DARWIN’S THEORY AND MEDICINE

Could Gas be the Energy of Transition?

Scanning the Past with RAMAN SPECTROSCOPY

Landscape Dynamics in Central Asia
Always craved for knowledge

In 2015, CNRS is recruiting researchers in all scientific fields:
- Life sciences
- Physics
- Nuclear and Particle Physics
- Chemistry
- Mathematics
- Information technologies
- Earth sciences and Astronomy
- Humanities and Social sciences
- Environmental sciences and Sustainable development
- Engineering

Disabled candidates can also be recruited by contractual agreement.

Online registration at www.cnrs.fr from December 1, 2014 to January 5, 2015

Facebook
Twitter
Linkedin
www.cnrs.fr

CONFÉRENCES JACQUES-MONOD 2015

Institute of Biological Sciences
and Institute of Ecology and Environment

- Actin and microtubule cytoskeleton in cell motility
  and morphogenesis: an integrated view
  Roscoff (Bretagne) May 26–30, 2015
  Deadline for applications: February 20, 2015

- Marine eco-systems biology
  Roscoff (Bretagne) June 22–26, 2015
  Deadline for applications: March 20, 2015

- Building, repairing and evolving biological tissues
  Roscoff (Bretagne) September 13–17, 2015
  Deadline for applications: May 15, 2015

- Comparative biology of aging
  Roscoff (Bretagne) October 12–16, 2015
  Deadline for applications: June 26, 2015

- DNA methylation and demethylation
  Roscoff (Bretagne) November 16–20, 2015
  Deadline for applications: September 1, 2015

For more information
E-mail: conf.monod@cnrs-dir.fr • http://www.cnrs.fr/insb/cjm/
For more than 20 years, scientists have warned both governments and the public at large about climate change caused by the increasing concentration of atmospheric greenhouse gases (GHG). A consequence of human activity, this phenomenon is mostly due to the massive release of fossil carbon that was trapped in the ground for millions of years in the form of oil, coal, and gas. Given the inevitable depletion of fossil resources, a rising global population, and people’s legitimate aspiration to have access to the energy required for their well being, there is an urgent need to switch to an energy mix that emits fewer GHGs.

Energy transition will be one of the main challenges facing humankind in the 21st century. And it is not only a technological undertaking but also a significant societal issue and the subject of heated debate. The recent broadcast of documentaries about shale gas and hydraulic fracturing in the US, which expose the disastrous environmental consequences of the hasty exploitation of a new resource coupled with an obvious lack of regulatory framework, have already stirred international public opinion.

Scientific research should be able to inform the public and political decision-makers objectively and openly, about the respective benefits and drawbacks of the various energy options, all of which bring their share of potential inconvenience. In this context, a scientific seminar was held at the CNRS in January 2014 to review current knowledge on source rock gas and the technologies required to exploit it.

It is the topic of this issue’s cover story, which takes a broader look at the latest gas production methods, such as the fermentation of organic matter from waste, or the stimulation of former coalmines by depressurization (without fracking). Methane from conventional reservoirs is an energy source that releases less CO2 than oil and much less than coal, which several countries are now starting to exploit or re-exploit massively. Gas can also be used as a way of storing or hybridizing intermittent renewable energy. For all these reasons, gas will continue to be one of humankind’s main energy sources over the next 20 to 30 years—if not longer.

By Alain Dollet,
Deputy Scientific Director of the CNRS Institute for Engineering and Systems Sciences (INISI), and in charge of the organization’s Energy Task Force.
18

IN DEPTH

SPECIAL REPORT | Gas, Energy of Transition? 18
Exploring France’s Potential 24
The Green Gas Alternative 26

PROFILE | Clément Sanchez, Chemistry as a Giant Lego Set 28

PORTFOLIO | Scanning the Past 30

5

IN THE SPOTLIGHT

2014 Fields Medal and CNRS Gold Medal Recipients 5

6

SCIENCE AT WORK

FOCUS | Darwinian Medicine 6

LAB WATCH |
Stars’ Turbulent Beginnings 8
Disoriented Bees 9
Brain Imaging at its Best 10
When Numbers Help you Run 12
Early Detection of Lung Tumors 12
Listening to Seismic Noise 13
The Attention Economy 14
The Pulmonary Sieve 15

INNOVATION |
New Biomarkers Help Diagnose Alzheimer’s 16

36

WORLDWIDE

PARTNERSHIP |
France and China on Landscape Dynamics 36

ON LOCATION |
GEOVIDE, Traces at Sea 38

NEWSWIRE |
South Korea, a Scientific Revolution 40
International Projects and Reading List 42

43

CLOSE-UP

Fossils of the Fezouata Formations in Morrocco 43
IN THE SPOTLIGHT

Computer Scientist **Gérard Berry** Awarded the CNRS 2014 Gold Medal

This year’s CNRS Gold Medal, France’s most prestigious scientific distinction, was awarded to Gérard Berry, holder of the first chair in computer science at the Collège de France since 2012.

Born in 1948, Berry studied at the École Polytechnique. Between 1970 and 2009, he occupied several engineer and researcher positions before joining Inria as director of research between 2009 and 2012, when he took the chair at the Collège de France.

Berry is a pioneer of computer science. Since 1980, his main focus, in collaboration with researchers at Inria, the CNRS, and the École des Mines, has been the development of a language, Esterel, which makes it possible to express the temporal synchronization of tasks and prove that they are properly executed. Various versions of the Esterel language have found industrial applications with companies like Dassault Aviation, Bertin, ILOG, ST Microelectronics, or Texas Instruments.

Berry’s most recent work has focused on diffuse programming, i.e., the programming of connected objects—computers, telephones, televisions, household appliances, etc. The use of such a network of devices involves many complex behaviors that are impossible to predict. Berry is currently developing a new programming language, called HipHop, whose objective is to coordinate these behaviors based on cooperation between sequential programming models.

Artur Avila, Recipient of the 2014 Fields Medal

Last August, Artur Avila, senior CNRS researcher at the IMJ-PRG, was awarded the 2014 Fields Medal. The 35-year-old Franco-Brazilian mathematician, who also works at the IMPA in Rio de Janeiro (Brazil), is being recognized for his outstanding work in dynamical systems and analysis.

Born in 1979 in Rio de Janeiro, Avila developed a passion for mathematics at the age of 16. Three years later, at only 19, he had started writing his dissertation on one-dimensional dynamics under the supervision of the renowned Brazilian mathematician Welington de Melo. In 2001, he entered the Collège de France for postdoctoral work with Jean-Christophe Yoccoz, another Fields medalist (1994), and was recruited by the CNRS in 2003. In 2008, aged 29, he became the organization’s youngest senior researcher.

His main interest is dynamical systems, i.e., systems that evolve over time. He specializes in determining the probability of a given system evolving toward one type of behavior or another. Examples include the movements of planets, climate models, or population dynamics.

Avila also focuses on one-dimensional Schrödinger operators associated with a dynamical system and, since 2003, in interval exchanges. He has authored more than 50 scientific publications.

Three other mathematicians received the Fields Medals this year: Martin Hairer from Austria, the Canadian-American Manjul Bhargava, and Maryam Mirzakhani from Iran, who is the first female laureate of the prize. The 2014 awards consolidate France’s position as the world’s second highest Fields medal recipient.
One of the world’s top antibiotics consumers, France recently went as far as launching a public awareness campaign advising patients not to misuse the drugs. Antibiotics are intended to eradicate bacterial infections, but are widely prescribed for viral infections among others. This has caused the most resistant bacterial strains to be selected, a real-case example of the Darwinian theory of evolution applied to human health.

Darwinian medicine postulates that like other species, humans have been shaped by the environment in which they have evolved, and that better understanding of adaptation sheds new light on the health problems we face today, as first hypothesized in the 1990s by American biologists Nesse and Williams. “For thousands of years, humans have co-evolved with many parasites, such as bacterial intestinal flora, against which they have developed a number of defense mechanisms,” explains Luc Perino, physician and professor at the faculty of medicine in Lyon. “At the same time, these parasites have undergone their own adaptation to maximize their reproduction at our expense.”

**Immunity on alert**
Fever is the best-known example of adaptation: by raising its temperature, the body makes the parasite...
uncomfortable. Prescribing a drug to remove the fever means suppressing the body’s capacity to fight the infection. “Before treating a symptom, it is wise to find out what category it falls into,” notes Perino.

Sudden environmental changes have consequences, including individuals having difficulty to adapt to their new environment. This is one of the explanations provided by Darwinian medicine for the current upsurge in autoimmune diseases and allergies. “Having evolved in environments rich in parasites, we have developed a powerful immune system,” explains Frédéric Thomas, research scientist in evolutionary biology at the MIVEGEC laboratory in Montpellier (southern France), specialized in infectious diseases. “But since the advent of vaccination and antibiotics, combined with better hygiene and other factors, our immune system is much less solicited.” When underemployed, it tends to bring out the heavy artillery for minor events, such as pollen grains, or even fight against the body that it is meant to protect. Understanding this mechanism has led to the development of a groundbreaking treatment for Crohn’s disease, a chronic intestinal inflammatory condition. Patients ingested worm eggs found in pig intestines. These eggs do not develop in human intestines, but they focus the immune system’s attention. This seemingly simple idea has led to long-lasting remission in clinical trial patients.

