's enough work for at least 200 years." Though the 2010 campaign unearthed a few more of their secrets, much more needs to be learned about the Lycians, whose territory covered some 5000 km². Their civilization peaked in the fifth century BC under Persian rule, before coming under the domination of the Greeks and Romans, and finally being incorporated into the Byzantine Empire.


01 Necropolises are the main visible remains of Lycian civilization. Shown here, the Simena necropolis, which dates from the Roman period and is located 70 km east of Xanthos.

02 In 2010, excavations revealed banquet halls on terraces overlooking the sanctuary of Leto.

03 After clearing away blocks from a Roman building, excavators attempt to find remains of pre-Roman architecture.

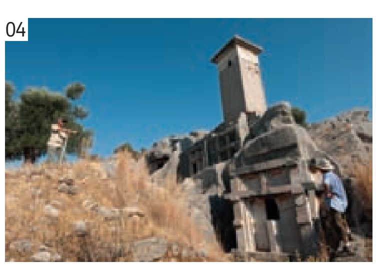
04 The stone walls of rock tombs imitate wooden constructions.

05 06 Two examples of pillars that held up the tombs of sovereigns, who were buried several meters above ground. The bas-reliefs are directly inspired by Greek art, which had a major influence on Lycia.

"The oldest material traces—mostly pottery shards—of this unusual civilization of Asia Minor date back to the seventh century BC," points out des Courtils, "though we learned of its existence from Hittite texts[2] dating from the second millennium BC."

"The Lycians had federal institutions, and formed for the most part an agrarian society, though they were also good sailors. Another of their characteristics is that they became urbanized as early as the fifth century BC, well before the rest of Anatolia. There were some 20 Lycian cities worthy of the name, including Xanthos, which was founded in the seventh century BC and destroyed by an earthquake in the seventh century AD."

04



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06

Xanthos, which includes a major religious sanctuary, the Letoon, has been the subject of continuous archeological surveys since 1950. Today it is both one of the most remarkable archeological sites in Turkey and a UNESCO World Heritage Site. One of the original centers of the city of Xanthos has been exhaustively explored. "We have uncovered a great deal of new information about the city as it was during the Roman and Byzantine periods," des Courtils enthuses. He is also thrilled by the recent discovery of another part of Xanthos, where remains dating from the city's foundation lie buried, and by the forthcoming exploration of residential areas.

The 2010 campaign was dedicated to restoring painted frescoes and mosaics, initiating the excavation of a cemetery dating from the Byzantine period, and working on making one of the city's ancient squares accessible to tourists.

As for the Letoon sanctuary, 80% of which has now been excavated, the latest campaign focused on exploring its outlying buildings. "It looks as if we've found one of the banquet halls where they served the meat of animals sacrificed during religious ceremonies," des Courtils explains. In fact, researchers continue to sift through archeological remains to shed light on the Lycians' religious practices, including the types of sacrifice, the frequency of festivals, and so on.

In the city of Xanthos, the excavations include intensive restoration of funerary monuments. In the Letoon sanctuary, a temple from the Greek period devoted to Leto, the mother of Apollo and Artemis, will be reconstructed piece by piece. Indeed, 75 to 80% of its original elements were preserved, which is extremely unusual for a Hellenistic temple. Such reconstruction "is important for us, scientists, but also for the general public—and for Turkey, since it will no doubt boost tourism in this splendid region," points out des Courtils, who remains fascinated by "the odd charm" that permeates every mission to Lycia.

01. Institut Ausonius (CNRS / Université Michel-de-Montaigne-Bordeaux-III).
02. In the 14th and 13th centuries BC, the Hittite empire encompassed a large part of Asia Minor.

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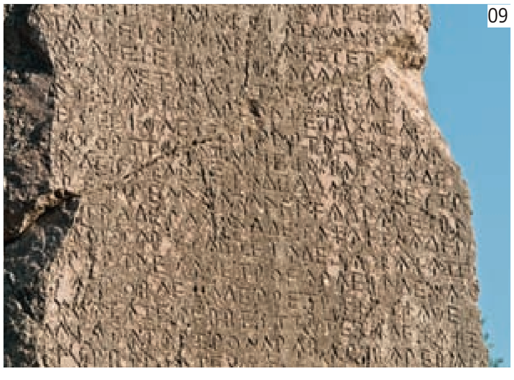


A full **photo** report can be viewed on the online version of CNRS magazine
> www2.cnrs.fr/en/384.htm

07 Still under excavation, this wide road dating from the Roman period was the main thoroughfare in the city of Xanthos.

08 The discovery of a Byzantine cemetery right in the middle of the main paved road that crosses Xanthos has made it possible to carry out anthropological and medical studies (life expectancy, causes of death, hygiene levels, etc.) on the population of the time.

