In this issue a pull-out periodic table of the elements

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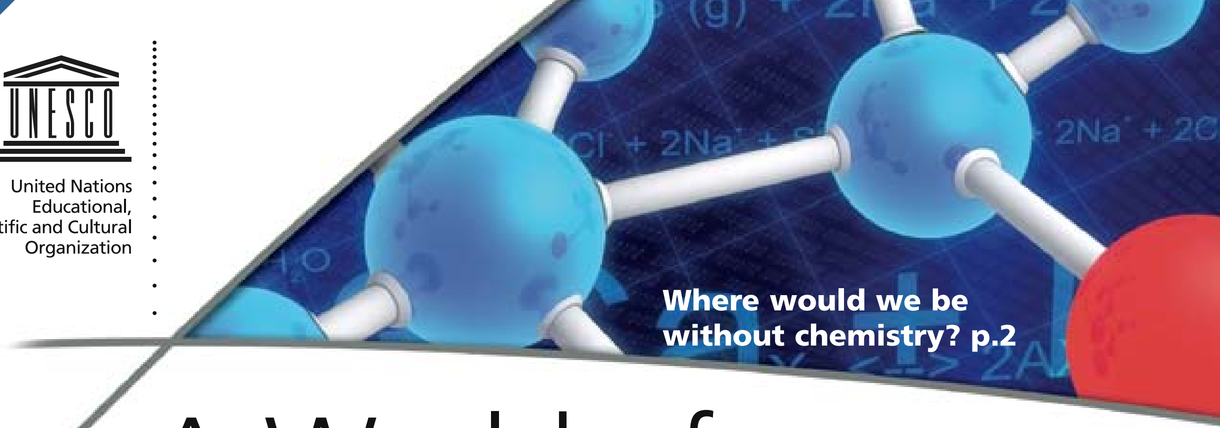

A World of SCIENCE

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IN THIS ISSUE

EDITORIAL

Chemistry: our life, our future

When two people are attracted to each other, there is said to be chemistry between them. This romantic notion is not far from the truth, for not only are we surrounded by all things chemical, we are a chemical factory ourselves: 99% of the human body is made up of oxygen, carbon, hydrogen, nitrogen, calcium and phosphorus. These elements bind together to form a wonderful diversity of molecules that make up all the structures of our bodies and allow us to breathe, eat, move and think – in short, to live.

Like chemicals in a test-tube, the chemicals in our body respond to stimuli and undergo transformations via chemical reactions triggered by the brain. When a person is confronted with danger, the brain makes a choice: fight or flight? Chemicals are then produced to prepare the person to run away or attack. Pharmaceutical drugs work because they interact with particular chemical entities in our body to combat disease, which can be viewed as disordered chemistry of the body.

Thanks to chemistry, our world has become a more comfortable place in which to live. Our cars and homes – even our clothing – are brimming with its creativity. Our energetic future will depend on it, as will achieving the Millennium Development Goal of safe water and sanitation. If we look back, it was chemists who discovered fertilizers, thereby enabling food production to keep pace with population growth. It was chemists who revealed the defining issue of our time, climate change, after monitoring carbon dioxide levels in the Earth's atmosphere for decades.

It is thus hardly surprising that the theme of the International Year of Chemistry getting under way this month should be Chemistry: our life, our future. We take up the gauntlet with a lead story that asks, 'Where would we be without chemistry?'

Chemicals as we know them in household and other industrial products, or in laboratories, must be handled with caution, of course, given the toxicity and volatility of some compounds. In this issue, we discover how forensic science manages to trace a chemical spillage back to the source, even decades after the event.

There would be no International Year of Chemistry, had Ethiopia not submitted a resolution to the UN with the support of over 20 countries. Jointly co-ordinated and led by UNESCO and the International Union of Pure and Applied Chemistry (IUPAC) which is celebrating its centenary, the Year also marks the centenary of the award of the Nobel Prize to Marie Sklodowska Curie. As a tribute to her memory, the Year will wind up with the première at UNESCO headquarters in Paris of an opera celebrating her life. Meanwhile, women chemists are participating in a networking breakfast on 18 January in Australia, Egypt and elsewhere to celebrate women's contribution to chemistry.

The Year gets under way officially at UNESCO on 27 and 28 January. Should you wish to submit an idea or organize an activity yourself, don't forget to record the details at the official website: chemistry2011.org.

Gretchen Kalonji
Assistant Director-General for Natural Sciences

Where would we be without chemistry?

This year sees the world celebrating the International Year of Chemistry. The celebrations are wholly justified because chemistry is hugely important for all of us, wherever we live. If you were to strip away all the contributions of chemistry to the modern world, you would find yourself back in the Stone Age, life would be short and painful, you would be underfed, there would be little colour in the world, you would be dressed in skins and surrounded by few of the appliances that entertain us and ease our lives.

I will admit from the outset that chemistry, like any great enterprise, does cause problems. It is used to make the explosives used in armaments, it creates poisons and the effluents of chemistry plants can ruin the environment. In some dreadful cases, accidents have killed and maimed thousands. The explosion at the Union Carbide plant in Bhopal in India in 1984 blighted thousands of innocent lives and the terrible consequences are still with us today. Pollution of water and air has wrought havoc with our surroundings. These disadvantages and horrors have to be acknowledged – but all technological and scientific advances bring difficulties in their train. We should weigh them against the advantages. With some exceptions, the chemical industry is well aware of its obligations to humanity and environment and does what it can to avoid the potentially damaging effects of its activities.

In this article, I shall concentrate on the positive contributions that chemistry makes to the modern world and leave you to judge whether the price is too high.

Chemistry is the science of matter and the changes that matter can undergo. In the broadest possible terms, chemists take one form of matter and conjure from it a different form. In some cases, they take raw material from the Earth, such as oil or ores, and produce materials directly from them, such as petroleum fuels and iron for steel. They might harvest the skies, taking the nitrogen of the atmosphere and converting it into fertilizer. In many cases, they take more sophisticated forms of matter and convert it into materials suitable for use as fabrics or as the substances needed for high technology.

©BASF

The application of a spray-applied membrane designed by BASF on the interior walls of a tunnel being built in the United Kingdom reduces the amount of concrete required, saving millions of euros in construction costs and reducing CO_2 emissions from cement-making.

Communal living is possible thanks to chemistry

Take water, for instance, the absolutely essential enabler of life. Chemistry has made communal living possible by purifying water and ridding it of pathogens. Chlorine is the principal agent enabling cities to exist: without it, disease would be rampant and urban living a gamble. Chemists have found ways of extracting this element from an abundant source: sodium chloride, common salt. Are there other ways, though? Can future chemists (of which you the reader might be one, or encouraging your students to pursue the study of chemistry) find ways of rendering urban life possible without the environmental disadvantages of using chlorine? Its replacement is highly desirable because chlorine is a dangerous and untrustworthy ally: although, through its potent chemical reactivity, it purifies water, that same reactivity means that it attacks other compounds and, for instance, enters the food chain as dioxins and related compounds. These compounds can attack the nervous system and accumulate in body fat. Chlorine and its compounds also rise high in the atmosphere where they contribute to the destruction of ozone and the formation of acid rain.

Chemists are at the forefront of the battle to obtain potable water from brackish water, from poisoned water in aquifers, such as the arsenic-laden water from deep aquifers in Bangladesh, and from that most abundant source of all, the oceans, by using water desalination plants. Chemists have contributed in direct ways to this crucial task by developing reverse osmosis, a process in which pressure is applied to brackish water to drive it through a filtering membrane, thereby rendering it potable. Chemists have also contributed in indirect ways by developing the membranes that contribute to the efficiency of the process by reducing its energy demands and increasing the lifetime and effectiveness of the membrane. It goes without saying that chemists' traditional skills of analysis – discovering what is present in it, what can be tolerated and what essential element should be removed to trigger the desired reaction – are crucial to this endeavour.

©UNESCO/Fiona Ryan

Rice farmer in China. The introduction of golden rice might help millions of people throughout Africa and Southeast Asia who suffer from vitamin A deficiency.

How the search for explosives spawned a green revolution

Then there is food. As the global population grows and the productive land area is eroded, so it becomes more and more important to coax crops into greater abundance. The traditional way to encourage abundance is to apply fertilizers. Here, chemists have contributed nobly by finding sources of nitrogen and phosphorus and ensuring that these can be assimilated by plants. Genetic engineering is another exciting way to proceed but remains controversial because of the fears of some as to the consequences of interfering with inheritable factors and the possibility of uncontrolled transfer into other species. Genetically modified food, though, can reduce the need for chemical pesticides, be resistant to viral infection and drought and can, like natural breeding, result in more abundant yields rich in desirable components. The introduction of golden rice, which includes genes from yellow daffodils to provide a high concentration of precursors of vitamin A, might help millions of people throughout Africa and Southeast Asia who suffer from vitamin A deficiency, responsible for millions of deaths and thousands of cases of irreversible blindness.

Nitrogen is astonishingly abundant, making up nearly three-quarters of the atmosphere, but it is there in a form that cannot be assimilated by most plants. One of chemistry's greatest achievements, made in the opening years of the 20th century under the impetus not of a humane desire to feed but of an inhumane desire to kill, was to discover how to harvest nitrogen from the air and turn it into a form that could be absorbed by crops. The original impetus was the need to replace the natural source of nitrogen, nitrates mined in arid regions of Chile, by far more abundant and reliable supplies that at the time of the First World War (1914–1918) were needed for the manufacture of explosives. The development in Germany of an effective, economical process for converting non-reactive gaseous nitrogen into a reactive form by the German chemist Fritz Haber and his compatriot the chemical engineer Carl Bosch initially in 1909 and on an industrial scale in 1913 was a landmark achievement for the chemical industry, for as well as depending on the discovery of appropriate catalysts, the production of fertilizer required the development of an industrial plant that operated at temperatures and pressures never previously attained.

The discovery of reactive nitrogen revolutionized agriculture in the 20th century by permitting more abundant yields. But the process remains energy-intensive. It would be wonderful if the processes known to occur in certain bacteria associated with the root systems of leguminous plants, such as clover, alfalfa and peanuts, could be emulated on an industrial scale to harvest nitrogen. In the natural process, nitrogen is released, in a usable form, when the plant dies and so becomes available to other plants. This is the basis for crop rotation in traditional farming practice and the emulation of traditional methods in organic farming. Chemists have invested decades of research into this possibility, dissecting in detail the enzymes that bacteria use in their quiet and energy-efficient, low-pressure, low-temperature way. There are glimmerings of success but if you want to go down in history as the chemist who cracked the problem of feeding the world, here is your opportunity.

©Courtesy of Peter Trusler

In a scene imagined by palaeo-artist Peter Trusler, a dinosaur lies dying about 110 million years ago when the South Pole enjoyed a more clement climate. If the body of this Leaellynasaura amicagraphica *is rapidly covered by sediments, it may fossilize, thereby trapping phosphorus in its bones in the form of phosphate rock.*

Recycling the dead to feed the living

Phosphorus is abundant too, being the remains of prehistoric animals. Their bones of calcium phosphate and their special internal power source – the molecules of adenosine triphosphate (ATP) that powered every one of their cells – lie in great compressed heaps below the oceans and the continents of the world. The most important use of phosphorus is for the production of fertilizers – derived from phosphate rock. Most of the world's phosphate rock reserves are concentrated in Morocco. Taken together, China and Morocco alone count 91% of the world's reserves. Thus, by turning fossilized animals into fertilizer, chemists help to recycle the dead to feed the living.

Without energy, civilizations would collapse

After water and food, we need energy. Nothing happens in the world without energy. Civilizations would collapse if it ceased to be available. Civilizations advance by deploying energy in ever greater abundance. Chemists contribute at all levels and to all aspects of developing both new sources and more efficient applications of current sources.

Petroleum is one of the legacies of the past, being the partially decomposed residue of organic matter, such as plankton and algae, that sank to the bottom of lakes and seas and was later subjected to heat and pressure. It is, of course, an extraordinarily convenient source of energy, as it can be transported easily, even in weight-sensitive aircraft. Chemists have long contributed to the refinement of the raw material squeezed and pumped from the ground. They have developed processes and catalysts that have taken the molecules provided by nature, cut them into more volatile fragments and reshaped them so that they burn more efficiently.

But burning nature's underground bounty might be seen by future generations as the wanton destruction of an invaluable resource. It is also finite and, although new sources of petroleum are forever being discovered, for the time being at least, they are proving hazardous and increasingly expensive. We have to accept that, although the empty Earth is decades off, one day it will arrive. Chemists will need to contribute to the development of new sources of energy. Young people entering the profession today will find that they have great opportunities to make an impact on the future well-being of the world and its populations.