Foods tolerated differently around the world

Some digestive disorders can also be explained by environmental changes. Milk is an example: we do not all tolerate it in the same way. “Barely 2% of Chinese adults tolerate cows’ milk, versus 98% of Dutch subjects,” says Perino. This difference can be explained by the selection of a genetic mutation that occurred more than six thousand years ago, when breeding first began. Because of this mutation, some individuals in northern Europe were able to continue to produce lactase—the enzyme that degrades lactose—after weaning, thus increasing their chances of survival during food shortages. This phenomenon is not innocuous in the present era of globalization. Soy, for example, a plant commonly consumed in Asia for millennia, contains phytoestrogens, substances that have hormonal effects in mammals and whose impact on Westerners not used to consuming it is little known. “There is always a risk when people eat plants they didn’t evolve with,” bemoans Michel Raymond, a research scientist at the ISEM.

The Darwinian approach also seems very valuable with regard to age-related conditions. “During evolution, mechanisms for maximizing reproduction have been favored systematically, even if they have harmful effects in the longer term,” states Perino. “Calcium strengthens bones and makes people more resistant, therefore more likely to reproduce. But it is also deposited in arteries, which becomes a problem with age.”

Cancer research could also benefit from this evolutionary approach. “Due to natural selection, our defenses against cancer are globally efficient as long as we can reproduce,” observes Thomas. “This is why the most common cancers (prostate, breast, colorectal) are most often triggered in the post-reproduction phase of life.” Some mechanisms favorable to reproduction may then turn against the individual: for instance, men who produce much testosterone have a reproductive advantage, but a higher risk of developing prostate cancer.

**Shedding light on cancer**

The disease itself, characterized by uncontrolled tumor cell growth, presents a typically Darwinian function. Cancer cells prove to be selfish, reproducing to the detriment of their neighbors—a dysfunction that may date back to the appearance of multicellularity, half a million years ago. “Initially, life was unicellular, so each cell was responsible for its own reproduction,” explains Thomas. “When multicellular beings appeared, specialized cells—called gametes—became responsible for reproduction. In theory, cells now only renew themselves. Yet in case of deregulation, they can regain the old reflexes of unicellular organisms.” These observations prove that our health problems are well worth considering in the light of Darwinian thought.

**Darwin’s Theory of Evolution**

Because of infinitesimal genetic mutations, every individual in a species differs slightly from the others. Mutations that improve an individual’s chance of survival, and therefore of reproducing, are transmitted to the subsequent generations and eventually spread within the species. This mechanism of natural selection was described by Charles Darwin in the mid-19th century.
Stars’ Turbulent Beginnings

**Astrophysics.** Using Europe’s most powerful supercomputers, astrophysicists were able to simulate the effect of two galaxies colliding, and gain better insight into so-called “starbursts.”

BY TOM RIDGWAY

In an isolated galaxy, a star is formed when gas in certain regions becomes dense enough to collapse in on itself. When two galaxies collide, the resulting turbulence ought to slow or even stop the star formation process, yet the opposite occurs: stars form two orders of magnitude faster than in isolated galaxies—in what are known as starbursts.

To explain this seeming paradox, a team of French researchers used two supercomputers\(^1\) to create two simulations of unprecedented detail: a control model of the birth of a star in an isolated galaxy similar to the Milky Way, and a simulation of the conditions created when two galaxies collide. The latter was based on the Antennae Galaxies, two well-known galaxies that began interacting several hundred million years ago and are currently in a starburst phase. This model was so accurate that changes of just a fraction of a light year across could be studied for the first time.\(^3\)

The simulation, which covers 600,000 light years across, revealed that starbursts are caused by the change in the shape of galaxies when they collide. “When two galaxies come in close contact, their gravitational attraction is not uniform,” explains Florent Renaud,\(^4\) team leader of the simulation project. “This pulls them out of shape—much as the Moon does to the Earth’s oceans. But when the two galaxies interpenetrate, these deformations no longer stretch matter but compress it instead.” This compression, which has a gravitational origin, changes the nature of the turbulence, and it is this shift in particular that leads to increased star formation. It also helps lift the veil on how stars do not simply form at the nuclei of two colliding galaxies—where gas is drawn in by gravitational forces—but also across stretches of the galaxy a thousand times larger. “The two effects coexist and are complementary,” adds Renaud.

The researcher and his team have already initiated other collision simulations. In the long term, they hope to model groups of galaxies in which collisions follow one another, such as those observed by Hubble. “We think that gas compression might be even stronger there,” Renaud concludes. \(^\text{II}\)

---

1. The Curie supercomputer at GENCI, Bruyères-le-Châtel (France) and the SuperMUC at the Leibniz Supercomputer Centre, Munich (Germany).
3. The same two calculations on a single CPU would have taken 970 and 1300 years to complete.
4. CEA-Irfu.
Disoriented Bees

By Eddy Delcher

Following up on their 2012 study linking pesticide use to the disruption of foraging bees’ ability to return to their hive, a joint research team decided to measure the impact of environmental parameters, like weather and landscape, on the phenomenon.

As in the previous survey, RFID microchips were fitted on the thorax of about a thousand bees, which allowed the researchers to monitor their return to the hive. Half the bees were exposed to sub-lethal doses of thiamethoxam, an active ingredient found in several insecticides. The foragers were then released approximately one kilometer away from their hives in various types of landscapes and weather conditions.

“In favorable weather, average return rates vary by only 2.5% between control bees and those exposed to the insecticide. In case of inclement weather however, this number jumps to 26%. Complex landscapes, such as bocage and hedges, further increase the gap, bringing it to 35%, compared with 18% in open areas,” explains Mickaël Henry from INRA, who led the study.

Complex landscapes, such as bocage and hedges, further increase the gap, bringing it to 35%, compared with 18% in open areas. “Our next step is to further explore the complexity of environmental and toxicological interactions,” concludes Henry.

PSS: Chemistry in Space

In July, a Russian cargo vessel carried a collection of organic samples up to the “Photochemistry on the Space Station” (PSS), an astrochemistry and exobiology laboratory located on the exterior of the International Space Station. The carbon- and hydrogen-based samples will be exposed to space conditions from October this year until late 2015, before being returned to Earth for analysis. The PSS experiments—financed by the CNRS, CNES, and partner institutions—will help researchers elucidate the chemistry of organic matter in a number of regions of our Universe, including the interstellar medium, the atmosphere of Titan, carbon-rich comets and asteroids, and the surface of Mars.

Ethology

Disoriented Bees

HESS-II: First Pulsar Detected

HESS-II (High Energy Stereoscopic System), the large instrument developed by an international collaboration involving the CNRS and CEA, has detected a pulsed gamma-ray signal in the 30 GeV energy range. This signal is thought to come from the Vela pulsar, which is only the second pulsar ever spotted by a ground-based gamma-ray telescope. This finding reflects the enhanced performance of the Namibia-based HESS-II, upgraded in 2012 with the addition of a fifth, larger (28-meter wide) reflecting telescope. Combined with updated software, this latest Cherenkov array provides vastly improved gamma-ray yields, opening up new observational possibilities in the inner Galaxy.

Sphere: First Images from Exoplanet Hunter

The Spectro-Polarimetric High-Contrast Exoplanet Research Instrument (SPHERE) has sent its first images of giant gas exoplanets and dust discs orbiting nearby stars (up to 300 light years away). Installed on the ESO’s Very Large Telescope in Chile, SPHERE provides results an order of magnitude better than existing instruments. Developed over 12 years by a European consortium including a number of CNRS institutions, the instrument works by removing star glare, thus allowing researchers to directly observe exoplanets a million times fainter than their stars. SPHERE will be made available to researchers in 2015.

PSS: Chemistry in Space

In July, a Russian cargo vessel carried a collection of organic samples up to the “Photochemistry on the Space Station” (PSS), an astrochemistry and exobiology laboratory located on the exterior of the International Space Station. The carbon- and hydrogen-based samples will be exposed to space conditions from October this year until late 2015, before being returned to Earth for analysis. The PSS experiments—financed by the CNRS, CNES, and partner institutions—will help researchers elucidate the chemistry of organic matter in a number of regions of our Universe, including the interstellar medium, the atmosphere of Titan, carbon-rich comets and asteroids, and the surface of Mars.

Brain Imaging at its Best

Neurobiology. Three new basic research studies have used cutting-edge imaging techniques to elucidate brain physiology.

BY CLÉMENTINE WALLACE

In a recent study involving the largest number of left-handed subjects to date, French researchers challenged the common assumption—not yet scientifically proven—that all right-handed individuals think and speak with their left brain, while left-handers do so with their right brain. “Our study was simple in its design, yet it had never been done before,” explains lead author Bernard Mazoyer.

Language and hand preference are both controlled by so-called “lateralized” brain regions, where either the right or the left hemisphere is dominant. But are these two lateralizations correlated? To figure this out, Mazoyer and his colleagues recruited 300 subjects, half of whom were left-handed. All participants underwent functional magnetic resonance imaging (fMRI), to detect which brain regions lit up while they performed a language test. The results identified three groups.

Speak your mind
Most individuals predominantly activated the left hemisphere of their brain when speaking—regardless of hand preference (88% of right-handed and 78% of left-handed participants). In a small proportion of subjects, both hemispheres were activated equally when speaking, independently of preferred handedness (in 15% of left-handers and 12% of right-handers). Finally, less than one percent of participants showed predominant activation of their brain’s right hemisphere when speaking. Interestingly, this only concerned left-handers. “These results tell us that knowing someone’s preferred handedness isn’t enough to determine which hemisphere dominates for language,” says Mazoyer. “Yet a connection does seem to exist in a very small subgroup of left-handers.” Mazoyer is now investigating this phenomenon, which may be genetically determined. “Its rarity does not make it a defect in any way. Our

1. B. Mazoyer et al., “Gaussian mixture modeling of hemispheric lateralization for language in a large sample of healthy individuals balanced for handedness,” PLOS One, 2014. 9(6):e101165. 2. Director of the Neurofunctional Imaging Group (UMR5296 / CEA / Université de Bordeaux).
tests showed that these individuals had the same cognitive abilities as the others.”