09 This funerary pillar discovered in Xanthos bears the longest Lycian inscription found to date. Lycian was an Indo-European language related to Hittite, and is still poorly understood. The alphabet was borrowed from Greek, and adapted by the Lycians to their own language around 500 BC.

10 In the foreground, the well-preserved mosaic in the temple of Apollo. Behind it are the ruins of the Artemis temple, and in the background, the temple of Leto, in the process of being reconstructed.

Biology Last May, the American scientist Craig Venter announced the creation of the first synthetic living cell. Geneticist Jean Weissenbach puts this scientific milestone in context.

# First Step Towards **Artificial Life?**

BY PHILIPPE TESTARD-VAILLANT

**"This is the first self-replicating cell on the planet whose parent is a computer!"** commented US biologist and entrepreneur John Craig Venter when releasing his team's results in *Science* last May, which unleashed commentary from around the world.

Yet behind this upheaval lies a real scientific advance, raising major ethical and philosophical questions. This team reconstituted the 1.1 million base pairs that make up the DNA sequences of the *Mycoplasma mycoides* bacterium, and successfully transplanted this artificial genome into *Mycoplasma capricolum*. The latter divided to reproduce, thus reaching the status of living organism.

"By piecing together the genome of a bacterium using cutting-edge chemical technology, and then transferring this thousand-gene molecule into another bacterial species with very similar genetic traits, Venter's team has indeed performed a remarkable experimental achievement," comments Jean Weissenbach, director of the Genoscope,[1] France's genome sequencing center. "These scientists must have benefited from extremely efficient technological resources. Unfortunately, they do not provide enough experimental details to reproduce their experiment. Yet stating they have 'created life' is a great misconception," says Weissenbach. "The team replaced the complete genome of a bacterium with a foreign genome that took control of the recipient cell, which is already a major step forward."

Qualified by Craig Venter as a "very important philosophical step in the history of our species," does this manipulation pave the way for entirely man-made living organisms? "A very plausible scenario," replies Weissenbach. "Yet 'inventing' a new species from scratch will take an enormous amount of time, insofar as the method developed by Venter can only reconstitute small genomes of about two million base pairs. The mouse genome, for example, is 1200 times larger. Above all, we must bear in mind that today's species have been selected through evolution over millions—even billions—of years. An entirely 'artificial creature,' devoid of that long genetic evolution would most probably be unable to adapt to the living world, or compete against other life forms."

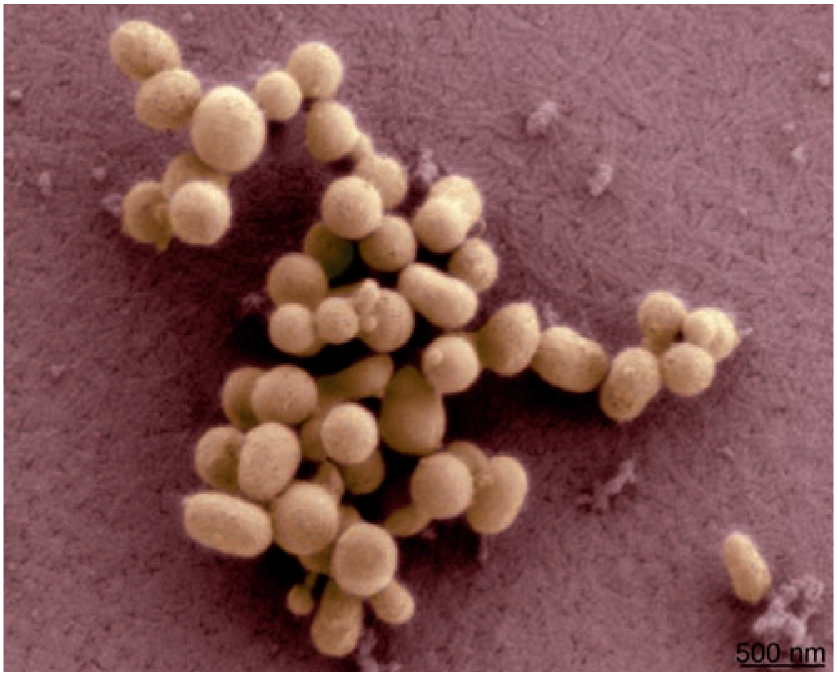
For the time being, Venter is concentrating on the design of "minimal" microorganisms, i.e., that carry the minimal amount of genes necessary to accomplish certain tasks useful to man, such as $CO_2$ uptake or the production of biofuels. "In theory, a synthetic genome could be 'profiled' to carry out a specific function," acknowledges Weissenbach. "Even so, we cannot at present determine which genes are useful or not in a genome. For me, even the concept of a minimal genome cannot answer that question. Besides, one doesn't need to synthesize a genome to turn a microorganism into a factory of useful products. Engineering genetics has been doing this for decades. Yet the work performed by Venter's team is a remarkable technical prowess that paves the way for man-made design and synthesis of genomes. Testing sophisticated gene combinations to replace those that derived from natural selection is no longer science-fiction, but requires that all necessary experimental and ethical precautions be taken."