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Oil rig. Today, numerous objects are built from synthetics derived from oil.

Where do chemists currently look for new sources? The Sun is an obvious source and the capture of its energy that nature has adopted, namely photosynthesis, an obvious model to try to emulate. Chemists have already developed moderately efficient photovoltaic materials and continue to improve their efficiency. Nature, with her four-billion year start on laboratory chemists, has already developed a highly efficient system based on chlorophyll. Although the principal features of the process are understood, a challenge for current chemists and perhaps future chemists like yourself will be to take nature's model and adapt it to an industrial scale. One route is to use sunlight to split water (H_2O) into its component elements and to pipe or pump the hydrogen to where it can be burned.

I say 'burned'. Chemists know that there are more subtle and efficient ways of using the energy that hydrogen and hydrocarbons represent than igniting them, capturing the energy released as heat and using that heat in a mechanical, inefficient engine or electrical generator. Electrochemistry, the use of chemical reactions to generate electricity and the use of electricity to bring about chemical change, is potentially of huge importance to the world. Chemists have already helped to produce the mobile sources, the batteries, that drive our small portable devices, such as lamps, music players, laptops, telephones, monitoring devices of all kinds and, increasingly, our cars.

Chemists are deeply involved in collaboration with engineers in the development of fuel cells on all scales, from driving laptops to powering entire homes and conceivably villages. In a fuel cell, electricity is generated by allowing chemical reactions to dump and extract electrons into and from conducting surfaces while fuel, either hydrogen or hydrocarbons, is supplied from outside. The viability of a fuel cell depends crucially on the nature of the surfaces where the reactions take place and the medium in which they are immersed. Here is another branch of chemistry where you, the reader, the perhaps aspiring chemist, could make a profound difference to the future of your country and the world.

Even nuclear power, both fission and one day fusion, the emulation on Earth of the Sun, depends on the skills of chemists. The construction of nuclear reactors for nuclear fission depends on the availability of new materials. The extraction of nuclear fuel in the form of uranium and its oxides from its ores involves chemistry.


© UNESCO/S. Schneegans

Solar panels on the roof of a sports stadium in the Spanish town of Baeza

Everyone knows that one fear holding back the development and public acceptance of nuclear energy, apart from political and economic concerns, is the problem of how to dispose of the radioactive spent fuel. Chemists contribute by finding ways to extract useful isotopes[1] from nuclear waste and by finding ways to ensure that it does not enter the environment and become a hazard for centuries to come. If you could collaborate with nuclear engineers to solve this problem, the world might take a more relaxed view about the perils of nuclear power and give a breathing space for the less hazardous nuclear fusion to be developed.

Nuclear fusion depends on smashing isotopes of hydrogen together and capturing the energy released as they merge to form helium, as happens on the Sun. The challenge is to achieve high temperatures because only then do the nuclei smash together with sufficient force to overcome their electrical repulsion – and to avoid the entire apparatus melting. The major nuclear fusion research effort taking place in France, known as the International Thermonuclear Experimental Reactor (ITER) project (*iter* is Latin for 'the way'), involves international collaboration on an unprecedented scale, involving countries representing half the world's population (*see also page 20*).

Plastics from oil

I have alluded to the seemingly wanton destruction of an invaluable resource when the complex organic mixture we know as oil is sucked from the ground where it has lain for millennia then casually burned. Of course, not all the oil goes through the exhausts of our cars, trucks, trains and aircraft. Much is extracted and used as the head of an awesome chain of reactions that chemists have developed which constitute the petrochemicals industry.

Look around you and identify what chemists have achieved by taking the black, viscous crude oil that emerges from the Earth, subjecting it the reactions that they have developed and passing on the products to the manufacturers of the artefacts of the modern world.

Perhaps the greatest impact of these processes has been the development of plastics. A century ago, the everyday world was metallic, ceramic or natural, with objects built from wood, wool, cotton and silk. Today, an abundance of objects are built from synthetics derived from oil. Our fabrics have been spun from materials developed by chemists, we travel carting bags and cases formed from synthetics; our electronic equipment, our televisions, telephones and laptops are all moulded from synthetics. Our vehicles are increasingly fabricated from synthetics. Even the look and feel of the world is now different from what it was a hundred years ago: touch an object today and its texture will be typically that of a synthetic material. For this transformation, we are indebted to chemists.

Even if you mourn the passing of many natural materials, you can still thank chemists for their preservation where they are still employed. Natural matter rots but chemists have developed materials that postpone decay. For instance, new wood preservatives, typically based on copper, have been developed to avoid problems with the old preservatives leaching into the soil and poisoning it with arsenic, copper and chromium.


Photo: Wikipedia

An assortment of everday household items. One urgent challenge chemists face is to reduce the time it takes for plastics, aluminium cans and the like to biodegrade. See also page 14.

Lighter cars, molecular computers and intelligent clothing

Plastics are but one face of the materials revolution that has characterised the last one hundred years and is continuing vigorously today. Chemists develop the ceramics that are beginning to replace the metals that we use in vehicles, lightening them and thereby increasing the efficiency of our transport systems. Ceramics are already used in the exhaust manifolds of some high-performance cars and experiments have been conducted on replacing the entire engine block with ceramics. The car engine's cooling system has been simplified and its weight lessened because today's engines can withstand high temperatures. There remain problems with fabrication and crack-resistance, which you might be able to help to solve. Chemists are also responsible for developing the semiconductors that underlie the modern world of communications and computation. Indeed, one of the principal contributions of chemistry is currently the development of what could be regarded as the material infrastructure of the digital world. Chemists develop the semiconductors that lie at the heart of computation and the optical fibres that are increasingly replacing copper for the transmission of signals. The displays that act as interfaces with the human visual system are a result of the development of materials by chemists.

Currently, chemists are developing molecular computers, where switches and memories are based on changes in the shape of molecules. The successful development of such materials – with the optimism so typical of science, we can be confident that this endeavour will be successful – will result in an unprecedented increase in computational power and an astonishing compactness. If you are interested in the development of such smart materials, you can expect to contribute to a revolution in computation. There is also the prospect of the development of quantum computing. This will depend on chemists being able to develop appropriate new materials and result in a revolution in communication and computation that defies the imagination.

Modern fabrics depend crucially on the contributions of chemistry. Take away those contributions and we are left almost naked, cold and drab. Even traditional dyes, such as those used in Javanese batik and Indian block-printing, are chemicals that have been extracted from plants and applied to fabrics. Modern fabrics include polyesters, nylon and polyamides. However, chemistry makes more subtle contributions than providing the material itself.

© Richard Stamper/IStockphoto

Thai monk with a laptop. Chemists collaborate with engineers to develop the fuel cells that drive laptops.

A model on the catwalk at a fashion show promoting Central Asian designs. Modern fabrics are heavily dependent on chemistry.

It contributes to flame retardants by incorporating typically bromine compounds into the fabric. Modern developments include incorporating nanomaterials into fabrics to prolong their resistance to chafing, introducing resistance to bacteria and suppressing wrinkling. We are on the edge of even more exciting developments to which you might contribute: e-textiles (so called 'intelligent clothing') are being developed with embedded electronic capabilities, the ability to change colour, with swirling, changing, patterns (and advertisements!) that reflect our mood. Such textiles will be able to adjust their thermal properties to the ambient conditions and, let's hope, be self-cleaning.

Agents against disease: pharmaceutical companies

I have barely mentioned health. One of the great contributions of chemistry to human civilization –and, it must be added, to the welfare of our herds – has been the development of pharmaceuticals. Chemists can be justly proud of their contribution to the development of agents against disease. Perhaps their most welcome contribution has been the development of anaesthetics in the late 19^{th} and early 20^{th} centuries and the consequent amelioration of the prospect of pain. Think of undergoing an amputation two hundred years ago, with only brandy and gritted teeth to sustain you! Some of the anaesthetics currently used, such as procaine, have been developed by chemists to avoid adverse side effects, including addiction, that accompanied the use of materials derived from traditional medicine, such as cocaine obtained from Peruvian coca. Next in importance has been the development by chemists of antibiotics, often by observing nature closely. A century ago, bacterial infection was a deadly prospect; now it is curable. We have to hope that it remains that way but we still need to prepare for the opposite.

The pharmaceutical companies often come under attack for what many regard as their profligate profits and exploitation but they deserve cautious sympathy. Their underlying motive is the admirable aim of reducing human suffering by developing drugs that combat disease. Chemists are at the heart of this endeavour. It is highly regrettable that drug development can be so expensive. Modern computational techniques are helping in the search for new lines of approach and to reduce reliance on animal testing. However, extraordinary care needs to be exercised when introducing foreign materials into living bodies and years of costly research can suddenly be trashed if, at the last stage of testing, unacceptable consequences are discovered. Your involvement in the industry one day might transform it in a manner we cannot yet foresee and you might become one of the proud chemists who have contributed to saving millions of lives.

Source: Wikipedia

This 19th century patient has been given nitrous oxide (N_2O) to dumb the pain of having a tooth extracted. Also known as laughing gas, nitrous oxide was identified as an anaesthetic in 1772 by the English chemist Joseph Priestly.

How biology became chemistry 50 years ago

Closely allied with the contribution of chemists to the alleviation of disease is their involvement at a molecular level. Biology became chemistry just over 50 years ago when the double helix structure of DNA was discovered. Molecular biology, which in large measure has sprung from that discovery, is chemistry applied to organisms. Chemists, often disguised as molecular biologists, have opened the door to understanding life and its principal characteristic, inheritance, at a most fundamental level and have thereby opened up great regions of the molecular world to rational investigation. They have also transformed forensic medicine, brought criminals to justice and transformed anthropology by tracing ethnic origins and ancestry.

The shift of chemistry's attention to the processes of life has come at a time when the traditional branches of chemistry – organic, inorganic and physical – have reached a stage of considerable maturity and are ready to tackle the awesomely complex network of processes going on inside organisms, human bodies in particular. The approach to treating disease – and more importantly preventing it – has been put on a rational basis by the discoveries that chemists continue to make. If you plan to enter this field, genomics (the study of the genome of organisms) and proteomics (the study of the panoply of proteins that spring from the genome) will turn out to be of crucial importance to your work because they help to put the treatment of disease on a rational basis and relate it directly to the individual. This is truly a region of chemistry where you can feel confident about standing on the shoulders of the giants who have preceded you and know that you are attacking disease at its roots.

Magicians of matter

I have focused on a few of the achievements of applied chemistry, for they are the tangible outcome of the labours of myriad working chemists over the ages and, it must be said with some caution, the alchemists. Even though alchemists were misguided in their efforts to turn base metals into gold, through their experiments they nevertheless acquired familiarity with matter and the transformations it can undergo.

Source of text and image: Wikipedia

Muhammad ibn Zakariya ar-Razi (865–925) was a Persian alchemist, chemist, physician and philospher. Many firsts are attributed to him, including that of writing the first book on pediatrics. He was also the first to discover sulfuric acid, after perfecting the methods of distillation and extraction, as well as numerous other chemicals and compounds, including kerosene, alcohol and ethanol.

There is, however, another aspect of chemistry that should not go unnoticed and which, for many, is its justification. Chemistry provides insight into matter and the workings of the material world. It is thus a deeply cultural pursuit: it is fitting that, in the light of UNESCO's support of the International Year of Chemistry, chemistry should at the same time be educational, scientific and cultural. Chemistry opens our inner eye to the properties and behaviour of matter. Moreover, it is a truly transnational and transcultural activity, with advances built on contributions from almost every country in the world.

Chemists like Englishman John Dalton (1766–1844) brought the existence of atoms and molecules to our attention and their descendents have shown us how to relate those entities to what we observe. Although we can take pleasure from merely looking at the vibrant colour of a flower, through chemistry we can perceive the molecular origin of the colour and thus deepen our delight.

The early chemists began to understand why one substance reacted with another but not with something else. Their descendents have discovered the motive power of chemical change and have thereby opened our understanding of why anything happens in the world. We understand what drives the world forward, why crops grow, why we live and die and why anything happens at all.

Much remains to be done, of course. Although the fundamental principles of chemistry are now well established, their application remains as challenging and vigorously pursued as ever. Chemistry lets us plumb the depths of matter, enabling chemists on Earth to fabricate subtle arrangements of atoms that might not exist anywhere else in the Universe and which possess properties that are exquisitely tuned for a hitherto unforeseen application. If you are or intend to become a chemist, then you will become a magician with matter, able to conjure unexpected or intended new forms from what surrounds us. But you will not be an actual magician: you will be a rational, understanding manipulator, an architect on the scale of molecules.