**Scent of a region**

In another imaging study, scientists used functional Ultrasound (fUS) to visualize, for the first time, the activity of the anterior piriform cortex (aPC), a brain region involved in olfaction. “The aPC is deeply buried inside the brain, so it was inaccessible with standard functional imaging until now,” explains Hirac Gurden, who led the study. The use of fUS allows to detect variations in blood volumes inside tissues with unprecedented time/space resolution. In the brain, variations in blood volumes mimic those in neuronal activity—the higher the activity, the more blood is needed, and the stronger the ultrasound signal.

The team showed that when stimulating anesthetized rats with different types of smell (freshly cut grass or banana, for example), the aPC responded in the same way, by activating all its neurons with no distinguishable odor-specific pattern. “In that matter, the aPC behaves differently than the olfactory bulb, another structure involved in olfaction, which has been shown to exhibit different patterns of activation depending on the smell,” explains Gurden, who confirmed these results by fUS. “Until now, we knew which structures were associated with olfaction, but had little understanding of their respective roles.”

Gurden hypothesizes that the aPC might be a structure that integrates information gathered in the bulb over time: “For instance, the bulb first perceives the hundreds of different molecules, then the aPC integrates what this mass of data corresponds to.” As fUS becomes more powerful, it might soon be possible to use it in alert animals performing behavioral tasks.

**Individual neurons**

In a third study, researchers pushed functional imaging to new limits: the detection of the activity of a single neuron. To do so, they used MEMRI, a magnetic resonance imaging method enhanced with manganese—a contrast agent that accumulates inside neurons when they are activated. While MEMRI made it possible to get a mean reading of the signal from clusters of hundreds of neurons, it had never been used to record that of a single one.

“Two elements were necessary to conduct our experiments: first, we had to design tiny detectors for the MRI—about 2 mm in diameter—to be able to get down to a level of resolution of individual neurons,” explains lead author Luisa Ciobanu. “Secondly, we worked with Aplysia, mollusks with very few neurons that exhibit enormous cell bodies.” In animals with smaller neurons, this level of precision could not be achieved.

Researchers compared MEMRI images of the buccal ganglia of three Aplysia groups: one left unstimulated (used as a control), one fed with algae, and one that smelled algae but did not consume it. The results showed that the same neurons of the buccal ganglia responded differently when animals smelled or ate algae, with consumption leading to higher activation. “This technique, which allows us to identify exactly which neurons are involved in different functions, significantly improves the precision of neuronal activity mapping,” concludes Ciobanu.
Mathematics

When Numbers Help you Run

BY ARBY GHARIBIAN

While devising the best way to run a race used to be a matter of experience and training, it now also depends on advanced mathematics. By modeling running in the form of equations, and then solving them, researchers can predict optimal strategies to help a runner cover a distance in the shortest amount of time.1

“We have developed a model involving several differential equations for the unknown variables of the runner,” explains Amandine Aftalion of the CNRS,2 who co-authored the study. “These include velocity, propulsion force, and anaerobic energy, which the body uses when in oxygen deficit. The model relies on two basic principles of physics: energy is preserved, and velocity variation is equal to the sum of all the forces. We have incorporated physiological parameters to identify the type of runner involved, including maximal oxygen uptake and total available anaerobic energy.”

The model can provide “instantaneous” measurements for velocity and energy expenditure, in other words, indicate their real-time values (rather than a mean figure) at any moment of the run. It couples the different variables so that none can be solved independently of the others, but still a full numerical solution can be obtained. This model could potentially be used to develop coaching software able to generate customized training regimens, or running applications that race against the user by simulating the optimal strategy.

“Our predictions closely match the actual strategies used by runners, from Olympians to regional champions,” adds Aftalion. “In fact, our numerical solver is able to identify the physiological parameters by fitting the time measurements of a given race. In the future, we hope to apply these computations to help our Olympic teams win medals, and adapt our modeling expertise to other sports such as cycling, swimming, or triathlon.”


Medicine

Early Detection of Lung Tumors

BY CLÉMENTINE WALLACE

French scientists were recently able to detect millimeter-sized tumors grafted inside the lungs of living mice models using the newly-available Ultra-short Echo-Time (UTE) Magnetic Resonance Imaging (MRI), combined with nano-sized contrast agents.

Until now, MRI—one of the most adequate techniques for identifying diseases in the brain, heart, or liver—was not adapted to lung exploration, mostly because of the alveolar air/tissue interface. “Today, we have to rely on computed tomography, which is a good tool but can only detect tumors of a certain size. This is why lung cancer is usually diagnosed at a late stage,” explains Yannick Crémiel, who led the study. “But the latest UTE MRI technology can overcome these intrinsic obstacles.”

The team also used three-nanometer diameter particles, one of the best contrast agents available. “The immune system cannot detect such tiny particles, so they accumulate inside tumors very effectively,” adds the scientist.

The researchers’ main innovation, however, lies in testing a novel route of administration: inhalation. In their experiments, inhaling the contrast agent

Ground vibrations from sources like machines, wind, or ocean swell are continually picked up by seismometers, potentially blurring seismic wave readings. But this so-called "seismic noise" is no mere background nuisance. By interpreting its evolutions over time, French geoscientists from the IST1 and the IGP2, along with Japanese researchers,3 have developed a novel method for mapping disturbances to the Earth’s crust. The resulting study,4 using data from Japan’s magnitude-9 earthquake in March 2011, reveals how it affected volcanic areas.

Thanks to the 800 seismic detectors of Japan’s Hi-net, one of the world’s densest seismograph networks, the Tohoku-Oki mega-quake, notorious for the deadly tsunami it set off, was extremely well recorded. From this source, the scientists looked at seismic noise data collected 6 months before and after the quake to track a year of changes in seismic wave velocity, with variations reflecting the damage it caused underground.

Florent Brenguier of the IST compares the results to “an ultrasound scan showing how the Earth’s interior evolved over time.” Much to the team’s surprise, the most disturbed underground spots were not near the quake’s epicenter where shaking was the strongest, but rather in volcanic zones, mainly around Mount Fuji. There, seismic velocity clearly decreased after the seism. The researchers believe this change was caused by an upflow of high-pressure volcanic fluids from the depths to the upper crust—which occurred after the seismic strain opened up cracks. As volcanic fluids build up pressure before major blasts, seismic noise-based monitoring emerges as a new tool for weighing the risk of future eruptions.

The team is currently examining seismic noise from the magnitude-6 earthquake in the San Francisco Bay area in August 2014. Brenguier anticipates “speeding up seismic noise analysis with super-calculators” in a prospective partnership with the IDRIS5 center for high-performance calculations.6

---

1. Institut des sciences de la terre (CNRS / Université Joseph Fourier / Université de Savoie / IRD / IFSTTAR). 2. Institut de physique du globe de Paris (CNRS / Université Paris Diderot). 3. From the National Research Institute for Earth Science and Disaster Prevention (NIED) and the University of Tokyo. 4. F. Brenguier et al., “Mapping pressurized volcanic fluids from induced crustal seismic velocity drops,” Science, 2014: 345: 80-2. 5. Institut du développement et des ressources en informatique scientifique (CNRS).

---

florent.brenguier@ujf-grenoble.fr

Seismic map of Japan showing areas of high volcanic fluid pressure (orange), Quaternary volcanoes (triangles), and central Japan’s volcanic front (red line).
The Attention Economy

Social Sciences. Films, books, websites... In today’s information-flooded world, attracting the public’s attention has become a key economic challenge. Researcher Yves Citton explains the phenomenon.

How would you define the “attention economy”?

Yves Citton: This notion, used since 1996, was actually developed by the American psychologist and economist Herbert Simon in an article published in 1971 where he compared past civilizations, characterized as “information-poor societies,” with modern-day “information-rich” societies. Today we all have access to a quantity of pertinent data that far exceeds our attentional capacities. For this reason, our analyses must incorporate a new and very important scarcity: attention, which must now focus on the reception of cultural assets rather than solely on their production. Today, the main difficulty is not so much to produce a film, a book, or a website, but to attract the attention of an over-solicited public.

Is this a new phenomenon?

Y.C.: No. As art historian Jonathan Crary has convincingly argued, this type of question was already raised in the period between 1870 and 1920. The French sociologist Gabriel Tarde (1843-1904), for example, was already keenly aware that industrialization leads to an overproduction of goods, a situation in which issues of attention (which advertising was then beginning to address) become a key factor in the economy. But recent economic approaches are giving increasing importance to reception and consumption. What’s new is the acceleration induced by the mass dissemination of technological developments like personal computers, the Internet, and search engine algorithms.

How can attention be a commodity, and even a key commodity?

Y.C.: As the German sociologist and architect Georg Franck explained in the early 1990s, a number of conditions must be met for attention to be considered a “new currency.” We must first be able to reduce the infinite diversity of actual attentions down to a standard unit of measurement (like television audience ratings before, or Google PageRank listings today). Secondly, attention, which is a transient phenomenon, needs to be capitalized into what is referred to as fame or prominence. Lastly, institutions must be developed that function like banks for the currency of attention—these are the mass media outlets, which create content to attract an audience, and then sell it to advertisers.

How does the attention economy measure up in terms of research?

