A World of SCIENCE

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Protecting a land of fire and ice

A garden in the desert

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Genetics, genomics: where to from here?

When his newborn son was rushed to intensive care with breathing problems in 1999, American Jonathan Rothberg feared a genetic disease might be the cause. It wasn't and his son recovered but, while waiting anxiously for the diagnosis, Dr Rothberg had a brainwave: he would develop a portable machine able to screen a person's genome in just a few hours – or even minutes.

He isn't there yet but his printer-sized device can nevertheless sequence the genome of a bacterium or virus in record time. That is already a leap forward, when you consider how many days it takes to culture bacteria. Imagine how much faster you could identify the cause of an epidemic, if you could sequence the microscopic suspect's genome in just a few hours.

Next-generation genomics offers exciting possibilities for medicine but also for agriculture – and for criminals or terrorists, if the technology fell into the wrong hands. Those hands might even be well-intentioned but ignorant of the dangers of experimenting with DNA sequencing or with assembling genes to customize new organisms, what is known as synthetic biology. These new organisms could escape from a backyard garage into the environment, where they could contaminate other species – the stuff horror movies are made of. Each new technology poses ethical challenges.

UNESCO's International Bioethics Committee (IBC) plans to enhance collaboration next year with its sister Commission on the Ethics of Science and Technology, in order to reflect on overarching topics, such as the risks associated with synthetic biology and converging technologies, which blend nanotechnologies, biotechnologies and ICTs – as in the case of next-generation genetic screening devices.

There are also questions of access. Will genetic screening be too costly for the poor, for instance? As the Chair said when the IBC met in June,' the issue of financial gain from the human genome is a looming conflict between intellectual property rights and the right of every human being to have access to quality health care'.

All three international declarations on bioethics adopted by UNESCO since 1997 reaffirm the same overriding principle: respect for human dignity. The IBC is currently putting together policy recommendations for prohibiting the commercial exploitation of the human body, including via organ trafficking or the sale of biobanks.

UNESCO's involvement in the biological sciences dates back much farther than the 1990s, of course. By anticipating the revolution in applied microbiology in the 1970s that followed the discovery of the molecular structure of DNA in 1953, UNESCO's biological sciences programme was well-prepared for the emergence of genetic engineering. As early as 1962, UNESCO launched the International Cell Research Organization. The Molecular and Cell Biology Network followed in 1990, the first centre of its kind to function under the auspices of UNESCO after becoming an NGO in 2002. In the early 1980s, UNESCO threw its support behind the fledgling Human Genome Project, which would hail the birth of genomics. Today, UNESCO's International Basic Sciences Programme is supporting the successor to the Human Genome Project, the Human Variome Project, which is mapping genetic variation in the human population to improve diagnostics.

Last June, UNESCO celebrated these three milestones by hosting an event in Paris on Sixty Years of DNA, from the Double Helix to the Human Variome, through the Human Genome. We retrace this extraordinary journey in the article beginning overleaf.

Gretchen Kalonji
Assistant Director-General for Natural Sciences

60 years of the double helix

Photo: Henryk Kotowski/ Wikipedia Commons

Tobacco field in Cuba. The first genetically modified plant was a herbicide-resistant strain of tobacco, developed in 1983.

In February this year, American actress Angelina Jolie decided to have both breasts removed after genetic screening showed that she carried a rare mutation in a gene (BRCA1) which greatly increases her chances of developing breast cancer.[1] In July, Connor Levy was born in Philadelphia (USA) after his embryo was chosen from a batch of 13 created by in vitro fertilization. DNA screening of his entire genome had shown he had a healthy chromosome structure, unlike several of his rivals.