The International Year of Chemistry is rightly a celebration of the transformation of the world and the lives of its inhabitants. It rightly celebrates current achievements, the impact of chemistry on people everywhere and its advancement by collaboration throughout the world. It also rightly anticipates its putative contributions to the unforeseen new world yet to come.

Peter Atkins[2]

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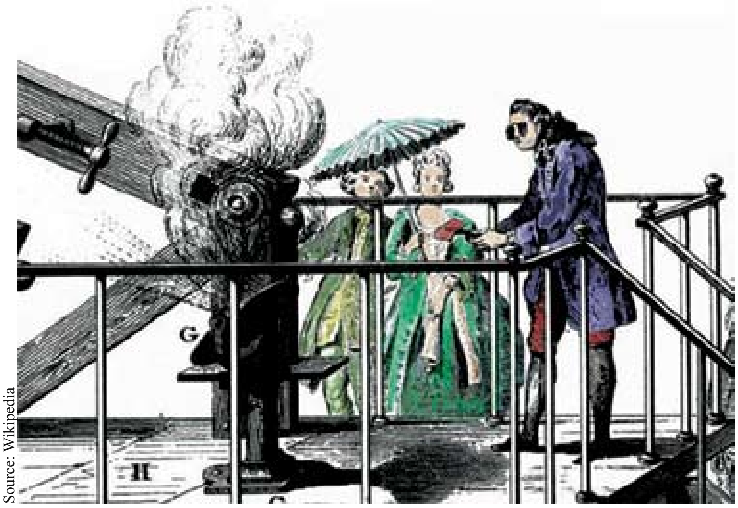
Professor Tebello Nyokong in her laboratory in the Department of Chemistry at Rhodes University of South Africa. One of five L'OREAL–UNESCO laureates in 2009, she earned the award for her research on chemical compounds known as phthalocyanine dyes. These could be used to attack cancerous tissues in a procedure that would be less intrusive than chemotherapy. Activated by exposure to a red laser beam, the dyes are used to target cancerous tissues selectively. With her in the laboratory are Wu Xi,an exchange student from China, and Taofeek Ogunbayo, a South African PhD student.



Source: Wikipedia

Antoine Lavoisier (1743–1794) experimenting a combustion engine that focused sunlight over flammable materials. The French chemist determined that water was composed of oxygen and hydrogen and that the air was a mixture of primarily nitrogen and oxygen. He was guillotined at the height of the French Revolution.

1. *Each element has a given number of protons. Isotopes of an element share the same number of protons but the number of neutrons may change. Carbon-12, carbon-13 and carbon-14, for example, are three isotopes of carbon. The atomic number of the element always remains the same; in the case of carbon, it is six, as each carbon atom has six protons.*
2. *University of Oxford, United Kingdom*

Engineer shortage a threat to development, says report

More than ever, the world needs creative engineering solutions for its biggest challenges, from poverty to climate change, yet many countries are seeing a decline in enrollment in engineering, especially among women. This slump endangers future engineering capacity, particularly in developing countries where brain drain is an additional problem, says UNESCO's first international report on engineering.

Engineering: Issues, Challenges and Opportunities for Development highlights the escalating demand for engineering talent. It is estimated, for instance, that 2.5 million new engineers and technicians will be needed in sub-Saharan Africa alone if the region is to achieve the United Nations Millennium Development Goal of better access to clean water and sanitation. Meanwhile, experts predict the global market for climate change solutions such as low carbon products and renewable energy systems will rapidly reach US$1 trillion dollars and continue to grow.

There is a marked shortage of engineers in many countries. Germany reports a serious shortage in most sectors and, in Denmark, a study showed that, by 2020, the labour market would be lacking 14 000 engineers. Although the population of engineering students is multiplying worldwide, percentages are dropping compared to other disciplines. In Japan, the Netherlands, Norway and the Republic of Korea, for example, a drop in enrollment of 5–10% has been recorded since the late 1990s.

Efforts to increase women's participation in engineering in many countries had boosted female enrollment in the 1980s and 1990s from 10–15% to 20% or more but, since 2000, the numbers have been sliding again. In some countries, the percentage of women in engineering is below 10% and, in a few countries, there are virtually none at all. A recent two-year study in the UK of why engineering does not attract more women pointed to persistent stereotypes that identified engineering as being a strictly technical, masculine occupation.

The report makes suggestions for stimulating interest in engineering, notably the adoption of hands-on, problem-based learning to reflect engineering's problem-solving nature.

The report also emphasizes the urgent need for better statistics and indicators on engineering. It is not possible at present, for instance, to compare the numbers or types of engineers per capita around the world because such data at the international level aggregate scientists and engineers. Refining indicators would drastically improve the information available to policymakers and planners.

More generally, the report points to an overall need for better public and policy-level understanding of engineering and how it drives development. This is particularly crucial in the aftermath of the global recession. The report underlines the importance of investing in infrastructure and innovation in times of economic downturn.

For details, see page 24.

Earthquake monitoring stations for Nepal

UNESCO plans to establish a network of multiparametric earthquake monitoring stations in and around Kathmandu Valley to improve earthquake prediction.

Once operational, the monitoring stations will study variations in the concentration of certain gases in the soil, such as radon (Rn), helium (He), carbon dioxide (CO_2), nitrogen (N_2) and methane (CH_4), tell-tale signs of heightened geological activity. The stations will also monitor changes in water pressure in aquifers using piezometers and carry out electromagnetic and geomagnetic studies to help detect signs of stress underground. The statistical data collected will then be analysed and anomalies computated to determine when the next earthquake might strike.

Nepal has a long history of destructive earthquakes. In 1934, an earthquake destroyed 20% of buildings in the Kathmandu Valley and one-quarter of those in the capital city. A large earthquake in or near Kathmandu Valley today would cause much greater losses than in the past. With a population of almost 1.5 million, the valley is becoming increasingly vulnerable to earthquakes with each passing year. The 1934 earthquake was far from an isolated event. The seismic record of the region, which extends back to 1255, suggests that earthquakes of the magnitude of the one in 1934 occur approximately every 75 years. This suggests that Nepal is 'due' for a major earthquake in the near future.

A recent loss estimation study by the National Society for Earthquake Technology (NSET) and GeoHazards International indicates that the next major earthquake to affect Kathmandu Valley could cause tens of thousands of deaths. Damage to

View of Badghaon in Kathmandu Valley

housing, businesses, public buildings, utilities and transportation networks would run into the millions of US dollars.

Nepal is vulnerable to earthquakes because the northward movement of the Indian plate is approximately perpendicular to the Himalayan collision belt. Studies over the past 40 years indicate that this movement is exerting a compressive stress in some transverse faults in the region, heightening the risk of an earthquake.

The preparatory phases of the project are being steered jointly by UNESCO's offices in Kathmandu and New Delhi, with strong collaboration from the competent authorities in Nepal and India.

For details: b.neupane@unesco.org; www.nset.org.np/

The **best weapon against cancer**: a healthy lifestyle

A few years ago, people would have smiled at the idea that a healthy diet and exercise could help prevent cancer. Yet experts speaking to a packed auditorium on 9 November during the UNESCO Scientific Forum on Progress in Preventing Cancer and a Relapse were unequivocal: many international epidemiological studies are now saying that lifestyle *can* influence the progression of a cancer and help prevent its return.

The forum was held at UNESCO headquarters in Paris, in collaboration with the French weekly magazine *Paris Match*, which publishes a regular column on health. Over the past seven years, these annual fora have disseminated information to the general public on the latest findings of research and therapeutic innovations.

Diet has been linked to the common cancers of the digestive tube, breast, prostate and lungs, which make up 30% of all cancers, according to French physician Prof. David Khayat. He recommends eating organic food, citing a recent Canadian study which demonstrated that 15% of fruits and vegetables sold at market contained pesticide residues. A healthy diet should begin in childhood, he says, as a bulging waistline in your youth can increase your risk of breast or colon cancer later in life. Other precautions include avoiding barbecue grills or cooking food in a wok, as their emissions can be cancerigenic. He also warns that certain fish species should be eaten in moderation, as red tuna and salmon, for instance, can contain heavy metals that are cancerigenic.

©UNESCO/Katy Anis

A woman smoking in Timor-Leste

Even vitamin supplements can be dangerous. Men over 50 who take vitamin E supplements increase their risk of prostate cancer, he warns, and taking a vitamin A supplement augments the risk of lung cancer among smokers.

Smoking itself is responsible for 80% of all lung cancers and can lead to throat and bladder cancer. The length of the addiction matters more than the number of cigarettes: a person who smokes 10 cigarettes a day for 20 years is more likely to develop lung cancer than a person who smokes 20 a day for 10 years, for instance.

Depending on your sex, an immoderate consumption of dairy products may be a bad or a good thing: a man over 50 who consumes more than 2 g of calcium per day increases his risk of prostate cancer; a woman of the same age with a similar diet reduces her risk of colon cancer.

Another risk factor is lack of exercise. A vast study conducted in France for 12 years on 90 509 healthy women aged 30–60 years found that those women who exercised at least five hours a week reduced their risk of breast cancer by 25%. In 2010, the scientific journal *Breast Cancer Research and Treatment* found that subjects with a predisposition for cancer on account of their diabetes, overweight or family history reduced their risk of developing breast cancer by as much as 40% if they exercised five hours a week. This trend has been observed for a wide spectrum of cancers, with the exception of those caused by smoking.

Excessive exposure to sunlight can favour skin cancer, even the artificial sunlight produced by ultraviolet tanning lamps in beauty salons. Some people are more likely to develop skin cancer than others, however. In rare cases, there may be a genetic disposition but the biggest risk factors are simply blue eyes, red hair and a pale white skin. The only prevention is to limit your exposure to the sun.

The most insidious risk factor of all is the virus that may have been living in your body undetected for 10 years. This scenario is currently responsible for 10–15% of cancers. Vaccination can protect a person from some viruses, such as from hepatitis B and, in teenage girls, from the papillomavirus responsible for cervical cancer.

'For many cancers, the prognosis has improved considerably in recent years', observes Professor Dominique Maraninchi, President of the French National Cancer Institute. 'Some 85% of breast cancers, 90% of prostate cancers and more than 80% of colon and rectum cancers can now be cured if picked up early', he says. Moreover, thanks to the development of 'intelligent medicines', we now dispose of products that attack only the malignant cells, unlike chemotherapy.

Watch the forum (in French): www.longevitv.com; for details: Sabine de la Brosse: parismatch.lecteurs@lagardere-active.com ; r.clair@unesco.org

Experts advocate geoengineering **research programme**

On 12 November, an international expert meeting recommended creating an international research programme in geoengineering similar to the World Climate Research Programme sponsored by the International Council for Science, WMO and UNESCO's Intergovernmental Oceanographic Commission (IOC).

Geoengineering is the intentional, large-scale alteration of the climate system. This controversial field of research has grabbed the headlines over some of its more outlandish proposals. One scheme proposed installing a giant parasol in orbit to cool the planet, for instance. More down to Earth are schemes to inject carbon dioxide (CO_2) into the ground or ocean at depth to sequester carbon for long periods of time. The ocean is a tempting target because it absorbs about one-third of atmospheric CO_2; several controversial experiments have 'fertilized' parts of the ocean with iron in an attempt to stimulate plankton growth at the surface.

Geoengineering: the way forward? was the theme of the meeting organized by UNESCO at the Organization's headquarters in Paris in November. The objective was to use UNESCO's 'honest broker' role to create a forum for international discussion and create awareness of the science and governance of this rapidly evolving field. The invited experts included 20 participants from a dozen countries and various academic, non profit, governmental and intergovernmental institutions.

It was felt that a geoengineering research programme could address the technological and scientific challenges of geoengineering and ensure that legitimate scientific research in this controversial area may proceed. This move comes after the Secretariat of the Convention on Biological Diversity made a statement at its October meeting in Nagoya (*see page 13*) recognizing that small-scale geoengineering research experiments should be allowed as long as a number of controls are put in place.

Organized jointly by the UNESCO-IOC, International Geoscience Programme and Division of Basic and Engineering Sciences, the UNESCO meeting considered that geoengineering fell into two broad categories:

- ✓ **Solar geoengineering**, referring to interventions that reduce the amount of solar radiation absorbed by the Earth's climate system, such as the injection of reflective particles like sulphur dioxide into the lower or upper atmosphere, resulting in lower global average temperatures; and
- ✓ **Carbon geoengineering**, referring to the active removal of CO_2 from the atmosphere through engineered CO_2 scrubbers or the enhancement of ecosystem processes, resulting in a reduction of the detrimental impact caused by the build-up of greenhouse gases in the atmosphere.