01. www.genoscope.cns.fr



JEAN WEISSENBACH

A world-renowned expert in genomics, he received the CNRS Gold Medal in 2008.






→ *Mycoplasma mycoides, the bacteria whose genome was recreated by American biologists and transferred into another bacteria.*

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Israel One of the fastest-growing economies in the world is actively seeking to commit both resources and brainpower to scientific research.

# Small Country, Big Prospects

**KEY FIGURES**

| | |
|---|---|
| 7,353,985 | inhabitants (2010 est.) |
| 4.8% | of GDP allocated to R&D (2008) |
| 9792 | scientific publications (2008) |
| 246 | co-publications with CNRS (2008) |
| 327 | CNRS missions to Israel in 2008 |

**BY** ELAINE COBBE

**Israel may be a young country with a population of just over seven million,** yet its scientists are among the best in the world. Israel ranks fourth worldwide in terms of scientific activity as measured by the overall number of scientific publications per million active citizens.[1] These publications predominantly cover engineering science, applied biology, and medical research.

Israel has claimed three Nobel Prizes in Chemistry and one in Economy over the past seven years. The latest laureate, in 2009, was Ada Yonath, from the prestigious Weizmann Institute of Science, who won the prize for her work on ribosomes, the main protein builders of cells.

Israel invests heavily in research, spending 4.8% of its GDP on R&D, more than any other country in the world. The majority of funds dedicated to civilian R&D purposes is allocated to economic development, mainly in industry and agriculture. The country is one of the world's five leaders in terms of registered patents, which can be seen as one measure of the effectiveness of the relationship between universities and industry.

Seven major institutions form the backbone of research endeavors: the Weizmann Institute; the Hebrew University of Jerusalem; Tel Aviv University; the Technion (Israël Institute of Technology in Haifa); Ben-Gurion University; the University of Haifa; and the Bar-Ilan University. And four of them rank in the top 150 in the world.[2] The Weizmann Institute, which was founded in 1934 in Rehovot (near Tel Aviv) and specializes in graduate and post-graduate studies, came second in *The Scientist* magazine's best ten workplaces worldwide for scientific researchers in 2010. In the last decade, seven graduates of the Hebrew University—Israel's oldest university (1925)—were awarded Nobel Prizes or Fields Medals.

Israel has one of the most highly-educated workforces in the world. Yet if Israelis are getting a top-grade education at home, many scientists prefer to work abroad. During the three decades from 1973 to 2005, the number of senior faculties in Israel's research universities increased by just 12% while the population of the country more than doubled (+109%). The US, which is Israel's main partner in terms of scientific cooperation, is the preferred destination.

## INTERNATIONAL COMMITMENT

Many of Israel's research programs rely on international partnerships. The US and Germany are its two main partners, offering major financial incentives for their bilateral programs. France is Israel's fourth-largest partner in terms of scien-