Meanwhile, people in Europe and North America are using much the same technology to trace their roots, like the American rapper Q-Tip, whose family was deracinated from Africa by the slave trade 300 years ago. 'Know who you are! Define a sense of cultural identity for you and your kids!' proclaims one website offering the service. Although its accuracy is sometimes exaggerated, DNA analysis has made it possible to trace all 10 000 South African carriers of the gene for a skin disease, variegate porphyria, back to just one couple of Dutch immigrants, Gerrit Jansz van Deventer and Adriaantje Jacobs, who settled in Cape Town in 1688.

These are just a few examples of how genetic and genomic technologies are beginning to encroach on our private lives, after revolutionizing the practice of medicine, agriculture, criminal investigation, insurance and even palaeontology. These developments all stem from a discovery made just 60 years ago: the molecular structure of deoxyribonucleic acid (DNA).

This year marks not only the 60th anniversary of this momentous discovery but also the tenth anniversary of the first complete description of the human genetic code (human genome). Together with the Human Variome Project, which is now cataloguing the variety of human genetic mutations worldwide to improve diagnosis and treatment, UNESCO celebrated these twin anniversaries on 10 June with an international conference and exhibition at its Paris headquarters. The event celebrated Sixty Years of DNA, from the Double Helix to the Human Variome, through the Human Genome.

Photo: Gage Skidmore/Wikipedia Commons

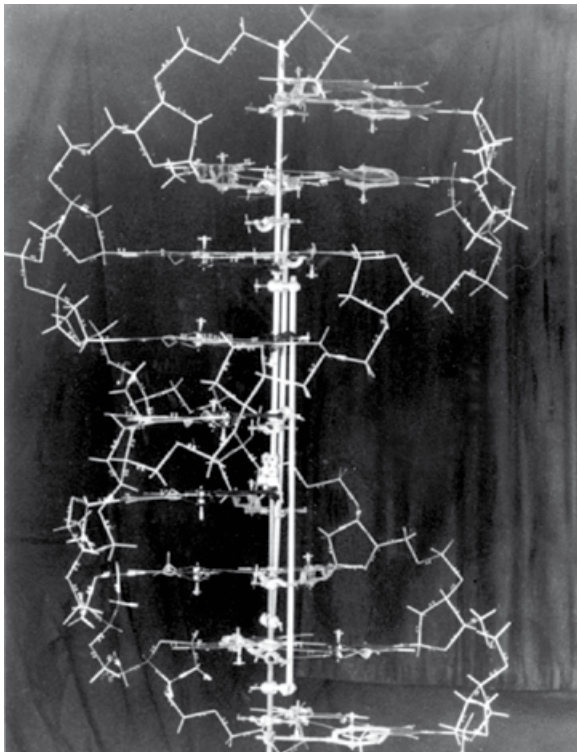
Angelina Jolie in 2010

Peas, fruit flies and the birth of molecular biology

Given the pervasiveness of the applications of genetics and molecular biology today, it is hard to believe that the term 'genetics' was coined only a century ago, in 1905, and the term 'gene' four years later. For hundreds, even thousands, of years before the discovery of the structure of the DNA molecule and the birth of genetic engineering, farmers had been cross-breeding plants and animals to produce varieties that met the criteria they were looking for: juicy apples, hardy strains of rice, sweet grapes, productive hens, pigs and cows… but it was a hit-and-miss process, based only on the appearance of the species (the phenotype) or its products, with no real understanding of how the inheritance process worked.

It was not until 1866, when Gregor Mendel, a monk living in the Austro-Hungarian Empire, published the results of his *Experiments on Plant Hybridization* that we learned that the inheritance of traits follows simple statistical rules and, in theory, is entirely predictable. Mendel's systematic studies of the garden pea earned him the title of the 'Father of modern genetics'.

In the first decade of the 20th century, in the USA, Thomas H. Morgan built on Mendel's work, this time studying eye colour in the fruit fly *Drosophila melanogaster*, which has large chromosomes that are easy to see under a microscope. Adding to the fly's appeal is the fact that it takes only a week for a new generation to hatch, enabling statistical data to be gathered quickly. In 1910, Morgan showed that it is the chromosomes, which divide and recombine inside the nucleus of a cell during replication, which carry genetic information. It would be another 43 years, however, before we began to understand how such tiny molecules could store and transmit all the information needed to make an organism.