Y.C.: We have just published a collective work that examines potentially positive or negative feedback from a number of disciplines about the attention economy. It seeks to clarify why it is vital to rethink the economy in terms of attention, but also why it is wholly insufficient to reduce attention to a purely economic issue. What all of these cross-analyses show is that attential questions are at the core of
Due to their useful properties, nanoparticles are widely used in consumer products and electronics, even if their impact on health or the environment is not yet fully known. Researchers have recently highlighted the potential toxicity of one such particle, carbon nanotubes (CNTs), by demonstrating that a significant number can cross the pulmonary barrier and accumulate in various organs when inhaled by mice.1 “Twenty micrograms of CNTs were administered to mice by pharyngeal aspiration,” explains Vincent Dive from the CEA, who co-authored the study. “We then studied the biodistribution of the CNTs over 12 months, both by in vivo radio-imaging and ex vivo analysis of tissue samples using electron microscopy.”

A truly multidisciplinary research effort, this work brought together four groups of the CEA2,3 and CNRS4 researchers, including chemists, physicists, and biologists. The CEA team synthesized CNTs and radiolabeled them by replacing stable carbon atoms (12C) with radioactive ones (14C). This allowed a highly-sensitive detection of CNTs in the liver, spleen, and bone marrow, thus demonstrating their ability to cross the air-blood barrier of the lungs.

Through the follow-up study, the researchers recorded the exact number of CNTs in each organ, and of CNTs eventually entered the bloodstream and relocated to other organs. Electron microscopy showed that CNT molecular structure apparently remained intact, suggesting that the prolonged presence of CNTs in the body did not modify or reduce their potential toxicity in any way. “Collaboration not only enabled us to find the proverbial needle in the haystack,” concludes Dive, “but it also helped to see the biodistribution of CNTs in a holistic way, under conditions that are more representative of the actual risks in our daily environment.” II

Nanotoxicology

The Pulmonary Sieve

BY ARBY GHRIBIAN

Due to their useful properties, nanoparticles are widely used in consumer products and electronics, even if their impact on health or the environment is not yet fully known. Researchers have recently highlighted the potential toxicity of one such particle, carbon nanotubes (CNTs), by demonstrating that a significant number can cross the pulmonary barrier and accumulate in various organs when inhaled by mice.1 “Twenty micrograms of CNTs were administered to mice by pharyngeal aspiration,” explains Vincent Dive from the CEA, who co-authored the study. “We then studied the biodistribution of the CNTs over 12 months, both by in vivo radio-imaging and ex vivo analysis of tissue samples using electron microscopy.”

A truly multidisciplinary research effort, this work brought together four groups of the CEA2,3 and CNRS4 researchers, including chemists, physicists, and biologists. The CEA team synthesized CNTs and radiolabeled them by replacing stable carbon atoms (12C) with radioactive ones (14C). This allowed a highly-sensitive detection of CNTs in the liver, spleen, and bone marrow, thus demonstrating their ability to cross the air-blood barrier of the lungs.

Through the follow-up study, the researchers recorded the exact number of CNTs in each organ, and of CNTs eventually entered the bloodstream and relocated to other organs. Electron microscopy showed that CNT molecular structure apparently remained intact, suggesting that the prolonged presence of CNTs in the body did not modify or reduce their potential toxicity in any way. “Collaboration not only enabled us to find the proverbial needle in the haystack,” concludes Dive, “but it also helped to see the biodistribution of CNTs in a holistic way, under conditions that are more representative of the actual risks in our daily environment.” II

New Biomarkers Help Diagnose Alzheimer’s

What if Alzheimer’s disease could be diagnosed before its clinical symptoms even appear? This is the ambitious goal of the Paris-based start-up Alzohis, cofounded by Myriam Taverna and Romain Verpillot, who are hoping to market a new diagnostic test in the short-term.

Alzheimer’s disease is a progressive form of dementia that damages and eventually kills brain cells, leading to memory loss and changes in thinking patterns and behavior. Over time, the brain shrinks as neurons wither and die, symptoms gradually worsen and eventually interfere with daily life. At the biological level, aggregates of a protein fragment called beta-amyloid build up between neurons to form plaques, and twisted fragments or tangles of a protein called tau form inside cells. Scientists are still not sure what causes cell death, but amyloid plaques and neurofibrillary tangles are the prime suspects.

A latest of time
The latest figures show that a staggering 36 million people worldwide have Alzheimer’s disease or related dementia. Yet only one in four cases is diagnosed. Current testing methods rely on clinical exams and questionnaires that assess cognitive abilities. These exams are designed to document mental decline and are thus drawn out over a period of several months, sometimes years. By the time functional and structural changes are detected in the brain by medical imaging, the disease is already at a fairly advanced stage.

In recent years, several attempts have been made to identify biomarkers that would help physicians diagnose the disease at an earlier stage. Many researchers looked for signs of disease in the cerebral spinal fluid, which comes directly from cells in the brain. This is how Taverna and Verpillot’s quest for identifying biomarkers began. “We were screening samples of cerebral spinal fluid for peptides derived from amyloid plaques,” says Verpillot. The researchers didn’t find what they were looking for, but as often in science they stumbled upon something even more interesting in the process. They noticed that the levels of several neurotransmitters, the chemical messengers that relay signals between neurons, were different in Alzheimer’s patients than in healthy individuals. “The analysis of several neurotransmitters gives a sort of molecular signature,” adds the scientist. “This can be used to calculate a diagnostic score, which represents a person’s likelihood of having the condition.”

Cheaper, better, faster
Blind tested on 150 Alzheimer’s patients, this diagnostic assay has so far identified the disease with an unprecedented 97% success rate. Alzohis hopes to test up to 500 patients by the end of the year with the help of collaborators in Germany.1 Moreover, the test is rapid and affordable and preliminary results show that the biomarkers can also be detected in the blood, which is much easier and less...
In brief

Improving Electron Microscopy

On September 12, the CNRS and Hitachi High Technologies corporation (HHT) signed a partnership agreement. It formalizes over five years of fruitful collaboration between the Japanese company and the CNRS’s CEMES, which have led to the development of a unique electron microscope, the I2TEM (in situ interferometry transmission electron microscope), inaugurated in spring 2013. I2TEM was designed to make significant advances in the research and development of next-generation semiconductors. The new partnership is a three-pronged project. One of its aims is to launch original experiments with I2TEM to display the vast capabilities of the instrument to future users. Besides, the CEMES has developed new electron sources, such as carbon nano-cones, patented by the CNRS, which Hitachi wishes to use for new technologies. Finally, the most ambitious project focuses on FemtoTEM microscopy, which aims to develop ultra-fast coherent TEM to study the dynamics of ultra-fast physical processes.

Exploiting Physiological Periodic Signals

Aqsitania, a company created last February, has developed a cutting edge technology for describing, understanding, and exploiting periodic signals. It is based on 20 years’ work by CNRS researcher and company founder Patrick Hanusse. The innovative process, protected by several patents, for the analysis of physiological parameters such as respiratory ventilation or heart beats. Applied to data collected by healthcare institutions or patients at home, it could help establish diagnosis and the appropriate treatment. The company has just raised €400,000 for its R&D development.

Contact

contact@alzohis.com

www.aqsitania.com

1. Centre d’élaboration de matériaux et d’études structurelles.
Pump jacks in operation in an oil and gas field in California (US).
Gas, Energy of Transition?

REPORT BY LYDIA BEN YITZHAK, LAURE CAILLOCE, AND YAROSLAV PIGENET

Environment  As the world prepares for energy transition, it is still in dire need of a storable energy source able to back up intermittent renewable power supplies. In this context, the discovery of new non-conventional sources of energy has led some to claim that the 21st century will be the golden age of gas, the least detrimental fossil fuel.

What do the CEO of the tube-manufacturing multinational Vallourec, Greenpeace Germany, and the International Energy Agency (IEA) have in common? They all believe that, no matter its shortcomings, methane (more often known as natural gas) will play a leading role in energy transition. And yet this gas, like oil and coal, has two significant drawbacks: it generates greenhouse gases, and, being a fossil fuel, it is non-renewable. “The development of new power sources must take into account the twin constraints of long-term sustainable energy to tackle climate change, and the increasing scarcity of conventional supplies,” explains economist Patrick Criqui of the Pacte-Edden Laboratory. “The fact is that, despite the increasing use of renewable energy sources such as wind, solar, and biomass, there is no short- to medium-term solution for the complete substitution of fossil fuels,” he adds. As a result, many specialists agree that gas, whether of conventional origin or not (see box p 20), will play a crucial role as a transitional energy source. In France, the importance given to gas in the Energy Transition Bill proposed by French Environment Minister Ségolène Royal will be debated this autumn by the French Parliament.

The least polluting fossil fuel

Gas, which is easy to store and distribute, is a versatile and readily available energy source. During peaks in electricity consumption, it is the ideal backup for wind and solar energy, intermittent by nature. “Today, in major industrial countries, photovoltaic solar and wind technologies alone cannot generate enough electricity to meet stable or ...
Conventional natural gas is extracted by drilling vertical wells in these reservoir rock deposits. Non-conventional gas, on the other hand, is the gas that still remains in the source rock after extraction or which has accumulated in rocks that are particularly difficult to access.

Geologists estimate that between 10% and 40% of the hydrocarbons produced in the source rock remain there while only a small fraction of the hydrocarbons expelled end up trapped in reservoir rocks. It is thus believed that non-conventional deposits today could represent as much as all the conventional deposits exploited since the beginning of the gas industry. In *Are we entering a Golden Age of Gas?* a document published in 2011, the IEA even thought it likely that gas consumption would rise by 50% by 2035, making up more than a quarter of the world’s total energy consumption.

**Reserve estimates in question**

This optimism is by no means unanimous, especially with regard to the IEA’s estimate of gas reserves that are exploitable at an acceptable economic, social, and environmental cost. According to Goffé, “current assessments are controversial, because little is known about these reserves. In Poland, for instance, where they were thought to...”