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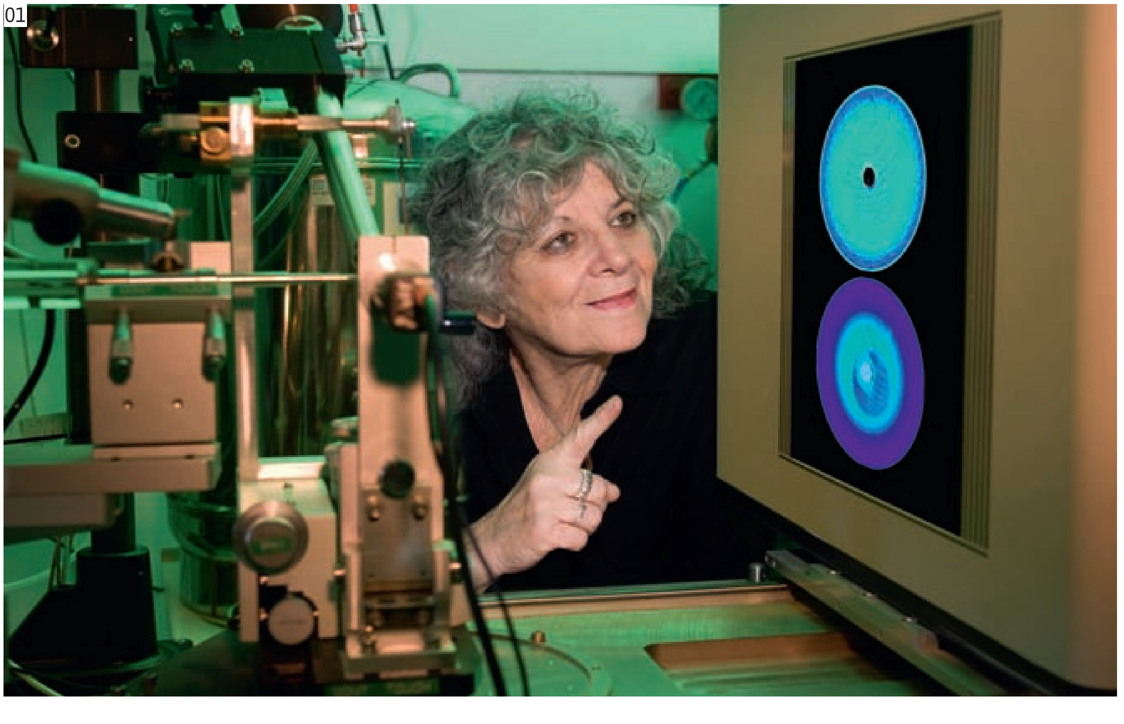

tific cooperation, behind the US, Germany, and the UK. Yet France is involved in just 11% of Israel's international co-publications—which represents half the number of co-publications with Germany. Israel has also been very successful as an associated country in the European Union Framework Programmes since the end of the 1990s and was the fifth largest grants beneficiary for young scientists from the prestigious European Research Council in 2010.

The major funding body for Franco-Israeli cooperative projects is the High Council for Scientific and Technological Research (HCST), jointly financed by both countries. Since its creation in 2004, it has supported over 120 research projects within the framework of separate programs including sustainable agriculture, astrophysics, human genetics, biomedical imaging, and neuroscience and robotics. The next round of funding, in 2011, will be allocated to projects in renewable energy and computational neuroscience.

## LONG-STANDING PARTNERS

CNRS plays a major role in promoting Franco-Israeli cooperation, initiating and running joint structures built on its own expertise associated with leading Israeli experts. CNRS laboratories are involved in 52% of total Franco-Israeli co-publications and in most Franco-Israeli research collaborations. Last year, CNRS was co-organizer of two conferences held in Israel, on biodiversity and on renewable energies, to encourage new developments in these areas.

CNRS's presence in Israel dates back to 1963, with the creation of the French Research Center of Jerusalem (CRFJ),[3] the oldest CNRS body abroad, mainly dedicated to archeology, but also to ancient and contemporary history. Today, CNRS is heavily involved in two successful European Associated Laboratories (LEAs), which bring together researchers and students at the cutting edge of their fields: the France-Israel Laboratory of Neuroscience (FILN) and the Nano Bio Science laboratory (LEA NaBi).

LEA FILN, which was created in 2004, was the first major cooperative venture between CNRS and the Hebrew University of Jerusalem. FILN brings together some 30 researchers and postdoctoral fellows and uses a multidisciplinary approach to investigate the workings of the human brain. In 2010, FILN widened its scope by extending its collaboration to the Weizmann Institute and the University of Haifa.

LEA NaBi was set up in 2008 with the Weizmann Institute. It runs projects in both fundamental and applied sciences, in the multidisciplinary and rapidly-expanding field of nanobioscience, at the interface between nanoscience and biology. Some of the projects include new developments in nanoscience, biomedical imaging, and new types of biosensors.

CNRS is also a partner and sponsor of the annual Award for Academic Excellence of the France-Israel Foundation. The award, a cash prize, honors one French and one Israeli scientist, under 40 years of age, who have excelled in their field. Although still in its infancy, the prize, which was set up in 2008, is already gathering interest. Three awards went to CNRS researchers working in the fields of cancer, water, and renewable energies, respectively.