The original DNA demonstration model, built by Watson and Crick in 1953.

In the early 20th century, biology was still very much based on whole organisms or cells that could be studied with the naked eye or under an optical microscope. Meanwhile, physics and chemistry were undergoing revolutionary developments as it became clear that all matter – both living and inanimate – was made up of atoms and subatomic particles like electrons and protons.

With the discovery of X-ray crystallography in 1912 by father-and-son team William Henry and William Lawrence Bragg, it became possible to observe and study the structure of whole molecules: combinations of atoms bonded together to form the smallest units that can take part in a chemical reaction.

It would still be a while, however, before scientists discovered that molecules of DNA were the building blocks of all life. When that happened, a bridge would finally be thrown between physics, chemistry and biology, laying the foundations for a new discipline, molecular biology, which would transform almost every aspect of human life on Earth.

The secret of life

In 1910, chromosomes had been identified as being the structures within the cell nucleus which carry inherited traits. Thanks to experiments carried out by Oswald Avery, Colin MacLeod and Maclyn McCarty at the Rockefeller Institute (USA), it had also become clear by 1951 that, within chromosomes, the key molecules to focus on were nucleic acids, rather than proteins as previously thought. The chemical building blocks of nucleic acids were known by this time: adenine (A), thymine (T), guanine (G) and cytosine (C).

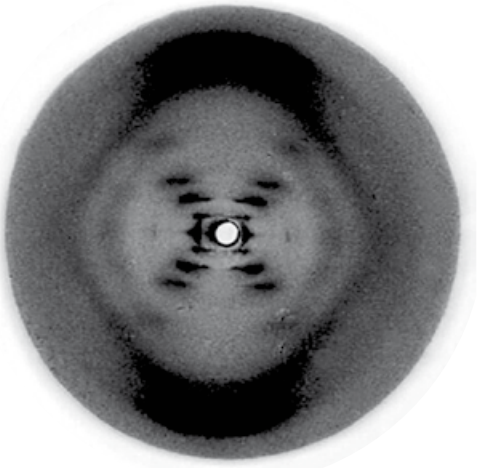


Photo 51 showing that the structure of DNA is a double helix. It was this image obtained by Rosalind Franklin which enabled Crick and Watson to complete their DNA model.

Erwin Chargaff at Columbia University (USA) had also recently discovered that, although the proportion of these bases was not constant in the DNA molecule, the *ratio* of the purines (A and G) to pyrimidines (T and C) was always roughly 1 to 1. This gave vital clues as to the way in which the components of the molecule were arranged. But how DNA could carry and transmit genetic information remained a mystery.

This breakthrough came after a race between three teams of scientists: British biophysicist Francis Crick and his American colleague, James Watson, working at the Cavendish laboratory in Cambridge (UK); Nobel laureate Linus Pauling at the California Institute of Technology (USA) and; Maurice Wilkins and Rosalind Franklin at Kings College in London. Ironically, it was a photograph of the DNA molecule (called Photo 51) taken in 1952 by Franklin, a gifted X-ray crystallographer, which gave Watson and Crick the final piece of the puzzle. The photo enabled them to conclude that DNA was made of two intertwined strands, in the form of a double helix.

On 28 February 1953, Crick walked into a pub near their lab in Cambridge and announced 'Gentlemen, we have discovered the secret of life!' The discovery was published in the journal *Nature* on 25 April 1953, alongside papers from Wilkins and Franklin supporting the model, and earned Watson, Crick and Wilkins the Nobel Prize for Physiology or Medicine in 1962. Rosalind Franklin could not be nominated, as she had died of cancer in 1958 at the age of 37, possibly as a result of prolonged exposure to X-rays.