---

Global distribution of natural gas resources

Projected primary energy consumption

Estimated natural gas resources by region (Tm³)

Estimated per capita consumption of natural gas (tons of oil equivalent, toe)

Projected primary energy consumption in millions of toe (tons of oil equivalent)

Trends in gas prices

Using a model based on a real but little proactive energy-climate policy at both European and global level by 2050, which seems the most likely scenario, European researchers at the SECURE consortium have forecast future trends for the energy mix in Europe and the world. It shows that the share of gas would increase until 2025, thus limiting the use of coal.

Trends in gas prices

By continent, in dollars per million BTU (British Thermal Units)

Until 2005, gas prices kept up with oil prices, and were almost identical on all continents. Decoupling between gas and oil prices first occurred in 2006, when exploitation of source rock gas started becoming widespread in the US. After 2009, US gas prices continued to fall, while in Asia, and to a lesser extent in Europe, negotiated gas rates started to rise again, realigning on oil prices.
Hydraulic fracturing and its environmental impact

In hydraulic fracturing, sometimes called fracking, a well is drilled vertically down to the source rock. From there, one or more horizontal wells are drilled into the rock. A mixture of sand and liquid under pressure is then injected into these galleries so as to fracture the rock. The micro-cracks produced under pressure and kept open by the sand grains release part of the gas trapped in the source rock. This gas, together with the fracking fluid, is then pumped back up to the surface to be used or reprocessed.

Yet the fact remains that from the 1970s onwards, the gas industry, faced with the rapid depletion of conventional reserves and encouraged by soaring prices, adapted and developed techniques to release and extract at least a tiny fraction of this non-conventional gas resource. And during the last decade, a combination of expertise in horizontal drilling and improved hydraulic fracturing techniques led to the first economic exploitation of source rock gas (see diagram left).

Fracking’s dirty beginnings

“Hydraulic fracturing was invented in 1949. More than a million wells have already been fractured for all sorts of uses, not only for non-conventional gas, but also for geothermal energy, conventional petroleum, and water,” explains Goffé. Yet the development of this supposedly tried and tested method got off to a bad start. "It is an unfortunate truth that the first series of drillings, which led to the current ‘shale’ gas boom in the US, were mostly carried out without any real risk assessment, without consulting the population, and in a completely unregulated way," says Criqui.

This resulted in significant environmental and human costs, hence today’s intense suspicion, particularly in Europe, of source rock gas exploitation. Furthermore, while landowners in the US also own the resources beneath their property and thus make a profit from drilling, in most countries, the subsurface belongs to the state, which is the sole beneficiary of its exploitation through concessions. “In this case, landowners have to put up with the inconvenience, without reaping any benefits,” explains Normand Mousseau, a physics professor at the University of Montreal (Canada), and author of several books and articles about non-conventional gas.

The main risks identified

“True enough, the setbacks suffered by the US operators taught us what not to do,” adds Goffé. Although opinions on non-conventional gas exploitation do vary, there is now a relative consensus about its main social and environmental risks and impacts: groundwater contamination by hydrocarbons and chemical additives released when fracking sludge leaks from wells; soil pollution as a result of poor reprocessing or even illegal spread of used fracking fluid; impact on the landscape of the incessant movement of trucks and proliferation of wells owing to their rapidly falling yields; excessive water consumption during the fracking stage, to the detriment of household and agricultural use; emissions of greenhouse gases, especially methane, during operation. “We know how to prevent these risks or at least...
find solutions through best practice such as fracking fluid reprocessing and recycling,” says Dollet. “But of course, best practice has a cost, which could deter potential operators, especially in Europe.”

**The necessary diversification of energy sources**

In fact, most experts believe that even if Europe started to exploit source rock gas, production costs would be equivalent to, or even exceed, international prices. “Concerning the exploitation of non-conventional gas, the US model is unlikely to be transposed to the rest of the world, due to both geological conditions and the specific nature of the US oil industry,” Criqui believes. “Nonetheless, as conventional resources are running out and gas has become two to three times more expensive in Europe than in the US, the question is now how to supply the Old Continent with gas, while reconciling security of supply with industry competitiveness.” According to Criqui, Europe will in any case need gas if only to meet demand for electricity without relying too heavily on coal, the dirtiest but cheapest fossil fuel (see infographics p 2). The recent decision by the German Government to allow source rock gas exploration with a view to exploitation reflects this compromise. “Gas is neither a panacea nor a disaster for energy transition, but it plays a key role in the diversification of energy sources that will make this transition possible,” Dollet concludes.

---

**Is there an alternative to Fracking?**

According to geologist Bruno Goffé, “fracking is the only efficient, controlled technique for the recovery of source rock gas, and will continue to be for the foreseeable future.” However, a study published by the French National Alliance for the Coordination of Energy Research (ANCRE) has identified several research avenues for a more efficient and environmentally-friendly exploitation of non-conventional deposits, including the possibility of doing away with fracking altogether. To obtain a more reliable assessment of France’s reserves and optimize output from any future wells, ANCRE suggests addressing the lack of knowledge about France’s subsurface, made up of patchy data collected in the 1950s and 1960s, and improving understanding of the physical and chemical properties of the source rocks where the gas is trapped. ANCRE is also looking at the potential development of fracking fluids other than water—including CO2 and butane—and considering the possibility of using heat or electricity for fracturing as an alternative to fracking. Such research would require setting up experimental sites, which is impossible since the French government banned shale gas exploration research in July 2012.
Exploring France’s Potential

Shale gas, which can no longer be exploited legally in France, is not the only gas in the country’s subsurface. Coal bed methane, found in the former coalfields of Lorraine and Nord-Pas-de-Calais (eastern and northern France, respectively), holds out great promise.

According to estimates confirmed by the French Institute of Petroleum, the Lorraine (eastern France) and Nord-Pas-de-Calais (northern France) coalfields contain 370 billion cubic meters of coal bed methane, the equivalent of 10 years of French gas consumption. This is more than the amount extracted over 50 years of operation of the Lacq natural gas deposit (south-western France), which was permanently closed in November 2013. This home-grown gas, made up of more than 90% methane, is getting a lot of attention today. It is France’s last chance to produce gas, now that fracking has been permanently banned and that no serious alternatives are expected to crop up in the foreseeable future (see box p 23). It could make a small but significant contribution to the energy independence of a country that had to import nearly all its gas in 2013, and ensure the transition towards a model based on a greater proportion of renewable energy sources. The French government has delivered an exploration license to the Australian company EGL (European Gas Limited) to determine the feasibility and conditions of possible exploitation.

Stimulating rather than fracking

And yet, coal bed methane is nothing new. “The old coal miners knew it well,” says Raymond Michels, a geochemist at the Géoressources laboratory. Natural gas from coal deposits has three different names depending on the way it is extracted. When the gas is captured while coal is being mined—mostly to prevent firedamp explosions caused by methane buildup in the galleries—it is known as coal mine methane (CMM). When it is pumped out of mine galleries that are no longer in use, it is called abandoned mine methane (AMM). This type of gas has been exploited by the Gazonor company (taken over by EGL in 2008) in the Nord-Pas-de-Calais coalfield. Lastly, the gas extracted by drilling into coal seams that have never before been exploited is dubbed coal bed methane (CBM). This is the gas that EGL hopes to exploit in Lorraine. Coal bed methane is sometimes improperly named coal gas. In fact, genuine coal gas, a mixture of methane and carbon monoxide, is not a natural gas but a by-product of the transformation of coal to coke for the steel industry.
developed in North America and Australia, where coal bed methane is already being extracted. According to researchers, it is nothing like the fracking used to extract shale gas. In fracking, large amounts of water (with suitable additives) are pumped down so as to generate excess pressure and fracture the rock where the gas is trapped. By contrast, depressurization is necessary to extract coal bed methane. “The water naturally present in the rock is pumped out, and the pressure deficit created forces the gas out of the coal micro-cracks,” Michels explains.

This is not the only innovation. Horizontal drilling, a method transferred directly from the oil industry, should also be used. “From a vertical well, we drill horizontal wells in a star-shaped pattern that follow the coal seams,” Michels explains. This makes it possible to exploit the resource efficiently, while reducing the number of surface wellheads and subsequent environmental nuisance. In all, EGL, which has already sunk five exploratory wells in Lorraine, estimates that 30 production sites will eventually be in operation in the region, with exploitation scheduled to start within the next three years. No wells have yet been sunk by EGL in Nord-Pas-de-Calais, where the deposit is thought to represent the equivalent of two years’ gas consumption in France.

No exploitation for at least 10 years

“We’re still in an exploratory phase,” points out Yann Gunzburger, a researcher at the Géoressources Laboratory and coordinator of the GazHouille project, a multidisciplinary group of researchers (geologists, economists, legal experts, social psychologists, etc.) in charge of assessing the risks and challenges of coal bed methane exploitation in Lorraine. “We cannot predict what the public authorities’ decision will be. In any case, should exploitation be feasible and authorized, it would not begin before at least 5 to 10 years.” Initial public opinion surveys show that there is interest in coal bed methane and seemingly little opposition, especially as the currently preferred scenario for its commercialization would be beneficial to Lorraine’s economy. “Rather than feeding the gas into the national network, where it would be sold at the market price, the idea would be to sell it at a cheaper price to local industry,” Gunzburger explains. In the best-case scenario, this might attract new companies to a region badly hit by unemployment.  

L.C.
The main advantage of producing gas from biomass or from renewable energy is that it helps curb greenhouse gas emissions. Indeed, biogas recycles carbon that is already present and available in our immediate environment. Conversely, the extraction and combustion of fossil methane—natural gas—releases carbon trapped underground for millions of years into the atmosphere, which is inconsistent with reducing greenhouse gas emissions. Furthermore, using a renewable gas is a step toward energy independence.