02

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03

© M. BARAZANI, CRFJ

01 Professor Ada Yonath, recipient of the 2009 Nobel Prize in Chemistry.
02 The Koffler Accelerator at the Weizmann Institute.
03 The French Research Center of Jerusalem.

## LOOKING TO THE FUTURE

**Building on its existing structured and long-term cooperative projects with the Hebrew University and the Weizmann Institute, CNRS is expanding its horizons to reinforce links with other Israeli institutions and has a number of associated laboratory projects in the pipeline.**
**CNRS is now joining forces with Tel Aviv University to set up new joint projects. These will include an associated laboratory in computer science, which is expected to facilitate the development of joint post-graduate studies.**
**Among other upcoming CNRS projects is the new Paris-Jerusalem Doctoral College, a partnership between French, Israeli, and Palestinian institutions, expected to be launched in September 2011. It will draw on the resources of the French Research Center of Jerusalem, three French universities,[1] the Ben-Gurion University, and the Al Quds University in Jerusalem. The College's main goal is to teach mediation skills and build on intercultural exchanges between Israeli and Palestinian researchers in social sciences.**

01. Universités Paris-V, Paris-VII, Paris-XIII.

01. Source: 2008 OECD and SCI (DVD Ed.; Thomson Reuters).
02. Hebrew University of Jerusalem, Tel Aviv University, Technion and the Weizmann Institute (Shanghai Jiao Tong University 2010 Academic Ranking of World Universities).
03. Centre de recherche français de Jérusalem (CNRS / Ministère des affaires étrangères).

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International Affairs Last July, CNRS established its new European Research and International Cooperation Office (DERCI). Director Minh-Hà Pham Delègue explains its objectives.

# DERCI: CNRS's New Office for **International Cooperation**

© F. PLAS/CNRS PHOTOTHÈQUE

**BY** FABRICE DEMARTHON

**Can you outline DERCI's mandate?**
DERCI's goal is to coordinate all operations run by CNRS both in Europe, to strengthen European research, and in the rest of the world, to develop international cooperation. It combines the former Offices of European Affairs and International Relations. Indeed, CNRS President Alain Fuchs and the board of directors believe it is essential that our French and foreign contacts rely on a single point of entry. Hence the creation of DERCI, a central authority to implement the international strategy of CNRS and its ten institutes.

**What are your current priorities?**
We first intend to strengthen our links with other CNRS departments and with our ten institutes. Our mission is to help them build international partnerships and meet their scientific objectives. We will set up new indicators to assess our activities: the number of joint publications and patents with our foreign partners, student exchanges, etc. We would like to monitor our collaborations over the long term, to be able to see how they evolve. We also wish to consolidate our network of partners—embassies, universities, or other higher education institutions —by giving them access to our infrastructures. In connection with French embassies' scientific and technological services, our offices could become real hubs for French research abroad.

**CNRS has a number of offices abroad. What is their current status?**
CNRS offices abroad are not intended to be permanent. Those in London and Bonn, for example, have been closed, as our researchers can easily collaborate with their European colleagues. Others are created to initiate new cooperations. We have just opened an office in India, and we plan to establish one in Malta. As an emerging country, India is a strategic partner, but it is naturally inclined to work with English-speaking countries. This is why we need to reinforce our presence in the country. As for our Malta office,

it will be our bridgehead to the countries around the Mediterranean. This region is proving to be of paramount importance for many scientific fields, including environmental research and space science.

**CNRS has also established unique cooperation tools to develop and run its international collaborations. What are they?**
International Research Networks (GDRIs), International Associated Laboratories (LIAs), and International Joint Research Units (UMIs) are collaborative tools created to promote exchanges between researchers from different countries. GDRIs and LIAs are virtual laboratories that facilitate communication between researchers from CNRS and from foreign institutions on a defined subject, whereas UMIs bring together researchers and technicians on projects at a specific location.

We would like to see the emergence of scientific collaboration clusters by establishing links between

*"Our offices could become real hubs for French research abroad."*

various CNRS structures located in the same country or region. In Singapore, for example, we have two UMIs involving a dozen researchers. We would like to strengthen exchanges so that their activities are coordinated with local scientific partners. We also intend to encourage the emergence of inter-institute research networks on specific themes including Environment and Sustainable Development, especially in countries where our contingent is scattered, like China.

**Do you plan to create new collaborative tools?**
We are working on creating French extensions to the existing UMIs. Established on French university campuses, they would host students and researchers sent by our partners abroad. This type of structure should encourage balanced exchanges between French researchers and their foreign counterparts.