Two big questions remained unanswered, however: how was the genetic information encoded in the DNA and how was that code translated into the proteins which form the building blocks of all living organisms? Building on a series of recent discoveries, a French scientist, François Jacob, and Sidney Brenner from South Africa showed, in 1961, that it is another nucleic acid, ribonucleic acid (RNA), which carries the genetic information, within the cell, from the nucleus to the cytoplasm, where amino acids (chemical compounds) are arranged into proteins. Strands of RNA are formed as a mirror image of specific parts of the DNA and serve as a template for the order of amino acids forming each protein.

It was to be another five years before the genetic code was finally cracked. In 1966, Marshall Nirenberg at the US National Institutes of Health managed to prove experimentally that, for all 20 known amino acids, the functional units of the genetic code, known as 'codons', were, in fact triplets, with 64 (4 x 4 x 4) possible permutations of three bases. The DNA codon for glycine turned out to be GGT, GGC, GGA, GGG, for instance, and that for lysine AAA, AAG. Thus, just 64 permutations sufficed to code all 20 amino acids.

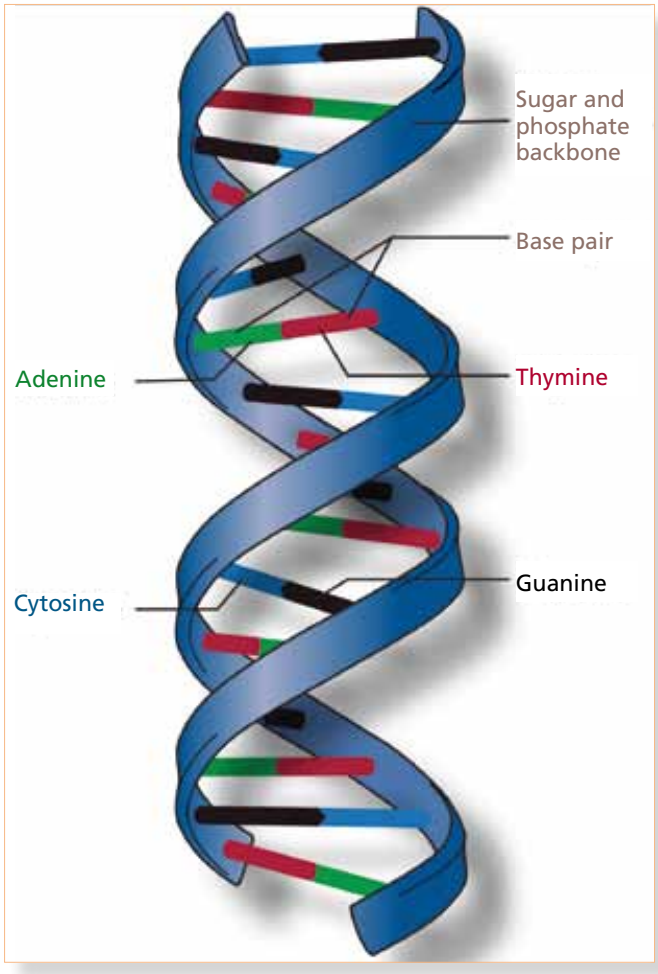


Photo: Wikipedia Commons

In the past 20 years, the number of people with diabetes worldwide has risen from 30 million to 230 million. Until synthetic (human) insulin became available in the late 1970s, people with diabetes were given animal insulin. Now, you can clone human insulin and even take insulin from the patient.

Scissors, designer genes… and freaks

A crucial next step in our understanding of genetic coding was the discovery of genetic 'scissors'. Working at the Johns Hopkins University in 1970 and building on the research carried out by Werner Arber in Geneva in 1968, Hamilton Smith isolated the first 'restriction enzyme', endonuclease R, from the bacterium *Hameofilus influenza*. He showed that the enzyme cuts DNA strands at specific sites and can be used as 'molecular scissors' to break and recombine DNA molecules precisely, thus allowing scientists to manipulate specific strands of DNA as needed.