Promoting a circular economy

Biogas is the gas produced by the spontaneous fermentation of animal or plant organic matter in an oxygen-free environment, a process known as methanization. A significant advantage of large-scale biogas production is that it is part of a circular economy. Mainly because it makes it possible to recycle all sorts of organic wastes like those produced by agriculture (slurry and other farm by-products), common households, and certain industries, such as sludge from water treatment plants.

Biogas can be directly captured in landfills but it can also be produced through various recycling processes. For example, biogas can be produced from slurry from farms, sludge from water treatment plants, or even kitchen scraps. This makes biogas a versatile and sustainable alternative to fossil fuels.
example, industrial crushers can extract organic matter from packaging, making it possible to use waste from supermarkets, as well as from canteens and restaurants. Cooking oil is particularly sought after, since fats can optimize methanization. One of the most striking recycling applications comes from Obernai, in the Alsace region (north-eastern France), where sludge is added with sauerkraut juice. This juice was previously discarded in water treatment plants, where it accounted for 30,000 m³ of waste water. This excellent recycling solution is in line with the 2012 French law that requires producers to recycle biowaste when it exceeds 120 tons per year. In 2016, this threshold will be lowered to 10 tons per year. At the end of the methanization process, a nitrogen-rich residue is obtained, which can be used as an agricultural fertilizer. Switzerland has however banned this type of manuring for fear of uncontrolled dissemination of micropollutants and pharmaceutical waste.

In France today, this process is mainly aimed at self-sufficiency: methanization is made at the farm, where farmers use the biogas from their slurry and manure to heat their buildings. Any surplus gas is then converted to electricity and fed into the grid. This is known as co-generation. In fact, conversion to electricity results in a 65% loss of energy efficiency. Although the gas could be fed back into the natural gas network, France lags behind in this field. Negotiations with industrial actors are underway to set a buy-back price for this gas, along the same principle as the buy-back of kilowatt-hours of electricity for certain renewable energy sources. In Chile, this connection to the natural gas network has been operating smoothly for the past five years.

The problem of inorganic input
Methanization is an environmentally-friendly solution as long as it follows certain rules. France can learn from the setbacks suffered by its neighbors, especially Germany and Belgium, where gas production units are facing supply issues. Since the digester—the large tank where methanization occurs—needs a homogeneous organic input, some producers are forced to use dedicated crops, while others spend a fortune buying suitable organic material, sometimes from other countries. Belgium, for instance, buys stocks of organic matter, common household refuse, and used frying oil from northern France at great expense.

Dedicated crops, in other words plants specifically grown to feed a digester, can lead to conflicts over land use, since they may replace food crops. Germany is backtracking on the subsidizing of dedicated maize crops, since it caused an imbalance in the agricultural land market, with adverse effects on consumer prices for electricity. In general, the proximity and availability of resources, such as the cost of collecting bio-waste, are essential factors to take into account.

Hythane, the Optimum Biogas

Obtaining biogas is easy enough: take some biomass, whatever its origin, and let it break down. The organic matter releases biogas (CH₄ (methane) + CO₂) as it decomposes via a fermentation process (methanization). The organic material is broken down by various strains of bacteria. Fermentation is said to be wet when dry material represents less than 15%, and dry when it exceeds 25%. This process also produces hydrogen whose energy efficiency is three times greater than that of methane, and which only generates heat and water. The ideal mixture, called hythane, is made up of 80% methane and 20% hydrogen, and it can be fed back into the gas distribution network. When burnt, the mixture reduces CO₂ emissions by a fifth. In Sweden for instance, collected waste already undergoes methanization with production of hydrogen. Marie-Thérèse Giudici-Orticoni works on stabilizing bacterial hydrogen production through improved microbiological understanding of the metabolism and interactions of bacteria. She specifically belongs to a consortium which studies how the interactions between bacteria control their metabolism. The ultimate goal is to optimize the system and be able to propose pilot projects with mixtures of sewage sludge and household waste.

“Thermochemical processes for the conversion of biomass into methane and/or electricity also use forest resources (lignocellulose) which can be optimally managed to minimize CO₂ emissions,” points out Alain Dollet, in charge of the CNRS’s Energy Task Force. This is the objective of the CNRS’s FOREVER project, which focuses on sustainable technologies for recovering energy from such resources.

Making better use of renewable energy sources
“Besides these co-generation units, in which a methanizer produces biogas and electricity, there are hybrid systems that use the gas to stabilize the production of electricity from intermittent renewable energy sources,” Dollet explains. “The PEGASE project, led by the CNRS’s PROMES laboratory at the THEMIS solar power plant in southern France, is developing a solar plant concept where air expanded in a turbine (which generates electricity) is heated not only by concentrated solar energy but also by a back-up gas produced from biomass, which keeps the production of the turbine at a constant level.”

L.B.Y.
Clément Sanchez is an optimist. Definitely not the kind of person who believes that the world is doomed, or that the energy crisis can't be solved. Hardly surprising: his research into the chemistry of hybrid materials, a field involving the creation of customized materials that combine the features of the inorganic world with the properties of the organic or living world, has led to a host of highly promising applications.

“The chemistry of hybrid materials consists, for example, in giving a simple piece of transparent glass both flexibility and the vivid color of a flower petal, so as to create a material with very efficient mechanical and optical properties,” explains the 65-year-old chemist, former CNRS senior researcher and professor at the Ecole Polytechnique, who now holds a professor position at the Collège de France. “The range of possibilities is only bound by our imagination,” he adds. “Just looking at renewables and the environment, we can make photovoltaic cells on hard or flexible substrates, sensors able to detect toxic materials, photo-catalysts that can clear liquids of pollution, catalysts that change heavy hydrocarbons into petrol with minimal energy expenditure, and so on.”

Pioneer of hybrid materials
It is no wonder that Sanchez received the 2014 Eni Protection of the Environment Prize, considered to be the most prestigious award in the field. Last June, French chemist Clément Sanchez was awarded the 2014 Eni Protection of the Environment Prize, considered to be the most prestigious award in the field.

Architect of the infinitesimally small
Encouraged by Livage, whom he considers to be his mentor, Sanchez undertook theoretical and experimental research of a very high level from the 1980s onward. The time was ripe for hybrid materials chemistry. With his early-acquired knowledge of organic chemistry, and that of inorganic chemistry—which he studied while preparing his PhD—Sanchez was to become one of the discipline's uncontested pioneers.

When asked “why chemistry?” he answers without hesitation: “Because everything is chemistry! Our bodies, the planets, the galaxies, even our love stories, to some extent. It’s just a collection of interacting molecules and chemical systems, a huge and extraordinary Lego set. And playing with the Lego of matter is great fun!”

Five Key Dates

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1949</td>
<td>Born in Paris</td>
</tr>
<tr>
<td>1978</td>
<td>Joins the CNRS</td>
</tr>
<tr>
<td>1995</td>
<td>Awarded the CNRS Silver Medal</td>
</tr>
<tr>
<td>2011</td>
<td>Elected member of the French Academy of Sciences, appointed professor at the Collège de France</td>
</tr>
<tr>
<td>2014</td>
<td>Winner of the 2014 Eni Protection of the Environment Prize</td>
</tr>
</tbody>
</table>

1. At the laboratory Chimie de la matière condensée of Paris (CNRS / UPMC / Collège de France).
The rules of the game are as follows: molecules play the role of the basic building blocks. To make hybrid materials, Sanchez and his team use “soft chemistry,” in other words, polymerization reactions in temperate conditions so as to preserve the organic material, much more fragile than the inorganic material. Before building hybrid architectures, the chemists select the functions they need, frequently drawing inspiration from biological materials.

But just how can such functions be incorporated into the molecular structure? To explain this, Sanchez uses an application, still under development, which he finds extremely promising: “We’re in the process of creating therapeutic vectors that can identify, target, and destroy cancer cells efficiently and locally. We equip our vectors with molecules that recognize organic groups overexpressed by cancer cells, which lets them target the tumor. We also make these vectors magnetically or optically active, for example by incorporating tiny particles of iron oxide or gold into them. Then, when they are in the immediate proximity of the tumor, we excite them with a magnetic or optical field, which heats the tumor locally and destroys it. The heat can also make it easier to release the drugs contained within the large number of pores in our vector, which we have deliberately made porous. Hybrid materials chemistry allows us to create complex, multifunctional architectures.”

Co-author of over 50 patents
In fact, such architectures are so complex and novel that Sanchez is a co-author of more than 50 patents, has won around 15 national and international awards, and has been elected to five Academies of Science (in France and Europe). And he is very much in demand all over the world. “I’ve been offered many jobs abroad, some of them with a far higher salary than mine,” he says. “But the reason I’ve decided to stay in France is that the French system still lets researchers enjoy considerable freedom to carry out both basic and applied research, and recruit young, creative and talented collaborators.” The very ones who will become tomorrow’s top international hybrid materials chemists. And chances are, they will be just as optimistic.

“Everything is chemistry! Our bodies, the planets, the galaxies, even our love stories, to some extent.”

© P. IMBERT/COLLÈGE DE FRANCE
Scanning the Past

Materials. Raman spectroscopy is a technique that analyzes the external structure of a material in a non-destructive manner. In recent years, researchers have been using this method to study rock paintings, museum exhibits, and stained-glass windows without damaging them.

BY AUDREY DIGUET AND CYRIL FRESILLON
PHOTOS BY CYRIL FRESILLON,
CHRISTOPHE LEBEDINSKY AND LUC RONAT / CNRS PHOTO LIBRARY

1. A team from the MONARIS Laboratory (CNRS / UPMC, formerly LADIR) chooses which areas to analyze on the stained-glass windows of the 13th century Sainte-Chapelle on the Île de la Cité, in Paris.
2. The composition of the glass is determined using a Raman spectrometer to identify which parts of the medieval stained-glass windows were replaced or restored in the 19th century.