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## INTERNATIONAL COOPERATION

### MOROCCO

**→ A framework agreement between CNRS and the Moroccan CNRST[1] was signed in Paris last July to enhance cooperation between the two institutions. This agreement aims to support joint research projects, researcher exchanges, the organization of bilateral conferences and seminars, and cooperation in data and information diffusion, as well as in training.**

01. Centre National pour la Recherche Scientifique et Technique.

### CHINA

**→ On October 22, 2010, an agreement was signed in Shanghai to create an International Research Network (GDRI) on the Quantum Manipulation of Atoms and Photons (QMAP). It brings together eight institutions from China and ten from France, all specialized in quantum physics. The main objective of the GDRI QMAP is to strengthen existing exchanges and cooperation, and enhance coordination between French and Chinese laboratories and research institutes.**

### SOUTH KOREA

**→ A joint research center between the IPCMS[1] in Strasbourg (France) and the Ewha Womans University in Seoul (South Korea), was inaugurated last October in Seoul. Several teams from IPCMS will work with local researchers on spintronics, spin-photonics, and quantum imaging applications in the new "Quantum Dynamic Imaging Research Center."**

01. Institut de physique et chimie des matériaux de Strasbourg (CNRS / Université Strasbourg-I).

→ From left to right: Marc Drillon (IPCMS Director), Bertrand Girard (CNRS Institute of Physics Director), Minh-Hà Pham-Delègue (DERCI's Director), Jeong Weon WU (Professor at Ewha Womans University).

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# Grants / Fellowships

**EURAXESS I**
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/

**CORDIS I**
Cordis is the gateway to European research and development. It lists all information on the funding allocated by the 7th European Framework program (FP7).
› http://cordis.europa.eu

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

## 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 find employment.
› 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

Sociology

# Democracy in Question

BY SEBASTIÁN ESCALÓN

**Far from being a universal concept, the word "democracy" covers multiple realities** depending on the country. The aim of the European Associated Laboratory "Comparing Democracies in Europe" (LEA Code) is to analyze the differences and similarities that make up the structure of an array of democratic systems. Established in 2005 and renewed in 2009, this LEA has enabled its two partners—the Bordeaux laboratory Spirit[1] and the Institute of Social Sciences of the University of Stuttgart (ISSUS)—to develop ambitious international research programs on this theme and increase exchanges between students and researchers from France and Germany.

© LUDOVIC/REA

The Franco-German laboratory Code launched an extensive survey aimed at comparing the work of MPs in both countries, and assessing how the general public viewed their mandates.

In February 2010, the LEA launched a major study entitled "Citizens and Representatives in France and Germany" (Citrep). "The idea is to compare how politicians and citizens perceive the political process in France and Germany," explains Éric Kerrouche, head of the laboratory's French contingent. The study will begin with a survey to find out what the French and Germans know—or think they know—about the work carried out by their members of parliament (MPs). Next, researchers will follow 120 MPs for one week in both countries during their constituency visits. "It is virtually an ethnographic study on the work of parliamentarians in the field," Kerrouche adds.

Other themes covered by this Franco-German laboratory include euroscepticism, citizen participation at the local level, and people's perception of the concept of democracy itself. "Democracy is not understood in the same way in both countries. For example, violent action is considered as a possible, even legitimate form of participation in France, which is far from being the case in Germany," Kerrouche explains.

The creation of this LEA has institutionalized a 20-year-old collaboration between the two laboratories. This project will come to an end in late 2012, but researchers hope to keep investigating and comparing the perception of politics in their respective countries in the future.

01. Science politique relations internationales territoire (CNRS / IEP Bordeaux / Université de Bordeaux).

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NuPNET

# The Future of European Nuclear Physics

BY MARIE LESCROART

**On October 15, 2010, the members of NuPNET, a joint European network for nuclear physics coordinated by CNRS,** defined strategic goals for the financing of European research in the discipline.

Representatives of 18 research-funding institutions across 14 EU countries gathered at CNRS headquarters in Paris to draw up a list of priority research themes in nuclear physics. These were divided into three major areas: technological R&D for new generation detectors; R&D for the infrastructures of the "Eurisol" new generation accelerator; and nuclear theory related to structure and reactions.

"Europe needs joint initiatives, as technologies are becoming increasingly complex, and the infrastructures necessary to expand our research programs and remain competitive are ever more expensive. This prompted us to set up NuPNET," explains Sydney Galès, deputy scientific director of CNRS's National Institute of Nuclear and Particle Physics (IN2P3),[1] director of the National Large Heavy Ion Accelerator (GANIL),[2] and NuPNET coordinator.