Read the proceedings and policy brief:www.unesco.org/new/en/natural-sciences/environment/earth-sciences

Groundwater to **alleviate Iraq's water shortages**

On 3 October, UNESCO launched a scientific survey of Iraq's groundwater in an effort to improve government capacity to address water scarcity. Iraq is currently facing severe water shortages across most parts of the country, with over 7.6 million Iraqis lacking access to safe drinking water and the agriculture sector suffering from years of drought.

Absent until now, this complete picture of groundwater resources in the country will provide national and local authorities with the tools to identify accurately and manage sustainably this precious resource.

Incorporating the priorities put forward by the Government of Iraq for the water sector, the project will be undertaken in two phases. The first phase, funded by the European Union under the auspices of the United Nations Development Group Iraq Trust Fund, will establish an interactive database using Iraq's existing hydrogeological data and a team of government experts trained to manage the database. Data and analysis gathered in Phase I will be integrated into a national survey of Iraq's hydrogeological resources. Planned for 2011, Phase II will identify aquifers down to 3000 m below the surface, study soil composition and aquifer replenishment and prioritize areas for agricultural development.

Upon the project's completion, the Government of Iraq will have a wealth of new data about the status of groundwater and will be able to move quickly to address water shortages in worst-affected areas. The project will also improve planning of new agriculture projects and enable sustainable management of Iraq's underground aquifers. Additionally, the project will allow Iraqi water engineers across the country to share information on groundwater resources with each other quickly and efficiently.

For details: c.walther@unesco.org; www.unesco.org/en/iraq-office

Ten medals in **nanoscience** and **nanotechnologies**

On 2 November, UNESCO Director-General Irina Bokova presented the two laureates of the UNESCO Medal for Contributions to the Development of Nanoscience and Nanotechnologies to Russian Academician **Zhores Alferov**, Nobel Prize in Physics in 2000, and Professor **Chunli Bai**, Executive Vice-President of the Chinese Academy of Sciences. At a second ceremony on 18 November, Ms Bokova awarded a further eight medals to:

- ✓ **the Intergovernmental Foundation for Educational, Scientific and Cultural Cooperation** of the Commonwealth of Independent States, represented by Armen Smbatian, Executive Director;

- ✓ **the State Oil Company of the Azerbaijan Republic,** represented by Eldar Shakhbazov;
- ✓ **Valery Chereshnev**, Chairman of the Committee on Science and High Technologies of the State Duma (Parliament) of the Russian Federation;
- ✓ **Yuri Gulyayev**, Member of the Presidium of the Russian Academy of Sciences;
- ✓ **Alexander Sigov**, Rector of the Moscow Institute of Radio Electronics and Automatics;
- ✓ **Vladislav Panchenko**, Chairman of the Russian Foundation for Basic Research;
- ✓ **Alexander Khavkin** of the Oil and Gas Institute of the Russian Academy of Sciences;
- ✓ **Victor Alexandrovich Bykov**, President of the Russian Nanotechnology Society.

This UNESCO medal was established in 2010 by the international commission responsible for developing the theme on nanoscience and nanotechnologies for the *Encyclopedia of Life Support Systems* (EOLSS) published by UNESCO and EOLSS Publishers. A volume on this theme was published recently in Russian (*see page 24*).

For details: www.eolss.net; unesco-eolss@unesco.org

Eleven sites added to **Global Geoparks Network**

Between 1 and 5 October, the Global Geoparks Network Bureau admitted 11 new members from nine countries during the 9th European Geoparks Conference taking place on the island of Lesvos (Greece). Created under the aegis of UNESCO in 2004, the Global Network of National Geoparks now comprises 77 geoparks in 24 countries.

- ✓ Situated in northwest Spain close to the French border, the first of the new geoparks, **Gipuzkoa Euskadi/País Vasco Geopark** on the Cantabrian Coast, is bordered by a mountainous landscape rising to heights of 1000 m. A long cultural history is represented by cave paintings, artefacts that testify to earlier attempts to communicate with the spirtual world (shamanistic artefacts) and a magnificent Gothic church in Deba, Santa Maria la Real;
- ✓ Located in northernmost Vietnam, the **Dong Van Karst Plateau Geopark** in Viet Nam's Ha Giang province is characterized by a karst limestone landscape and geological diversity, combined with a rich cultural heritage. The geopark will bring real and sustainable development to a very remote and economically deprived area;
- ✓ Lying about 100 km south of the **Korean Peninsula, Jeju Island** in the Republic of Korea is a volcanic island with a vibrant economy based largely on tourism and several well-preserved geosites of global importance;
- ✓ Located in southwest China, **Leye-Fengshan Geopark** in the Guangxi Zhuang Autonomous Region is characterized by numerous karst features: large subterranean rivers, karst windows, natural bridges, extensive cave systems and so on. The most representative landscape features are a number of large depressions, the Tiankengs, with nearly vertical walls that are typically more than 100 m deep and wide;
- ✓ Also in China, **Ningde Geopark** in Fujian showcases the interaction of rocks and water present in gigantic rock erosion shapes and impressive landscapes;
- ✓ Set in the Apennine mountains, the **Cilento and Vallo di Diano Geopark** in Campania, Italy, offers rich geological diversity and outstanding mountainous landscapes, cave formations and coastal features;
- ✓ The network's northernmost geopark lying not far from the Arctic Circle, **Rokua Geopark** in Finland's Northern Ostrobthnia and Kainuu Regions sports landforms shaped by the Ice Age: glacial ridges, pine and lichen-clad heaths, kettle holes and small ponds filled with crystal clear water. In addition, the area tells the story of prehistoric human settlement;
- ✓ Situated inside a National Park on Honshu Island, **San'in Kaigan Geopark** in Japan is a successful example of the integration of geological heritage and local development. A booming tourist industry has grown out of its beautiful coastal features – sand dunes, beaches for sea bathing, hot spring resorts and marine resources;

© UNESCO/Leye-Fengshan Geopark

Leye-Fengshan Geopark in the Guangxi Zhuang Autonomous Region in southwest China

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2011

Periodic Table of the Elements

United Nations
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Cultural Organization

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Chemistry

Partners for the International Year of Chemistry 2011

Periodic Table

Key:

atomic number **Symbol** name standard atomic weight

1	2	3	4	5	6	7	8	9
1 **H** hydrogen 1.008								
3 **Li** lithium 6.941(2)	4 **Be** beryllium 9.012							
11 **Na** sodium 22.99	12 **Mg** magnesium 24.31							
19 **K** potassium 39.10	20 **Ca** calcium 40.08	21 **Sc** scandium 44.96	22 **Ti** titanium 47.87	23 **V** vanadium 50.94	24 **Cr** chromium 52.00	25 **Mn** manganese 54.94	26 **Fe** iron 55.85	27 **Co** cobalt 58.93
37 **Rb** rubidium 85.47	38 **Sr** strontium 87.61	39 **Y** yttrium 88.91	40 **Zr** zirconium 91.22	41 **Nb** niobium 92.91	42 **Mo** molybdenum 95.96(2)	43 **Tc** technetium	44 **Ru** ruthenium 101.1	45 **Rh** rhodium 102.9
55 **Cs** caesium 132.9	56 **Ba** barium 137.3	57-71 lanthanoids	72 **Hf** hafnium 178.5	73 **Ta** tantalum 180.9	74 **W** tungsten 183.9	75 **Re** rhenium 186.2	76 **Os** osmium 190.2	77 **Ir** iridium 192.2
87 **Fr** francium	88 **Ra** radium	89-103 actinoids	104 **Rf** rutherfordium	105 **Db** dubnium	106 **Sg** seaborgium	107 **Bh** bohrium	108 **Hs** hassium	109 **Mt** meitnerium

57 **La** lanthanum 138.9	58 **Ce** cerium 140.1	59 **Pr** praseodymium 140.9	60 **Nd** neodymium 144.2	61 **Pm** promethium	62 **Sm** samarium 150.4	63 **Eu** europium 152.0
89 **Ac** actinium	90 **Th** thorium 232.0	91 **Pa** protactinium 231.0	92 **U** uranium 238.0	93 **Np** neptunium	94 **Pu** plutonium	95 **Am** americium

www.iupac.org/reports/periodic_table/

International Year of
CHEMISTRY
2011

of the Elements

10	11	12	13	14	15	16	17	18
								2 **He** helium 4.003
			5 **B** boron 10.81	6 **C** carbon 12.01	7 **N** nitrogen 14.01	8 **O** oxygen 16.00	9 **F** fluorine 19.00	10 **Ne** neon 20.18
			13 **Al** aluminium 26.98	14 **Si** silicon 28.09	15 **P** phosphorus 30.97	16 **S** sulfur 32.07	17 **Cl** chlorine 35.45	18 **Ar** argon 39.95
28 **Ni** nickel 58.69	29 **Cu** copper 63.55	30 **Zn** zinc 65.38(2)	31 **Ga** gallium 69.72	32 **Ge** germanium 72.64	33 **As** arsenic 74.92	34 **Se** selenium 78.96(3)	35 **Br** bromine 79.90	36 **Kr** krypton 83.80
46 **Pd** palladium 106.4	47 **Ag** silver 107.9	48 **Cd** cadmium 112.4	49 **In** indium 114.8	50 **Sn** tin 118.7	51 **Sb** antimony 121.8	52 **Te** tellurium 127.6	53 **I** iodine 126.9	54 **Xe** xenon 131.3
78 **Pt** platinum 195.1	79 **Au** gold 197.0	80 **Hg** mercury 200.6	81 **Tl** thallium 204.4	82 **Pb** lead 207.2	83 **Bi** bismuth 209.0	84 **Po** polonium	85 **At** astatine	86 **Rn** radon
110 **Ds** darmstadtium	111 **Rg** roentgenium	112 **Cn** copernicium						

64 **Gd** gadolinium 157.3	65 **Tb** terbium 158.9	66 **Dy** dysprosium 162.5	67 **Ho** holmium 164.9	68 **Er** erbium 167.3	69 **Tm** thulium 168.9	70 **Yb** ytterbium 173.1	71 **Lu** lutetium 175.0
96 **Cm** curium	97 **Bk** berkelium	98 **Cf** californium	99 **Es** einsteinium	100 **Fm** fermium	101 **Md** mendelevium	102 **No** nobelium	103 **Lr** lawrencium

- ✓ Located on Canada's east coast, **Stonehammer Geopark** in New Brunswick is the birthplace of geological research in Canada. Moreover, geology is fully integrated into residents' daily life, thanks to numerous leisure and tourism initiatives, community participation and co-operation programmes;
- ✓ The **Tuscan Mining Park** is situated in the Colline Metallifere (Metalliferous Hills), the most important mining district in central Italy. This geopark stretches from the coast to the mountains, occupying a strategic position between the main cultural and artistic cities of Tuscany and some important seaside resorts;
- ✓ **Vikos-Aoos Geopark** in Ioannina, Greece, offers an unspoiled panoramic mountainous landscape that includes the most impressive gorges in northwestern Greece, Vikos and Aoos. The geopark's management consortium is responsible for a sustainable tourist industry in which local communities are integrated.

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Countries sign up for **Nagoya Biodiversity Compact**

The mood was euphoric on 30 October as delegates from 193 countries voted to adopt the Nagoya Biodiversity Compact. This landmark umbrella agreement includes a Strategic Plan for Biodiversity covering the period 2011–2020, a protocol on access and benefit-sharing and an undertaking to mobilize the requisite financial resources for the compact's implementation.

Meeting in Nagoya (Japan) between 18 and 30 October, the State Parties to the Convention on Biological Diversity (CBD) agreed to halve the loss of natural habitats and increase nature reserves from 12% to 17% of the world's land area and from 1% to 10% of marine and coastal areas by 2020. They also undertook to restore at least 15% of degraded areas and to make special efforts to reduce the pressures on coral reefs.