3. The spectrometer laser (bright green dot) sweeps the stained glass of the rose window, this time from the outside.
4. The uKhahlamba-Drakensberg mountains in the Giant’s Castle National Park in South Africa are home to many rock paintings by the San people, dating back 100 to 3000 years. Here, the measuring head of the spectrometer focuses the laser onto a jumping lion without damaging the painting.

5. The researchers use a portable Raman spectrometer to determine the state of conservation and composition of the pigments of these San paintings on sandstone.

7. The analysis will reveal how and when the beads were manufactured, and whether they were added at a later date.

8. The cloak was made with feathers, cotton, and plant fibers.

9. Raman spectroscopy of the patina and corrosion on the lotus pedestal of the great Buddha Amida. The analysis gave more information about its state of conservation and the techniques used to make it. This 17th-18th century bronze statue from Japan is kept in the Cernuschi Museum in Paris.
Earth Sciences. France and China join forces to study landscape dynamics in Central Asia.

BY ARBY GHARIBIAN

An Evolving Research Landscape

Landscape dynamics, or how landscapes form and evolve, has become a global issue due notably to climate change and desertification. With the Gobi desert expected to reach Beijing by 2100 if nothing is done to stop it, it is also a crucial challenge for China—and the focus of the International Associated Laboratory (LIA) Sediment transport And Landscape DYNAMics in Central Asia (SALADYN), formalized in April 2013 during French President François Hollande’s state visit.

“SALADYN is a virtual laboratory,” explains its co-director François Métivier from the IPGP. “Without being based in either country, this network of research institutions oversees the launch of large-scale projects designed to understand China’s evolving rivers and deserts.” Aimed at studying the impact of wind and water on the landscape, the four-year LIA combines 9 research organizations, 13 laboratories, and nearly 60 researchers in the two countries, including teams from the CNRS and the Chinese Academy of Sciences (CAS).

Long history and prosperous future
Métivier, who first visited China in 1995 as part of his doctoral thesis in geophysics, took annual field trips there for his research on landscape dynamics. In 2004, he began working with hydrologist Ye Baisheng of the CAREERI institute. Encouraged by their results, notably regarding the sediment transport dynamics of the Urumqi River, the researchers initiated long-term projects in 2010 and started planning the future LIA.

To address landscape dynamics, which involves understanding the interaction between topography, climate, sediment flux, hydrologic balance, and tectonics, the LIA associates geology, hydrology and ecology experts, as well as specialists in atmospheric and environmental sciences. It also pairs French and Chinese laboratories in mathematics, numerical modeling, field observation, and logistics, which has made it possible to launch joint projects of unprecedented size and scope.

Where math meets wind and sand
One such undertaking was the study of desert dynamics, especially the interconnection between dune growth and wind patterns. To counter the desertification that plagues
so many areas of the globe, scientists must identify the factors that facilitate or hinder the formation of new sand dunes. In a major experiment, researchers from the IPGP and MSC\(^3\) in France, and the CAREERI in China, flattened a 40-acre dune field in the Tengger Desert in Inner Mongolia, and then recorded wind and topography during the three years it took the dune to form back. Their results suggest that the crest alignment of wind-formed (aeolian) dunes can be used to extrapolate the prominent wind patterns on Earth.\(^4\)

“We were very pleased because the results confirmed the predictions of our mathematical models for wind-based sand transport,” explains Métivier. “Now that we know them to be accurate, we can use these models to predict prevailing wind patterns, and the subsequent direction sand dunes will be blown.”

The birth and fate of rivers

Another area of research is the study of rivers that provide the fresh water essential for human consumption and irrigation. Understanding their morphology, formation and evolution is crucial for developing suitable environmental policies. Earth scientists have been trying for over a century to explain why rivers change, transforming from a deep and stable single-thread to a shallower braided river system, or vice versa.

To answer this question, researchers from SALADYN have launched the first systematic morphological comparison of these two river types in the Bayanbulak grassland of the Tian Shan mountains, one of the few areas where braided gravel-bed rivers change into meandering rivers.

Using laser rangefinders and gauging instruments, the scientists measured river width, depth, slope, discharge, and bank aspect. Although more samples are needed, these new datasets seem to support their hypothesis that, of the two main drivers of river morphology, bedload sedimentary flux—rather than riparian vegetation—is the primary factor for river metamorphosis in Bayanbulak.

China, laboratory to the world

Western China provides an exceptionally complete and representative setting for studying landscape dynamics on every time scale, from the geological and historical, to the human and immediate. Moreover, these areas undergo intensive natural resource exploitation, thus incorporating the major factor of human pressure on the environment.

This prompted the LIA to organize the first-ever international workshop on sediment transport and landscape dynamics in Central Asia. The four-day event gathered 32 international specialists in Paris, and resulted in 11 publications in *Advances in Geoscience*, the open access journal of the European Geosciences Union (EGU).

“We are proud of the accomplishments that have resulted from our cooperation with Chinese Earth scientists,” says Métivier. “We look forward to more fruitful collaborations on other scientifically promising projects, such as the study of soil pollution and carbonate weathering.”

---

1. Institut de physique du globe de Paris (CNRS / IPGP).
2. Cold and Arid Regions Environmental and Engineering Research Institute (CAS).
3. Laboratoire matière et systèmes complexes (CNRS / Université Paris-Diderot).
5. Co-produced by the CNRS, Mona Lisa Production, and Arte.
**GEOVIDE**

**Traces at Sea**

**Oceanography.** For six weeks last spring, a research vessel traveled from Portugal to Newfoundland sounding the depths for nearly undetectable trace elements, vital to our understanding of the oceans.

**BY MARK REYNOLDS AND ISABELLE TRATNER**

Trace elements and their isotopes (TEIs) are present at very low concentrations in our oceans, where they play a crucial role. Some are essential to living organisms while others are toxic. Some also affect oceanic carbon cycles, and can help scientists understand key processes of past and present oceans, including oceanic circulation, the climate, marine ecosystems, and environmental contamination.

The study of TEI cycles in the North Atlantic was entrusted to GEOVIDE, the French contribution to GEOTRACES, a wider international program devoted to TEIs in oceans across the globe. The North Atlantic region plays a crucial role in the Earth’s climate. Indeed, in this area, warm surface water cools and sinks, creating water mass movements known as the meridional overturning circulation (MOC), a phenomenon that has a major impact on the climate. Moreover, trace elements in this region present highly contrasted sources, and their cycles are not well known.

**An international mission**

The GEOVIDE mission set off from Portugal aboard the ship “Pourquoi Pas?” on May 15th. It sailed northwest to Greenland, and southwest into the Labrador Sea off the East Coast of Canada, where the mission ended at St. John’s, on June 30th. Forty international experts in physical oceanography, geochemistry, and biogeochemistry, drawn from 15 laboratories in eight countries, were on board with an ambitious roadmap. They had to collect samples of air, seawater, and sediments all the way down the water column to analyze more than 50 chemical parameters, including many trace elements like mercury, iron, lead, copper, aluminum, and their isotopes. Some analyses could be performed on board, but most had to wait until the end of the voyage and are still in progress. “The work during the cruise was intense,” recalls chief scientist Géraldine Sarthou from the LEMAR.

“We were working 24 hours a day. Depending on the experiments, some teams were on shift, whereas others were hands on deck as soon as the samples came on board, sometimes for 30 hours in a row.”

“We stopped at 78 stations to take seawater, particle, and sediment samples,” explains Sarthou. “These stations were among those set up by the

---


© GEOVIDE/P. LHERMINIER-IFREMER

Map of the GEOVIDE stations. Colors indicate the extent of the analyses performed.

© GEOVIDE/P. LHERMINIER-IFREMER
ongoing OVIDE project, launched in 2002, mostly to collect physical data. Physical parameters such as temperature, salinity, but also oxygen content were analyzed at the same time. “This will give us a very comprehensive chemical and physical picture for these precise stations, now and over the past ten years.”

Deep data
Seawater sampling was performed using two “rosettes,” large structures equipped with twenty-four 12-liter bottles and sensors for physical parameters like conductivity, temperature, depth, oxygen, or fluorimetry, among others. For trace metal sampling, the bottles used were epoxy-coated to avoid contaminants when measuring elements in such low concentrations. In total, the two rosettes were deployed 216 times and went to a maximum depth of 5347 m in the Iberian Abyssal Plain, off the western coast of Spain. A sediment corer was used, as well as in situ pumps to collect suspended particles (with 140 h of pumping). Air and rainwater samples were also taken. Seventeen ARGO floats and 12 buoys were deployed, along with 60 expendable bathythermographs, to gather temperature, salinity, and meteorological data.

The scientists trust that this wealth of samples and results will help them improve their knowledge of the North Atlantic Ocean. To start with, they hope to elucidate and quantify the MOC and carbon cycle of the past ten years, in particular by measuring new tracers. They also wish to perform a complete analysis of the TEI distribution including their sources, sinks, and fluxes, especially at the boundaries of the oceans—i.e., the interface with the atmosphere and with the seafloor. Some TEIs, like iron, are necessary for the growth of phytoplankton, heavily involved in trapping CO2. Thus iron depletion affects planktonic growth and decreases the efficiency of the oceanic carbon sink. Researchers hope that the data collected during the GEOVIDE mission will help investigate the link between TEIs and the CO2 pump. Finally, some TEIs, like protactinium and neodymium, are history markers, and their analysis should provide significant information about past oceans.