Launched in 2008 for a three-year trial period, NuPNET was allocated a budget of €1.3 million by the European Commission. The program enables EU research financing agencies to pool resources for projects and installations that benefit all member countries. "A call for tender on the selected priorities will now be issued to European research laboratories," says Galès. "The first projects co-financed by NuPNET members should begin in the fall of 2011."

01. Institut national de physique nucléaire et de physique des particules.
02. Grand Accélérateur National d'Ions Lourds (CNRS / CEA).

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Sustainable Development

# Bio-Refineries of the Future

BY JEAN-PHILIPPE BRALY

→ **EuroBioRef[1] is a joint four-year project coordinated by CNRS.** It aims to optimize bio-refineries in order to transform a wide variety of biomass—such as non-edible crops and residues from agriculture and forestry—into high value added products, such as aviation fuel, chemicals, polymers, and solvents.

ONLINE
› www.eurobioref.org

EuroBioRef was launched in March 2010. It involves 28 partners in 14 countries, including laboratories, biochemical companies, and industrial stakeholders from the agricultural and biomass production sectors. The project has been allocated a budget of €37.4 million, co-funded by the EU and the participants themselves.

EuroBioRef focuses on every step of the process: from crop cultivation to marketed products through pretreatment of raw materials, improved separation and transformation of the biomass and its by-products, enhancement of final products, optimization of logistics, and adaptation to local conditions (e.g., climate and available land).

"In this unprecedented joint effort, CNRS researchers are notably contributing their expertise in chemical catalytic processes," points out Franck Dumeignil, project coordinator and deputy director of the UCCS laboratory[2] in Villeneuve d'Ascq. "The teams involved will develop catalysts to transform components that are seldom used—or not used at all—into molecules of interest, while using as little energy as possible."

The project aims to reduce the energetic cost of bio-refineries by 30% and the quantity of raw materials needed by at least 10%, with no waste output.

Another advantage is flexibility: existing European infrastructures which can so far only transform a single type of biomass into a single product (e.g., wheat into bioethanol) could be adapted with only minor modifications. By the end of the program, several pilot/plant-scale demonstrations will be performed. In Poland, for example, researchers even plan to produce a new kind of aviation fuel that could be used to operate airliners.

01. European Multilevel Integrated Biorefinery Design for Sustainable Biomass Processing.
02. Unité de catalyse et de chimie du solide (CNRS / Universités Lille Nord de France, Lille-I, and d'Artois / ENSCL / ECLille).

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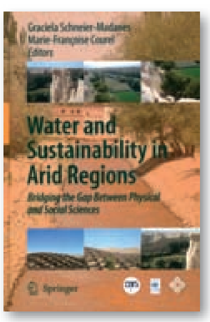
**BOOKS** I

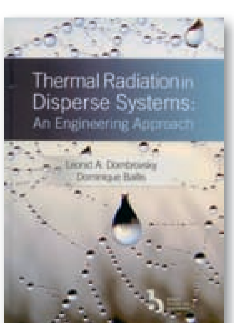


### Water and Sustainability in Arid Regions

**Bridging the Gap Between Physical and Social Sciences.**
Graciela Schneier-Madanes and Marie-Francoise Courel, Eds. (Berlin: Springer, 2010), 349p, €158.20.
→ **Through an interdisciplinary approach** that combines physical and social sciences, this book is a global and comprehensive scientific exploration of the issue of water and sustainability in arid lands across the planet.

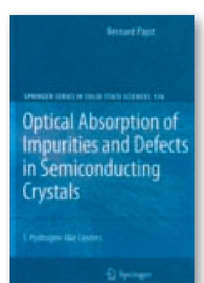
### Thermal Radiation in Disperse Systems:

**An Engineering Approach.**
Leonid A. Dombrovsky and Dominique Baillis. (Redding: Begell House, 2010), 520p, $326.
→ **Providing a systematic consideration of diverse problems** of thermal radiation in disperse systems, this book can be considered as a manual on applied radiative and combined heat transfer problems. It is written for students, engineers, and researchers in this field.



### Optical Absorption of Impurities and Defects in Semiconducting Crystals.

***Hydrogen-like Centres.***
Bernard Pajot. (Berlin: Springer, 2010) 470p, €158.20.



→ **Looking back at the knowledge accumulated in 60 years of research** on impurities and dopants of semiconductors and insulators, the author provides an update on the bulk optical properties of hydrogen-like centers, including specific classes of centers and absorption properties under external perturbations.