Described by CBD Executive Secretary Ahmed Djoghlaf as one of the most important legal instruments in the history of environmental protection, the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits arising from their Utilization stipulates the basic rules for co-operation between nations regarding genetic resources. 'The protocol will allow us now to fully implement the convention,' Djoghlaf said, adding that it had established the foundation for a new international economic and ecological order based on respect of nature in its diversity, including human beings. The protocol outlines how benefits – gleaned for example, when a plant's genetics are turned into a pharmaceutical drug or other commercial product – will be shared with countries and communities who conserved and managed that resource, in some cases for millennia. It also lays out rules on how substances and compounds derived from genetic resources will be managed and clarifies important issues related to pathogens, including how developed countries could obtain a flu virus to develop a vaccine in order to stave off an imminent epidemic.

The protocol is expected to enter into force by 2012, with backing from the Global Environment Facility to the tune of US$1 million.

By signing on to the Nagoya Biodiversity Compact, countries also endorsed a resource mobilization plan containing provisions for raising current levels of development assistance in support of biodiversity conservation. In addition, Japanese Prime Minister Naoto Kan announced US$2 billion in funding to support implementation of the Nagoya outcome and his Minister of Environment the establishment of a Japan Biodiversity Fund.

Biodiversity concerns also garnered support from the donor community. Representatives of 34 bilateral and multilateral donor agencies agreed to translate the plan into their respective development co-operation priorities.

In parallel, the meeting welcomed the *Multi-Year Plan of Action on South–South Cooperation on Biodiversity* for Development developed on the basis of an initiative by the 131 members of the Group of 77 and China.

© UNESCO/Jacob Asher – NOAA

Every year, roughly 52 tons of derelict fishing nets are removed from Papahanaumokuakea, a vast US marine park which became a biosphere reserve last year.

The Nagoya meeting also gave its green light to the establishment by the United Nations General Assembly of an Intergovernmental Science Policy Platform on Biodiversity and Ecosystem Services (IPBES). Weeks later, on 20 December, the United Nations General Assembly formally approved the creation of IPBES. UNESCO, the CBD Secretariat, UNEP, FAO and UNDP will collaborate in organizing the first plenary meeting of IPBES, scheduled to take place around July 2011, which will deal with the operating procedures of this new body, including the location of the IPBES secretariat.

In Nagoya, governments adopted a number of decisions of particular importance for UNESCO's Man and the Biosphere programme and its World Network of Biosphere Reserves. For instance, the joint programme between UNESCO and the CBD Secretariat developed by the International Conference on Biological and Cultural Diversity last June was recognized as a 'useful co-ordination mechanism to advance the implementation of the Convention and deepen global awareness of the interlinkages between cultural and biological diversity'.

State Parties and other relevant stakeholders were invited to 'contribute to and support the implementation of this joint programme'.

The next meeting of the Conference of the Parties to the CBD will take place in 2012 in India.

For details: www.cbd.int; www.unesco.org/en/biodiversity; for background on IPBES, see A World of Science*, July 2010*

Experts call for assessment of **microplastics in oceans**

An expert workshop has recommended carrying out a global assessment for policy-makers of the microplastics which litter the world's oceans. Despite assuming growing proportions, this complex problem is currently poorly understood.

The multidisciplinary assessment would be led by the Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP[3]), in co-operation with the technical agencies of the United Nations responsible for ocean governance, regional and national administrations, IGOs and NGOs. The assessment would ideally take place in 2013, in time for the first cycle of the United Nations General Assemblies' Regular Process for the assessment of the marine environment.

Hosted jointly by the UNESCO-IOC and GESAMP at UNESCO headquarters in Paris on 28–30 June, the workshop cited regional overviews and a growing volume of scientific literature which all suggest that we are piling up problems for the future. Microplastics are building up in rapidly developing regions of the world that lack adequate solid waste management practices.

There is also a dearth of information on the quantity and type of plastics flowing into the oceans, particularly among governments, municipalities, the plastics industry and multinational retailers. It is a well-documented fact that plastic litter causes physical harm to marine mammals, fish and invertebrates, with instances of death by entanglement, asphyxiation or organ blockage being common.

Microplastics are small fragments of plastic arising from the structural deterioration and disintegration of plastic objects, examples being packaging and films, clothing, toothbrushes and razors, as well as building materials and lost or discarded fishing gear.

Microplastics can also arrive directly in the oceans as plastic resin pellets that are either used in manufacturing plastics or purposefully fabricated as abrasives for shot blasting or in cosmetic facial scrubs. Microplastic particles have been found in nearly all coastal and ocean environments to date.

Global plastics production rises by about 9% per year on average. It peaked at 245 million metric tonnes (mmt) in 2008 before falling briefly to 230 mmt in 2009. As the world economy recovers, plastics production is picking up again.

Scientists are especially concerned about microplastics because they are directly digestible and concentrate toxic contaminants that may accumulate in the body and then cannot be eliminated. These contaminants include polychlorinated biphenyls, dichlorodiphenyltrichloroethane – a synthetic pesticide known by its acronym of DDT – polybrominated diphenyl ethers, used as flame retardants. Little is known of the impact of this contamination on the large marine mammals, sharks and human beings at the top of the food chain.

Plastics can take anything from decades to centuries to fragment. Moreover, rather than disappearing, they are more likely to be eventually incorporated in sediments and other surfaces. Even the advent of biodegradable or biosourced plastics is expected to have a limited effect, as the conditions required for the degradation of these 'intelligent plastics' are simply not present on land or at sea. Knowledge of how microplastics disperse once they enter the ocean and what ultimately happens to them is only just beginning to emerge.

For details: www.gesamp.org/publications/publicationdisplaypages/rs82; jl.valdes@unesco.org; at GESAMP: tim.bowmer@tno.nl; peter.kershaw@cefas.co.uk

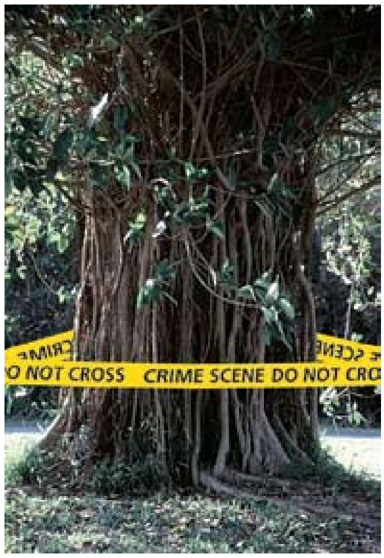
Photo courtesy of British Antarctic Survey

A young Antarctic Fur Seal (Arctocephalus gazella) entangled in a fishing net on Bird Island in South Georgia, which lies about 1000 km southeast of the Falkland Islands in the Southern Atlantic Ocean.

3. *GESAMP has a remit to advise its sponsoring agencies on emerging issues in relation to the state of the marine environment: IMO, FAO, UNESCO, UNIDO, WMO, IAEA, UNEP and UNDP.*

Jean-Christophe Balouet

Environmental crime scene



© UNESCO

When the police arrive at a crime scene, the chances are that they will be accompanied by forensic experts. The forensic team may be looking for traces of blood, hair or other DNA samples unwittingly left behind by an attacker. Or it may be called upon to examine fake banknotes, explosives or drugs, trace a fingerprint back to its owner, or determine what type of gun left behind a particular bullet casing. The forensic team will attempt to answer two key questions: what happened and who did it?

The growing number of environmental crimes and disputes is spawning a new type of investigator: the specialist in environmental forensics. The team may be responding to a complaint from an individual troubled by the contamination of his or her land, or it may be a case of attributing damages in a 'toxic tort' involving entire communities. In the search for evidence, the forensic investigator will rely on chemistry, biology, genetics, geology, toxicology and other areas of medicine, physics, mathematics and even engineering. Here, French environmental forensic expert Jean-Christophe Balouet teaches us some of the tools of his trade.

When is an environmental forensic expert called in?

The most common reason is pollution. There are between four and six million polluted sites worldwide, almost one polluted site for every thousand persons. Thousands of new cases are discovered each year around the world. In approximately 90% of cases, fossil fuels and solvents are to blame.

One of the easiest crimes to solve is the identity of the supertanker that dumped oil at sea. Once the expert has identified the problem, the next step is to look for evidence of the contaminant, in a process called fingerprinting. Analytical chemistry plays a key role here, as there are several ways to characterize chemicals, especially since chemical coupounds are rarely 100% pure.

Fossil fuels are a blend of hydrocarbons comprised of varying concentrations of paraffins (or n-alkanes), iso-alkanes, naphthenes, aromatics and olefins, which go by the acronym of PIANO. There is naturally a high concentration of other compounds in crude oil. These include sulphur, chlorine and trace metals found in a distilled product. Over the years, industry has used a lot of other additives, such as organic lead in leaded petrol brands.

Crude oil leaves a signature, providing another clue. Crude oil in the Arabian world will differ from crude oil in Alaska or the North Sea. The geological age of the oil field will also influence the oil's signature. Industrial processes used to distill crude oil likewise leave a distinct chemical and isotopic signature on the manufactured compounds. Chemical fingerprinting basically leaves the polluter little, if any, chance of remaining anonymous.

The same principles apply to tracing the origin of other pollutants, such as chlorinated solvents used by dry-cleaners that may have unwittingly seeped into the neighbour's soil.

Another example is the illegal trade in regulated or controlled substances. The Montreal Protocol adopted by the United Nations in 1987 and since ratified by 195 nations is gradually phasing out the manufacture of ozone-depleting substances like chlorofluorocarbons (CFCs). A CFC is an organic compound containing chlorine, fluorine and carbon. Smugglers have tried to circumvent the Montreal Protocol by passing off new CFCs for recycled ones or for authorized substances. They have shipped their cargo in small quantities to conceal it better, or had it transit by countries where CFCs are still authorized. Their mistake has been to underestimate the vigilance and scientific expertise of the authorities: in 1997, a Russian dealer was fined US$37 million by an American court for trying to smuggle close to 4000 tonnes of CFCs.

Is environmental pollution always detected rapidly?

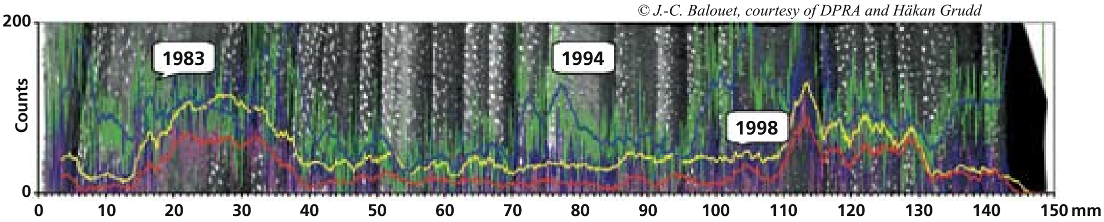
Not at all. In most instances, pollution is discovered years after it was first released. By this time, the compounds will have weathered and migrated away from the source. One source of pollution may even have mingled with another; this often happens at big industrial sites or when two sources are located close to one another, such as when leaded and unleaded petrol are installed at pumping stations on opposite sides of the road. In the case of a dispute involving a tort, the forensic expert may be called in to help determine how compensation should be allocated.

Forensics plays a major role in solving disputes. There may be a dispute over the timeframe for the release of the pollution, for instance, if the owner or insurance policy has changed over time. When you are looking to establish liability, a forensic expert can provide a suspect with an alibi, just as in a criminal case.

How do you date the time of release of a pollutant?

The additives used in petrol over the years help the investigator estimate a timeframe. Other age-dating methods exist, such as

© J.-C. Balouet, courtesy of DPRA and Häkan Grudd



Tree trunks record the trace of contaminants. Years or even decades after pollution has seeped into the soil, an investigator can identify chemical anomalies in the wood and date the time of the contamination by correlating these traces to their position on the rings in the trunk. Here, an X-ray of the core of a tree. Some reference rings have been dated. The colours on the graph indicate the presence of phosphorus (pink)*, sulphur (blue) and chlorine* (green)*. This technique is known as dendrochemistry.*

that of calculating the pollutants' decomposition rate. You can also date the age of groundwater, as surface contaminants will be incorporated in surface water like rain; rain itself will have been contaminated by time-specific atmospheric contaminants like CFCs or the tritium released globally by nuclear tests. These latter techniques are of varying precision and may not always be applicable. For instance, there is no point applying the tritium method around a nuclear plant.

New techniques have been developed recently which use trees as proxy recorders. When contaminants seep into the soil around a tree, they are taken up by the sap and fixed in the rings that develop in a tree year after year, giving its age. The forensic expert takes a sample from the trunk and analyses the tree rings on it to determine when a given pollutant affected the tree, in the same way that black boxes record the sequence of events in a plane crash.