On-board analyses
The first results analyzed on board are very promising. The physical parameters measured allowed the identification of water masses, and the observation of an intense front—i.e., a sudden change in these parameters—at 50°N, corresponding to the north branch of the North Atlantic Current. This front, already known from earlier OVIDE missions, was further south and more intense than previously observed. “We don’t have an explanation for this southern shift yet, but hope to find one in light of the data collected,” says Pascale Lherminier, from the LPO, in charge of the physical part of the GEOVIDE project and veteran of the OVIDE cruises.

Mercury (Hg), an environmental contaminant, was also analyzed on board. More than 1500 measurements were performed. The extremely low Hg concentrations, among the lowest ever recorded, suggest that the recent atmospheric Hg deposition is lower than in previous decades. Scientists therefore anticipate a decrease in Hg content of North Atlantic pelagic ecosystems, including commercially important fish species. These results show the efficiency of the global anti-pollution policies implemented by countries bordering the North Atlantic Ocean.

Presenting results
Back in the laboratories, samples are being analyzed with the aim of providing a comprehensive view of the physics and biogeochemistry of the North Atlantic. Scientists are also preparing for the next international Goldschmidt Conference (to be held in August 2015 in Prague, Czech Republic), where a session will be dedicated to the GEOTRACES program and where GEOVIDE results will be presented. 

© PHOTOS: GEOVIDE/G. SARThOU/CNRS

Geraldine.Sarthou@univ-brest.fr
pascale.lherminier@ifremer.fr
http://geovide.tumblr.com

The Ifremer’s vessel “Pourquoi pas?” during the GEOVIDE cruise.

Sampling for trace metals was done inside a clean container to avoid any contamination from the ship.
South Korea, a Scientific Revolution

International. Since 2013, the CNRS has been a partner of South Korea’s Institute for Basic Science (IBS), a new scientific organization whose goal is to open 50 basic research centers across the country by 2022.

Kim Jin-soo points at the cover of an issue of Nature on his desk. Since March 2013, the journal has been his genomics laboratory’s best calling card. “In ten years’ time, South Korea will be one of the top five countries in basic research,” he asserts. A brilliant researcher, he is the latest high-profile recruit of the country’s Institute for Basic Science (IBS). A new player in South Korea’s scientific landscape, the institute was founded in November 2011 to pursue “long-term, pioneering basic research that would be difficult to conduct in isolated universities or other governmental research organizations.”

Spearheading research in South Korea

Having recruited the directors of nearly half the 50 research centers it aims to open by 2022, the IBS is on its way to meeting its objective. Each director is granted a budget of €7 million and given considerable freedom in the choice of research programs. With an overall budget of €183 million and some 500 permanent employees—including 282 researchers—the IBS is headquartered in Daejeon, a city south of Seoul that is home to many private research centers. The institute also seeks to fulfill South Korea’s ambitions in terms of large-scale scientific installations. As part of its Rare Isotope Science Project, it has begun the construction of a particle accelerator called Raon. The name, which means “delighted” in Korean, was chosen to reassure the local population, who might have misgivings about living near the installation. The government expects this “mini-CERN” to be operational by 2019.

A strong sense of initiative

In figures, the IBS aims to increase South Korea’s R&D spending to 5% of GDP by 2017, compared with 4.4% in 2012. At €36 billion, the nation will have the highest R&D percentage of all OECD countries.

“In 2013, basic research represented 36% of our total research spending,” reports Shin Jun-ho, director of the Science and Technology Policy Bureau of the Ministry of Science, ICT and Future Planning (MSIP). “We are hoping to reach 40% by 2017.” This increase will redefine the role and share of public research within the country’s overall research system, where private organizations currently account for 74% of spending.

South Korea’s scientific ambitions are realistic. In the past 50 years, it has demonstrated its resilience by transforming itself from an underdeveloped nation into a global power, in the name of patriotism and at the cost of important efforts by its people. Since 2002, the country has more than doubled its number of scientific publications, making it the world’s 10th largest producer of research papers.1 “South Korea has devoted a great deal of effort and resources to basic research,” acknowledges Carlo Massobrio of the Strasbourg-based IPCMS,2 which has enjoyed a “special partnership” over the past few years with Ewha

Closer Ties with the CNRS

Collaboration between France and South Korea in the humanities and social sciences officially began on May 13, 2014, with the signing of a Memorandum of Understanding (MoU) between the CNRS, represented by Patrice Bourdelais, director of the organization’s Institute for Humanities and Social Sciences (INSHS), and Ahn Se Young, chair of South Korea’s National Research Council for Economics, Humanities and Social Sciences (NRCS). Covering a period of three years, this scientific collaboration agreement aims to facilitate joint research projects, researcher exchanges, and the organization of conferences. It was finalized following a symposium dedicated to industrial and social matters (in relation to the ageing of the population) as well as gender issues, all of which are of particular interest for the two countries and their researchers. It comes on the heels of another MoU signed with the Institute for Basic Science in 2013. These agreements crown a recent leap in scientific co-production. The number of CNRS co-publications with South Korea tripled between 2000 and 2010, and now represents three-quarters of all French-South Korean publications. However, the range of disciplines remains limited: 57% of all CNRS-South Korean joint research papers are in physics.

1. Source: Science Citation Index (Thomson-Reuters / DVD Édition), data processed by Dastr-SAP2S (not including the humanities and social sciences).
2. Institut de physique et chimie des matériaux de Strasbourg (CNRS / Université de Strasbourg).
Womans University and the Quantum Metamaterials Research Center, headed by physics professor Jeong Weon Wu.

**21 centers already created**

Physics, and notably nuclear physics, is given pride of place along with the life sciences, each with seven dedicated centers out of the 21 already set up by the IBS. Chemistry comes next with six centers, and one is devoted to mathematics. Still, the country is as determined to make headway in this field as in any of the others. “The South Korean government is taking every step to fund the institutes and international collaborations that are necessary to reach the highest level in the discipline,” observes Sinnou David, in charge of international relations at the CNRS National Institute for Mathematical Sciences. “At this pace, there is a good chance that it will succeed within the next 15 to 20 years.” No doubt the fact that South Korea hosted the International Congress of Mathematicians in Seoul in August reflects this forward-thinking policy.

In addition to recruiting prominent “foreigners” (Korean researchers who have left for other countries, mainly the US), the country wants to put a stop to the current “brain drain,” declares Lee Jae-heun of the MSIP. A program called Brain Return 500 has been introduced, offering sizeable budgets for young scientists (around €200,000 per year) and experienced researchers (about €330,000 per year).

**A positive influence on business**

This drive and ambition comes with its share of complications. Tensions are already being felt, especially among certain researchers who fear that public money will be diverted from existing programs to fund the IBS. The ministry seeks to reassure them and asserts that “no biased decisions will be taken to the detriment of existing programs.”

In the meantime, the positive effect of this effort to promote basic research is anxiously scrutinized. Some believe that the IBS was indirectly responsible for Samsung’s recent call for tenders. Totaling €1 billion, the program is divided into three equally-funded sections: basic research (for projects lasting up to five years), new materials, and innovative pluridisciplinary projects linked to IT and communication (both for projects exceeding 10 years). The program’s introductory brochure emphasizes the company’s will to develop a new research culture requiring long-term support. The results will be announced in November. II
**The Ruling Elite of Singapore**  
By Michael D. Barr  
(Bangkok: I.B.Tauris, 2014)

Michael D. Barr explores the complex and covert networks of power at work in one of the world’s most prosperous countries: the city-state of Singapore.

**September 11th-12th—The Individual and the State Faced with Terrorism**  
By Philippe Pierre (ed.)  
(Paris: Hermann, 2013)

This book reports on a conference held in 2011, which offered a transdisciplinary approach to the terrorist attacks of September 11th, 2001. Invited to speak were experts in neuroscience, psychoanalysis, psychiatry, and history, but also legal experts, law historians, and political science and public policy specialists.

**Sports Physics**  
By Christophe Clanet (Ed.)  

In sports, physics is everywhere—something that can be used to improve our understanding of athletes’ performance. The authors of this book believe that sports can thus be an important vector for the presentation of advanced concepts of physics.

**The Female Body: A Journey through Law, Culture and Medicine**  
By Brigitte Feuillet–Liger, Kristina Orfali, and Thérèse Callus (Eds)  
(Brussels: Bruylant, 2013)

This work examines the relationship between the female body and biomedicine from the multidisciplinary perspective of jurists, anthropologists, philosophers, sociologists, and medical doctors from 19 countries. It intends to show the complexity surrounding the question of a woman’s freedom over her body and the extent to which this is limited by the state.
It is in the early 2000s that the strange fossils sold to tourists by a Moroccan villager triggered the interest of a paleontologist. Originating from Zagora, in the Drâa valley, these findings were to rewrite a chapter of the evolution of life on Earth. Dating back 480 million years, the extremely well-preserved fossils of the Fezouata formations filled a gap in the evolution of the marine fauna between the late Cambrian and the early Ordovician periods. "At the time, it was thought that the high diversification phase of the early Ordovician had followed the major extinction of the late Cambrian," explains Bertrand Lefebvre, from the LGTPE, 1 who organized the first large-scale scientific excavations on site. But in the Fezouata biota, Cambrian and Ordovician fossils cohabit, demonstrating that extinction and diversification were more interwoven than previously believed, and extending the lifetime of certain species by 30 million years. Today, the site, still investigated, has become key to the study of this period of life evolution.

bertrand.lefebvre@univ-lyon1.fr

1. Laboratoire de géologie de Lyon: Terre, planètes et environnement (CNRS / Université Lyon-I / ENS Lyon).
The French National Center for Scientific Research (CNRS) is the largest basic research organization in Europe. It covers all scientific fields, including biology, chemistry, physics, the Earth sciences, astronomy, mathematics, and the humanities and social sciences.