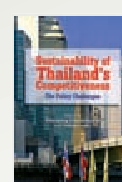
## IRASEC Publications:

→ **Based in Bangkok (Thailand) the Research Institute on Contemporary Southeast Asia (IRASEC) publishes books and periodicals on its activities—primarily focused on the political, economic, and social evolutions of the eleven countries of the region.**

*Recent publications in English:*

### Sustainability of Thailand's Competitiveness:

***The Policy Challenges.***
Patarapong Intarakumnerd and Yveline Lecler, Eds. (Singapore: ISEAS, 2010) 331 p. $49.90.



### New Dynamics between China and Japan in Asia.

***How to Build the Future from the Past?***
Guy Faure, Ed. (Singapore: World Scientific, 2010). 349 p. $108.

MORE AT
› www.irasec.com

# 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.

**Founded in 1939 by governmental decree, CNRS is the largest fundamental research organization in Europe.**

CNRS is involved in all scientific fields through ten specialized institutes dedicated to:

- Life sciences
- Physics
- Nuclear and Particle Physics
- Chemistry
- Mathematics
- Computer science
- Earth sciences and Astronomy
- Humanities and Social sciences
- Environmental sciences and Sustainable development
- Engineering

CNRS research units are either fully funded and managed by CNRS, or run in partnership with universities, other research organizations, or industry. They are spread across France, and employ a large number of permanent researchers, engineers, technicians, and administrative staff.

The CNRS annual budget represents one-quarter of French public spending on civilian research. This budget is co-funded by the public sector and by CNRS, whose revenue streams include EU research contracts and royalties on patents, licenses, and services provided. **CNRS's 2011 budget was €3.2 billion.**

CNRS employs some 34,000 staff, including 11,400 researchers and 14,200 engineers and technicians. Nearly 1100 research units (90%) are joint research laboratories with universities and industry.

**DERCI, an office dedicated to European and international collaborations.**

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

The European Research and International Cooperation Office (Direction Europe de la recherche et coopération internationale (DERCI)) coordinates and implements the policies of CNRS in Europe and worldwide, and maintains direct relations with its institutional partners abroad.

To carry out its mission, the DERCI relies on a network of 9 representative offices abroad, as well as on science and technology offices in French embassies around the world.

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→ CNRS's headquarters in Paris.

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**KEY FIGURES**

**CNRS SUPPORTS 572 SCIENTIFIC COLLABORATIVE STRUCTURED PROJECTS ACROSS THE WORLD**

| | |
|---|---|
| 343 | International Programs for Scientific Cooperation (PICS) |
| 114 | International Associated Laboratories (LEA + LIA) |
| 93 | International Research Networks (GDRE + GDRI) |
| 22 | International Joint Units (UMI) |

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**CNRS Photos are available at:** phototheque@cnrs-bellevue.fr ; http://phototheque.cnrs.fr



# Ocean Gems

→ **No necklace or rings will ever be decorated with these gems.** They are actually planktonic larvae and protists that were collected by Christian Sardet and his team at the Villefranche sur Mer marine station.[1] This image is from the online video and photo series "Plankton Chronicles."[2]

The sample was collected in the bay of Villefranche sur Mer using plankton nets (with a mesh size of 0.12 mm). It contains a diverse mix of zooplankton, including jellyfish, shellfish larvae, and egg cases—a few millimeters in size—but also microscopic single cell protists, a few acantharians (star-shaped), dinoflagellates (with horns), and diatoms (colored green by chloroplasts).

The Villefranche sur Mer marine station, created in 1885, is located on a site particularly well suited to collecting and studying plankton. Research teams on site are also actively participating in the Tara Oceans expedition,[3] which left Lorient (France) in September 2009 for a three-year mission to survey all the oceans around the world. It is dedicated to the collection and analysis of all kinds of marine plankton, from viruses and bacteria to small fish and jellyfish.

01. Observatoire Océanologique de Villefranche sur Mer (CNRS / UPMC).
02. Initiated with CNRS images. www.planktonchronicles.com.
03. http://oceans.taraexpeditions.org/

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**+WEB**
A **video** and a selection of **pictures** can be viewed on the online version of CNRS Magazine.
> http://www2.cnrs.fr/en/384.htm

# FRENCH NATIONAL CENTER FOR SCIENTIFIC RESEARCH

## Offices Abroad


cnrs advancing the frontiers

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