In volatile compounds like fuels, the different hydrocarbons that are part of the blend will behave differently over time. Some will evaporate or degrade more rapidly than others. In addition, micro-organisms will selectively decompose the contaminants, modifying the isotopic signature of compounds in a process called 'fractionation'. Transformations like these leave us with a partly decomposed chemical and some by-products, a major clue in determining what has happened to the pollutant over time.

What are the limitations of environmental forensics?

All environmental forensic methods have their limitations. The strongest cases tend to be those where a variety of methods are used that produce converging results.

If the evidence is overwhelming, parties will logically settle out of court. If not, the case may go to trial where the expert opinions of the opposing parties may, unsurprisingly, contradict one another. The best forensic experts not only need impeccable scientific credentials but also a solid grounding in environmental law and good oratory skills. In addition to determining the material facts, they have to sway the judge and jury.

Only a small percentage of cases of environmental pollution actually involve forensics. The liability is blatant in most cases, compelling companies to acknowledge their wrongdoings. The dumping of toxic wastes near Abidjan in Côte d'Ivoire one August night in 2006 caused the death of ten people. Seventy others were rushed to hospital and hundreds of thousands fell ill or developed related symptoms. Within just a few days, the culprits had been identified and a few weeks later environmental clean-up had got under way. The Trafigura company settled with government authorities in February 2007 for 1 billion CFA (€150 million). This type of settlement typically stipulates that no further claims may be made and excludes any further investigation.

Who calls upon the services of environmental forensics?

The request may come from government authorities or from private parties ranging from large industries to small land owners. It may also come from insurance companies looking for confirmation that they are indeed responsible for the cost of cleaning up. As a general rule, it is important for the evidence to be evaluated objectively by an independent expert, as otherwise vested financial interests and other conflicts of interest may influence testimony.

Attorneys may hire an environmental forensic expert to protect their client, such as when he or she is a victim or risks being held liable for damages. Environmental damages do not come cheap; the costs range from a few tens of thousand of dollars to clean up a small leakage from private underground storage tanks – a common problem – to hundreds of thousands or even millions of dollars when human health is affected. In some cases, the claims may amount to billions of dollars, such as in the trial currently opposing an NGO in Ecuador and a major oil company which could end up having to pay damages of US$27 billion.

How long has there been a specialization in environmental forensics?

Environmental forensics has developed over the two past decades especially. It has been nurtured by a combination of factors: the growing incidence of air, soil and water contamination, heightened environmental awareness, an expanding regulatory arsenal and progress in both the basic sciences and analytical tools.

The International Society of Environmental Forensics dates only from 2000. The first university course in environmental forensics was introduced by the University of Wales in 2003. Dozens of conferences have since been organized worldwide, helping to disseminate knowledge and spawn international networks. Malaysia established a centre of excellence in environmental forensics at the Faculty of Environmental Studies of the University of Putra Malaysia in September 2008.

With the principle of 'polluter pays' gaining ground, environmental torts are increasingly being considered a crime in many nations. Mitigation and litigation costs are so high that you need watertight evidence to establish liabilities in an objective manner. Given the growing number and variety of disputes, environmental forensics has a long career ahead of it.

Interview by Susan Schneegans

For details: jcbalouet@aol.com; www.environmentalforensics.org/
Upcoming conferences: www.rsf.org/inef; www.webs-event.com

Science without borders

Computer-generated image of the completed International Space Station in low orbit around the Earth

One of the most striking trends observed in the *UNESCO Science Report 2010* is the growing internationalization of science. This is evident from the statistics on scientific co-authorship but also from the multiplication of joint programmes and research centres involving two or more countries.

A favourable geopolitical environment, coupled with the increasingly cross-border nature of many challenges – climate change and pandemics among them – are inciting governments to forge new alliances or strengthen existing ones through science. Just last November, India and the USA signed three agreements covering clean energy, monsoon forecasting and disease surveillance via the launch of a global detection centre for diseases in India. Nor is this trend the sole preserve of diplomacy; a growing number of international business consortia are emerging in high-tech industries. Here, we track some of the partnerships portrayed in the *UNESCO Science Report 2010*.

Increasingly, international diplomacy will take the form of science diplomacy in the years to come.

Irina Bokova
Director-General of UNESCO

Foreword to UNESCO Science Report 2010

From 2012 onwards, ground stations in South Africa, the Canary Islands (Spain), Egypt and Gabon will be able to access data from an Earth observation satellite being developed by China and Brazil. This will be the third CBERS satellite designed and launched by the Sino-Brazilian partnership since 1999. Up until now, satellite images of the changing landscape have been delivered only to users in China and Latin America: more than 1.5 million of them since 2004. Now, China and Brazil have decided to extend the list of beneficiaries to African countries. Since a satellite does not stop at borders in its orbit of the Earth, it makes sense to share the collected data with those countries in the satellite's path and thereby forge new partnerships. The space race of the last century has been replaced by a new paradigm, space diplomacy.

The Sino-Brazilian partnership in satellite development has been beneficial to both parties. For one thing, it has enabled Brazil to overcome a technological handicap: at the time CBERS-2 was launched in October 2003 from the Taiyuan Satellite Launch Center in China, Brazil still lacked an adequate launch vehicle of its own. The partnership has also enabled Brazil and China to share the financial burden of building each of the CBERS satellites. The Brazilian participation in the programme amounts to about US$500 million, with 60% of the investment taking the form of industrial contracts.

This example illustrates a growing trend: the use of space technologies for environmental monitoring within international collaboration. This trend is one consequence of the growing concern at the rapid degradation of the environment and climate change. With recognition of the interconnected nature of the land, water and atmosphere has come the realization that data-sharing among countries and continents will be crucial to improving our understanding and monitoring of the Earth's environment.

It is concern about the state of the environment that has motivated the European Union to develop its own capacity for Earth observation via the Global Monitoring for Environment and Security initiative. Since 2006, this pan-European initiative has been extended within a partnership that is developing Earth observation infrastructure in support of African environmental policies.

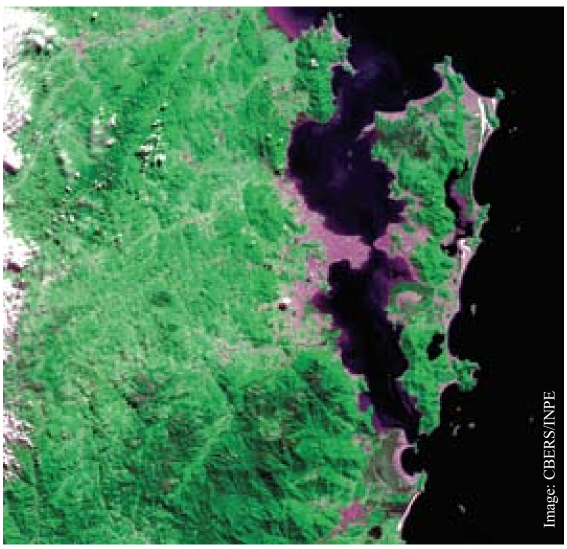


Image taken by the CBERS-2 satellite on 10 April 2005 showing ((in pink) Florianopolis, the capital of the State of Santa Catarina in southern Brazil

The changing face of international co-authorship

In addition to such factors as evolving geopolitics and financial considerations, the growth of international scientific collaboration in recent years owes much to the rapid spread of ICTs: Internet access doubled between 2002 and 2008 from 11% to 24% of the global population and even tripled in the developing world from 5% to 17% of the population.

The past few years have not only witnessed a surge in international co-authorship but also a diversification of research partners. One of Australia's top three partners for scientific co-authorship between 1998 and 2008 was China, along with traditional partners the United Kingdom and USA. In the Philippines, top billing went to the USA and Japan, followed by China. China was even the number one partner for Malaysia, ahead of the United Kingdom and India. There are signs that the growing role of China and India in scientific authorship as a consequence of their greater global influence is already reshaping the scientific landscape in Southeast Asia.

As for China itself, its biggest research partner by far is the USA. This was already the case in 1999–2003 but scientific authorship between the two countries has since pulled far ahead of China's next biggest partner, Japan.

The closest neighbours do not always make for the closest partners. India, Iran and Pakistan all publish 20–30% of research articles with scientists abroad but most of their co-authors live in Western countries. Just 3% of research articles are published in collaboration with scientists working in South Asia. In Brazil, where international scientific collaboration has remained steady for the past five years at about 30% of the total, 'US scientists are the main partners' write authors Carlos Henrique de Brito Cruz and Hernan Chaimovich, respectively Scientific Director of the São Paulo Research Foundation and CEO of the Butantan Foundation in Brazil. They cite a 2009 study which 'found that 11% of scientific articles written by Brazilians between 2003 and 2007 had at least one co-author in the USA and 3.5% a co-author from the UK. Argentina, Mexico and Chile combined represented just 3.2% of co-authors of Brazilian articles.'

Space diplomacy: a subset of a wider phenomenon

Space diplomacy is itself a subset of a wider phenomenon today: science diplomacy. Space is just one of three components of the broad partnership involving the European Union and African Union. A second component concerns science *per se*. Under this component, a Water and Food Security and Better Health in Africa project has been earmarked for €63 million in funding, for example. Meanwhile, the African Union Commission has contributed €1 million for the first year of another project for the Popularization of Science and Technology and Promotion of Public Participation.

A third component of the partnership concerns the information society. The AfricaConnect project, for instance, is seeking to integrate the African research community at both regional and international levels by improving bandwidth. In paralllel, the African Internet Exchange System (AXIS) is being developed to support the growth of a continental African Internet infrastructure. A 10 000 km-long sub-marine fibre-optic multipoint cable system is also under construction.

Around the world, countries are developing partnerships in science, technology and innovation within a wider policy to forge political alliances, enhance their presence on the world stage and rationalize resources. 'In order to facilitate its integration in the global arena of science and technology and assume a greater role, Russia has been stepping up its efforts to develop international co-operation,' write authors of the report Leonid Gokhberg and Tatiana Kuznetsova of the Higher School of Economics in Moscow. Today, approximately 10% of the scientists working at the European Organization for Nuclear Research (CERN) in Switzerland are of Russian origin, even though the Russian Federation is only an observer country.

Photo: Wikipedia Commons

The Southern African Large Telescope in South Africa's semi-desertic Karoo region involves no fewer than seven countries.

‘A road map for setting up the European Union–Russia Common Space of Education and Science has been developed jointly with the European Commission on the basis of the principles of equality and partnership,’ write Gokhberg and Kuznetsova. The European Union and Russia are implementing a growing number of initiatives in areas that include new materials, nanotechnology, non-nuclear energy production, information and communication technologies (ICTs) and biotechnology. During the European Union’s Sixth Framework Programme for Research and Technological Development (2002–2006), Russia even ‘ranked first among participating third parties, both in terms of the number of projects implemented with European partners and the amount of funding obtained from the European Union.’

Photo: CERN

Working on a segment of the Large Hadron Collider, a particle accelerator with which scientists at CERN hope to recreate the conditions of the Big Bang

The quest for clean energy sources is a growing focus of international partnerships. In June 2009, Sudan inaugurated its first biofuel plant, built in co-operation with the Brazilian company Dedini. A second project in Sudan involving Egypt at a cost of US$150 million is producing second-generation biofuels from non-edible crops, including agricultural waste such as rice straw, crop stalks and leaves.

Bilateral and multilateral soft power

Nor is science diplomacy restricted to bilateral partnerships. Inaugurated in November 2005, the Southern African Large Telescope in the semi-desertic region of Karoo in South Africa involves no fewer than seven countries. The largest single optical telescope in the Southern Hemisphere, it owes its existence to a consortium of partners from South Africa, the USA, Germany, Poland, India, the United Kingdom and New Zealand.

The Regional Centre for Renewable Energy and Energy Efficiency in Cairo has ten founding members: Algeria, Egypt, Jordan, Lebanon, the Libyan Arab Jamahiriya, Morocco, the Palestinian Authority, Syria, Tunisia and Yemen. Founded in 2008, the centre will be able to rely on financial support from its three development partners – the European Union, German Agency for Technical Co-operation and Danish International Development Agency – until 2012 when the centre is expected to become self-sufficient, thanks to contributions from member states and income generated from research and consultancy work.

Science diplomacy is being used in the Middle East and elsewhere to foster development and peace in parallel. Construction of the international Centre for Synchrotron-light for Experimental Science and Applications in the Middle East (SESAME) was completed in Jordan in 2008. The members of SESAME are Bahrain, Cyprus, Egypt, Iran, Israel, Jordan, Pakistan, the Palestinian Authority and Turkey. Once the world-class laboratory is fully operational four years from now, scientists will be able to work together across countries and cultures within the same research facility, itself operating under the auspices of UNESCO. In preparation for this day, approximately 65 men and women have spent periods of up to two years working at synchrotron radiation facilities in Europe, the USA, Asia and Latin America. The majority of these facilities are situated in SESAME observer countries, of which there are 12, including France, Japan, Kuwait, the United Kingdom and USA.

Under an agreement signed by the two countries in 2003, Pakistan and the USA now ‘contribute to a common fund which is jointly managed by the National Academy of Sciences in the USA and by the Higher Education Commission and Ministry of Science and Technology in Pakistan,’ writes author Tanveer Nair, who, as Chair of the Pakistan Council for Science and Technology, played a pivotal role in securing this landmark agreement. ‘Each year, proposals for research collaboration are invited with at least one US and one Pakistani scientist as principal investigators. The proposals undergo peer review in both countries and are selected on merit. This programme has resulted not only in capacity-building of Pakistan’s laboratories’, she says, ‘but also in the joint discovery of a vaccine to prevent a deadly disease caused by tick bites which afflicts those working with animal herds in the southern region of Sindh in Pakistan.’

Sharing megacosts on megaprojects

Beyond the lofty goal of furthering development, international collaboration in science and technology is of course also motivated by the more pragmatic desire to pool resources in the face of the escalating costs of scientific infrastructure. The bill for one international project to develop a clean energy source by mastering nuclear fusion has been estimated at no less than €10 billion. This is 'the most ambitious collaborative project in science ever conceived', writes author Peter Tindemans, a consultant formerly responsible for co-ordinating research and science policy in the Netherlands. The project is building an International Thermonuclear Experimental Reactor (ITER) in Cadarache, France, by 2018.

Photo: NASA

Space shuttle Endeavour lifting off from NASA's Kennedy Space Centre on 15 July 2009 for a rendez-vous with the team at the International Space Station

That the project should involve not only the traditionally dominant scientific powers of the European Union, Japan, the Russian Federation and the USA but also China, India and the Republic of Korea is a reflection of the growing economic and technological might of these countries. China, for instance, 'will assume 9.09% of the cost of construction and spend over US$1 billion in total,' writes Mu Rongping, Director of the Chinese Academy of Science's Center for Innovation and development, in the report. 'Some 1000 Chinese scientists will participate in the ITER project [and] China will be in charge of developing, installing and testing 12 components,' he explains.

Another extremely costly project is the ongoing assembly of the International Space Station in low orbit around the Earth, due for completion next year. This project draws on the competence and finances of the space agencies of Canada, the European Union, Japan, the Russian Federation and USA.

A tempting business

The business sector has been quick to weigh up the advantages of international scientific collaboration. In addition to cost-sharing, international consortia offer a golden opportunity to conquer new markets. The hugely successful Airbus consortium is the result of the merger of the formerly independent aircraft manufacturing companies of four European countries – France, Germany, Spain and the United Kingdom – and is a shining example of what pan-European co-operation can achieve. A no doubt lesser-known example is Sea Launch, involving a consortium of four private companies from Norway, the Russian Federation, Ukraine and the USA. Sea Launch offers customers a unique, mobile platform at sea from which to launch their spacecraft.

Two decades after the fall of the Iron Curtain, the Russian Federation is witnessing a growing volume of commercial contracts and joint ventures in science and technology involving both Russian and foreign companies. In 2010, the joint-stock enterprise comprised of the French company Alcatel-Lucent and state corporation Russian Technologies began investing in the development, manufacturing and marketing of telecommunications equipment for the Russian market and those of the countries of the Commonwealth of Independent States. Meanwhile, the jointly owned US–Russian company Isomed Alpha has begun producing high-tech medical equipment like computer tomographs.

'These international partnerships are making it possible to increase exports of high-tech products and services in certain areas,' observe Gokhberg and Kuznetsova. They go on to say that, in 2005–2007, exports of Russian ICT products doubled and those of electronic equipment, aircraft and spaceships grew by 40–50%.'

Susan Schneegans[4]

An abridged version of this article was printed in the UNESCO Courier *in January 2011.*

4. *Editor,* UNESCO Science Report 2010; *s.schneegans@unesco.org*

Biodiversity in a kit

© Hélène Gille

Throughout the International Year of Biodiversity, UNESCO has been preparing a Biodiversity Learning Kit. Comprised of a *Biodiversity Resource Book* and a *Booklet of Activities*, these new educational materials aim to inform and raise awareness of biodiversity issues among young people, their teachers and the general public.

What do we mean by ecosystem support services? Why are bee populations declining? In this excerpt from the *Resource Book*, we discover how ecosystems help to maintain the conditions that are conducive to life on Earth, be it via soil formation, nutrient cycles, biomass production, the supply of natural habitats, sediment retention and transportation, the production of atmospheric oxygen or the water and carbon cycles.

Biodiversity in a kit

Soil formation begins with the minerals found in outcrops of bare rock or in sediments. When this bedrock is exposed, it is hard but biodegradable. Climate action triggers an initial transformation via freezing and thawing, heat, water and the atmosphere. This weathering interacts with the very nature of the rock (granite, limestone) to transform and degrade it. The first, and sometimes unique, plants to take root on outcrops of bare rock are lichens, which can live without soil but produce acids capable of breaking up the rock surface.

The action of these tiny roots, which work their way into the cracks and produce secretions capable of degrading minerals, is known as biochemical erosion. While the texture of degrading granitic bedrock will differ from that of calcareous sediment, the result is the same: the products of mineral degradation mix with the products of plant degradation to form an ever thicker soil where once there was only bare rock. This is a very slow process: only over a considerable length of time will plants manage to take root in the collected debris; after lichens come mosses then herbaceous species like shrubs which erode the rocks. When the shrubs die, their remains are gradually incorporated in the inert mass of mineral particles, transforming them into a life support system.

Necromass recycling

Soil is nevertheless a complex matrix. Vegetation produces plant debris which forms a layer of organic matter known as plant litter. This plant litter is scattered on the ground, where it degrades and thus erodes the rock. However, the organic matter of this litter is not merely composed of branches, leaves, fruits and the roots of dead plants; it is also composed of dead insects and animals, excrement, mucus and moultings, thus forming a layer of various types of waste produced by living things. This dead organic matter is known as necromass, in opposition to biomass, which is living organic matter.

Necromass plays a major role in soil fertility and the nutrient cycle. It is broken down and recycled by a chain of organisms – insects and small animals, fungi and micro-organisms – that live in the soil or on the surface. Necromass produces humus and mineral compounds. The body of a dead grasshopper is soon covered by hyphae, the part of the fungus that feeds, grows and may ultimately produce a mushroom. The hyphae of the fungus act as a decomposing agent in the same way that ants are able to dissect large chunks, twigs or seeds. There are also insects which feed on dead flesh, such as some diptera (flies and midges) or coleopteran (beetles and weevils). There are also the 'champion cleaners' like dung beetles, which break down dung and bury debris in the soil, thus helping to eliminate parasites from vertebrate species, together with any other vectors of disease the corpse may contain.

Some decomposers refine dead matter and transform it so radically that it returns to an inorganic state, thereby recycling the nutrients in the soil. These decomposers include fungi and a wide range of bacteria. Without this recycling of necromass by living species, plants – which are producers – cannot grow, food chains cannot be constructed and the amount of energy required to kick start a functioning ecosystem cannot be passed on.

Production of humus

©Alan Morgan /Alpha Presse

As it decomposes, organic matter releases mineral compounds in a process known as mineralization. It also goes through a stage of humidification when soft organic compounds bind together and with clay. This process of humidification creates humus, without which fertile soil cannot form.

Humus acts as a surface 'cloak'. This layer of dark topsoil is naturally protective, a good water retainer and a chemical fertilizer that varies according to the type of organic matter. It sustainably maintains the lower, more or less permeable and aerated layers of soil by impregnating them in places and recharging them naturally with nutrients.

In arid or desertic regions where there is no plant cover, humus has difficulty forming. Without this protection, the soil becomes vulnerable to erosion and can be destroyed. The exposed land thus needs protecting from heavy storms and winds, often by using the available plant diversity: for example, you can plant hedges which offer protection or fertilize the soil; or fast-growing plants that anchor the exposed land.

Nutrient cycling

Nutrients such as nitrogen, phosphorus, magnesium, potassium, copper and calcium are essential to plant growth and consequently to building and sustaining ecosystems. Living species are constantly participating in the nutrient cycle: they absorb the nutrients in their food or extract them from the environment – plants do this through their roots, for instance; they store nutrients or transmit them through their own matter, such as when plants are eaten by animals; they recycle nutrients when they decompose necromass or when they themselves die, releasing nutrients in their decomposed remains.

During their life cycle, nutrients pass constantly from living to non-living matter, with biodiversity serving as the means of transmission. Let's take an example: nutrients include such macronutrients as carbon or nitrogen, which are used in large quantities by living things. Nitrogen regulates our metabolism by developing the proteins that are essential for our cells. Nitrogen occurs naturally in the atmosphere, 78% of which is made up of nitrogen gas, even if we humans cannot harness it directly. Like most species, we obtain our nitrogen requirements from our food.

Only bacteria are able to take up atmospheric nitrogen directly. Nitrogen falls to Earth with the rain as weak nitric acid. It is then harnessed by nitrifying bacteria in the soil which convert nitrogen compounds into nitrates. Plants then absorb nitrates through their roots before transmitting them to animals and ... to humans.

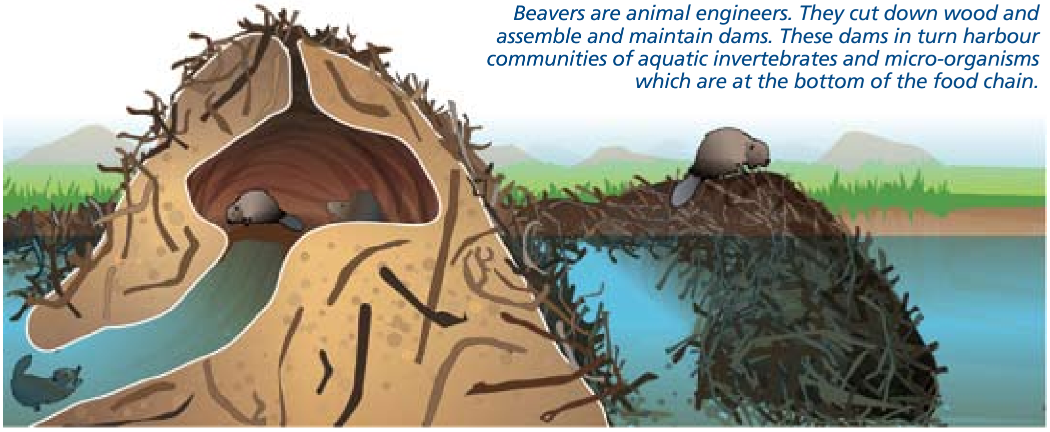
Thus, it is thanks to nitrogen-fixing bacteria that nitrogen combines with other elements. For example, the bacteria of the genus *Rhizobium* invade the deep roots of legumes (beans, lucerne, clover, vetch or alfalfa, depending on the region) and form nitrogen-fixing nodules. This nitrogen is then 'embedded' in the proteins of the plant, which in turn makes it available to other plants by circulating the nitrogen through its roots. Once the nitrates have permeated the soil, other bacteria absorb them and release nitrogen into the atmosphere, thus completing the cycle for this natural element vital to us all. (We ourselves are part of this cycle, as we release nitrogen compounds when we die!)

Biomass production

Biomass refers to the total mass of living organisms measured in a given space, area or population. Plants account for nearly 90% of all biomass. The production of biomass is generated by plants themselves, which, in a sense, manufacture their own plant material. Plants are producers, being at the bottom of the food chain. Most often rooted in soil, they absorb water and nutrients through their roots and carbon dioxide (CO_2) through the stomata in their leaves. During the natural process of photosynthesis, they capture solar energy and, thanks to the chlorophyll in their organs, use it to convert water and CO_2 into the simple sugars which make up their food. As they absorb this food, plants produce material that will subsequently be used to feed other living organisms.

In addition to photosynthesis, biodiversity contributes to the production of biomass via the many biological interactions underpinping it, as biomass emanates from extremely diverse organisms. We owe this process of diversification to the appearance of flowering plants (angiosperms) 150 million

Beavers are animal engineers. They cut down wood and assemble and maintain dams. These dams in turn harbour communities of aquatic invertebrates and micro-organisms which are at the bottom of the food chain.



years ago. The many families and species of flowering plants that make up the vast majority of plants today carry out their sexual reproduction with the help of 'third parties' – other species –, which assist them at different stages of their reproduction; these third parties comprise pollinators and various types of disseminator.

©Nadine Samson

Over time, this has engendered at least two phenomena, namely genetic exchange and a slow adaptation to their environment as the plants have 'co-evolved' with other species in their community. This has produced an extraordinary diversity.

Preserving a support service like the production of biomass implies preserving the precious links in the biological chain underpinning it. However, a drop has been observed everywhere in the diversity of the insect pollinators that are essential for plant reproduction. Air pollutants, including biocides, insecticides or fungicides, degrade the aroma molecules of flowers, thus reducing the range of floral fragrances and other phytohormones (plant hormones). This makes it more difficult for pollinators to locate flowers, a factor which partly explains the declining populations not only of bees but also of birds and bats that feed on nectar in many countries that have strong industrial and agricultural systems.

The decline in the number of pollinators affects some species' reproduction rates. This has a serious impact on fruit, vegetable and oilseed crops and – more generally – on the production of living matter. A study conducted by a team of French and German researchers and published in *Ecological Economics* puts the value of worldwide insect pollination in 2005 at €153 billion – and they were only counting the main crops consumed by humans.

Nor should we overlook the important role played by disseminators, or 'germinators'. Think of the role that seed-eating ants play in the Australian semi-desertic ecosystems. By consuming the seed coat of herbaceous plants and discarding the rest, they help to disperse the seeds evenly. This explains the density of the beautiful floral carpets which sprout in spring when the rains return.

Another example of co-operative germination is provided by the dung beetles in the Central American rainforests. By burying the seeds contained in the faeces of fruit-eating animals in the soil, they facilitate germination considerably. There are some particularly remarkable partnerships, such as that uniting the spotted nutcracker and the mountainous Swiss Pine or Arolla Pine. As spotted nutcrackers are rather partial to the large kernels contained in the pine cones, the birds store them in their throats and under their tongues, later disgorging them and burying them in anticipation of winter. The forgotten seeds will then germinate and ensure that the pine tree can spread into even the most inaccessible areas.

©Olivier Brestin

Biodiversity and the carbon cycle

Like the nitrogen cycle, the carbon cycle is one of our planet's main biogeochemical cycles. It describes the complex exchange of carbon elements in water, rocks, living material, necromass and the Earth's atmosphere. Like nitrogen, carbon is a macroelement: all living things contain carbon.

During photosynthesis, plants absorb carbon from the atmosphere as CO_2 and convert it into organic molecules that contain energy (carbohydrates, proteins and lipids). Animals absorb carbon the same way they absorb nitrogen, by eating plants or other animals.

When living things die, they are normally broken down by micro-organisms and the bulk of their carbon returns to the atmosphere. If there is not enough oxygen to generate any real microbial activity in the soil, the micro-organisms cannot decompose the carbon remains, which remain trapped and accumulate beneath the ground. These will eventually be transformed into coal, oil or natural gas, thus constituting natural carbon reserves.

Human industrial activity and that related to infrastructure depends massively on the combustion of carbon rock (coal, oil and gas). Burning these fossil fuels releases carbon into the atmosphere.

Another important source of carbon emissions is the massive combustion of organic matter as a result of deforestation. It is estimated that 750 million hectares of savannah are burnt annually, almost half of them in Africa.

The role of human intervention in the changing carbon cycle can now be quantified: in the past two centuries, atmospheric CO_2 concentrations have increased by one-third. This imbalance is largely responsible for the global warming we are experiencing as a result of the abnormally high atmospheric concentrations of CO_2 and methane, both greenhouse gases.

It is essential for us to analyse and acknowledge the role played by biodiversity in regulating the climate and its potential for storing carbon through photosynthesis. Biodiversity 'extracts' CO_2 from the atmosphere by trapping or storing it in natural reservoirs like forests. Every year, the Amazon rainforest recycles 66 billion tons of CO_2, nearly three times the level of emissions from fossil fuels burnt worldwide. Imagine what would happen in terms of global warming if the Amazon forest were to evolve from being a 'carbon sink' into being an atmospheric 'carbon source'.

Hélène Gille[5]

For details, see also page 24

5. *Editor and designer of the* Biodiversity Learning Kit*:* *h.gille@unesco.org*

International Year of
CHEMISTRY
2011

Diary

16–21 January
South African Chemical Institute (SACI)
Congress of Federation of African Societies of Chemistry with SACI, sponsored by UNESCO. Will showcase research in traditional branches of chemistry and pay tribute to Ethiopian chemists behind IYC designation. University of Witwatersrand, Johannesburg (South Africa): *jdarkwa@uj.ac.za; Neil.Coville@wits.ac.za; iyc2011@unesco.org*

17–20 January
Extreme natural hazards and disaster risk in Africa
Intl workshop co-spondored by intl scientific unions (IUGG, IGU, IUGS, IUTAM, AGU) and UNESCO-IOC Global Ocean Observing System. Hatfield, Pretoria (South Africa): *www.technoscene.co.za/hazardsws/*

18 January
Women sharing a chemical moment in time
Global campaign of networking breakfasts for women in chemistry, to be broadcast via SKYPE and aired during launch of Year at UNESCO Paris. Organizers (in Australia): m.garson@uq.edu.au; (in Egypt): *r.abou-el-azm@unesco.org; iyc2011@unesco.org*

24–26 January
The basics of biodiversity and climate change issues in the Arabian Peninsula
Training for media specialists. Muscat (Oman): *b.boer@unesco.org*

25 January – 27 February
Nobel laureates in chemistry
Portrait exhibition of 76 laureats, photos by Peter Badge. With CNRS, at Musée des arts et métiers. Ten other portraits will be exhibited at UNESCO (27–28 January). Paris (France): *france.auda@cnam.fr*

27–28 January
Launch of International Year of Chemistry
Will cover themes that include history of chemistry, role of women chemists, global trends and chemistry for sustainable development. UNESCO Paris. Other launches planned in Ethiopia and elsewhere: *iyc2011@unesco.org; www.chemistry2011.org*

7 February –18 March
Negotiation and mediation for water conflict management
Two courses developed jointly by UNESCO's programme From Potential Conflict to Cooperation Potential and UNESCO-IHE: 1st course 7–25 February, deadline for applications: 7 January; 2nd course: 28 February – 18 March; Deadline for applications: 28 January. Delft (Netherlands): *www.unesco-ihe.org; l.salame@unesco.org*

16–18 February
IGCP Scientific Board Meeting
UNESCO Paris: *m.patzak@unesco.org; r.missotten@unesco.org*

16–18 February
International Advisory Committee for Biosphere Reserves
17th meeting to recommend nomination of new sites. UNESCO Paris: *mab@unesco.org; www.unesco.org/mab*

21–24 February
Enhancing the capacity to provide quality chemistry education
at the secondary and tertiary levels in Ethiopia. Addis Ababa: *a.makarigakis@unesco.org*

21 February
IUGS 50th Anniversary
Intl Union of Geological Sciences celebrating 50 years. UNESCO Paris: *r.missotten@unesco.org*

21–22 February
MAB research sites
Meeting to discuss creating a set of MAB research sites, separate from the World Network of Biosphere Reserves. UNESCO Paris, Room XV: *t.schaaf@unesco.org*

28 February – 3 March
Seismicity and earthquake engineering in extended Mediterranean
UNESCO/USGS workshop for 60 scientists from 20 countries. Hosted by Cyprus Geological Survey Department. Nicosia (Cyprus): *b.rouhban@unesco.org*

2–3 March
L'OREAL–UNESCO Awards for Women in Science
Ceremony for 15 Fellows (2 March) and the five laureates (3 March) with focus on International Year of Chemistry. UNESCO Paris, Room IV: *r.clair@unesco.org*

22 March
World Water Day: Water for Cities
Worldwide annual celebration. World Water Assessment Programme inviting guests. Perugia (Italy): *www.unesco.org/water/wwap/*

23 March
Exercise Caribe wave 11
Tsunami exercise to assist tsunami preparedness efforts throughout the Caribbean region. Involves every Caribbean emergency management organization: *b.aliaga@unesco.org; www.ioc-tsunami.org/*

New **Releases**

Engineering: Issues, Challenges and Opportunities for Development
Edited by Tony Marjoram. UNESCO Reference Works series, UNESCO Publishing. ISBN: 978-92-3-104156-3. English only, €26.00, 396 pp.
Based on contributions from more than 120 experts around the world. See also page 9. Download: *http://unesdoc.unesco.org/images/0018/001897/189753e.pdf*

Nanoscience and Nanotechnologies
Thematic volume of Encyclopedia of Life Support Systems. Environment and Development series, UNESCO Publishing/Magister-Press. ISBN: 978-92-3-404137-9. Exists in Russian, €32.00, 1024 pp.
Includes articles by nanotechnologists from more than ten countries, including China, Russia and USA. Targets advanced students and their professors, researchers and decision-makers.

Sea-level Rise
T. Aarup, J.A. Church, W.S. Wilson and P.L. Woodworth (eds), based on Chapter 13 in: Church, J.A. et al. (2010) Sea Level Rise and Variability – Synthesis and Outlook for the Future. *Wiley–Blackwell Publishers. English only, 12 pp.*
Coastal zones have changed profoundly during the 20th century on account of growing populations and economies and urban spread. Society is becoming increasingly vulnerable to sea-level rise and variability, as Hurricane Katrina demonstrated in New Orleans (USA) in 2005. Based on a workshop run under the auspices of the World Climate Research Programme at the UNESCO-IOC in Paris in 2006, involving 163 scientists from 29 countries. For details: *t.aarup@unesco.org*; download: *http://unesdoc.unesco.org/images/0018/001893/189369e.pdf*

Advanced Simulation and Modelling for Urban Groundwater Management – UGROW
Edited by Dubravka Pokrajac and Ken Howard, Urban Water series, UNESCO Publishing/Taylor & Francis, ISBN: 978-92-3-104173-0, English only, €38.00, 252 pp.
Presents the results of a UNESCO-IHP project. UGROW is a complete, fully integrated modelling package for simulating urban water systems as a decision-support tool for urban water management. Although the focus is on urban groundwater, all other key urban water system elements are fully represented and seamlessly linked. Includes a CD-ROM containing a fully functional version of UGROW.

Biodiversity Learning Kit
*Editor and Kit designer: Hélène Gille. Director of Publication: Salvatore Arico. Graphic Design: Mecano/Laurent Batard. Produced by UNESCO-MAB. Volume 1 (*Biodiversity Resource Book, *approx. 150 pp.) and Volume II (*Booklet of Activities, *50 pp). ISBN pending. French version in press, English version to follow.*
Prepared as a contribution to the International Year of Biodiversity and Decade of Education for Sustainable Development (2005–2014) [*see page 21*]. To be tested via UNESCO's Associated Schools Network in 2011. For details and to request a copy: *s.arico@unesco.org; h.gille@unesco.org; n.lazic@unesco.org; mab@unesco.org; www.unesco.org/mab*

World Heritage
Heritage and biodiversity
Periodical, n° 56, UNESCO World Heritage Centre/UNESCO Publishing, ISBN: 92-3-1WH005-6, €7.50. Exists in English, French and Spanish, 88 pp.
This issue celebrates the International Year of Biodiversity. It reports on synergies between World Heritage sites and Key Biodiversity Areas, the Marine World Heritage Programme, the ties between biological and cultural diversity, and funding for biodiversity conservation. Profiled sites include Western Ghats (India) and Kew Gardens (UK), as well as a number of endangered sites.

Atlas of Mangroves
By Mark Spalding, Mami Kainuma and Lorna Collins. Published by International Society of Mangrove Ecosystems and International Tropical Timber Organization with project partners FAO, UNEP–World Conservation Monitoring Centre, UNESCO- MAB, UNU-Institute for Water Environment and Health, The Nature Conservancy. Funding from Japanese government. ISBN: 9781844076574, £65.00. English only with Spanish and French editions to follow, 336 pp.
Some 100 international mangrove experts, researchers and organizations contributed to this full-colour atlas detailing mangrove distribution and evolution around the world, including in national parks, World Heritage sites, biosphere reserves and Ramsar sites. All data and maps emanate from recent satellite images. In the annexes figure species ranges and line drawings, national species lists, as well as national statistics, including mangrove areas by country. For details: m.clusener-godt@unesco.org; to order a copy: *isme@mangrove.or.jp; www.earthscan.co.uk/tabid/34104/Default.aspx*

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