It was a further short step for Paul Berg and his colleagues at Stanford University (USA) to create the first recombinant DNA molecule (rDNA) in 1972. As the genetic code is universal for all living organisms, bits of DNA can be taken from one organism and spliced into the genome of another. The genes are usually introduced into the recipient organism via an artificial chromosome or virus, which serves as the carrier (vector). This makes it possible to create new DNA sequences – even new organisms with novel traits.

Indeed, this is precisely how scientists genetically 'engineered' a common bacterium, *Escherichia coli*, to produce human insulin, first used to control diabetes in 1977. Other bacteria have similarly been modified to produce growth hormone, in order to treat dwarfism, or blood-clotting agents for haemophilia sufferers.

The discovery of rDNA technology proved most timely. Up until its genetically engineered equivalent was commercialized in 1985, growth hormone had to be extracted from human cadavers, or pigs. In the late 1980s, a crisis erupted, particularly in the UK, when it emerged that the agent causing a degenerative brain disease, Creutzfeld-Jacob disease, was being passed on to patients receiving growth hormone derived from

Each living cell contains chromosomes formed by proteins and nucleic acids, including deoxyribonucleic acid (DNA). DNA has a deceptively simple composition, as shown in this image. Each person's genetic code is expressed in three-letter combinations of the four chemical (nucleotide) bases: adenine (A), thymine (T), guanine (G) and cytosine (C). Any change in one of the bases may cause a genetic mutation. For example, when GAG is misspelled GTP in the haemoglobin gene, the carrier is at risk of inheriting sickle-cell disease.

human cadavers that had not been purified properly. The use of genetically engineered hormones put a stop to this, while overcoming the unpredictability of a supply chain that depended on human cadavers.

Berg's discovery paved the way to the development of a number of genetically modified organisms (GMOs) over the coming decades which have become big business. The first of these transgenic plants – where a gene from one organism is added to another – was a herbicide-resistant strain of tobacco, developed in 1983. It was also the first GM plant to be tested in field trials, in France and the USA, in 1986.

Others include drought-resistant strains of maize, 'golden' rice that produces Vitamin A to help overcome dietary deficiencies and plants that produce toxins targeted at specific insect pests or viruses. Bt cotton, for instance, has been engineered to produce a natural insecticide by inserting genes in its genome from *Bacillus thuringiensis* (Bt), a bacterium which naturally produces a chemical harmful to the larvae of moths and butterflies, flies and beetles.

For some, this ability to design new organisms,[2] or to modify plants and animals to suit a human need, is seen as the answer to a growing global food shortage and a way to limit the disastrous economic effects of crop failure in developing countries. But it has also set alarm bells ringing in the minds of the public; some fear that scientists are 'playing at God' and unleashing 'freaks' that will spin out of control. Stories in the media of cats that glow in the dark, featherless chickens and muscular mice – all genuine examples – help fuel these fears.

The reaction against GM crops has been particularly marked in Europe. Legitimate concerns, such as the risks of cross-pollination between GM and natural crops, the emergence of new sources of allergies (allergens) or a reduction in biodiversity have been confused with unfounded fears of the unknown. In 2009, a protestor destroyed an experimental vineyard in Colmar (France) that had GM vines grafted onto the rootstock. The same vineyard was attacked again in 2010. GM crops have also been destroyed in several other countries, including an attack in Hungary this year. Today, round-the-clock security guards patrol an experimental field of GM potatoes belonging to the University of Leeds (UK).

The State of Andhra Pradesh is the biggest cultivator of Bt cotton in India. Three varieties of Monsanto's Bt cotton were banned from cultivation in the State in 2005, three years after being introduced, after they failed to control the plant's main enemy, the larva of the bollworm moth.

Photo: Claude Renault/Wikipedia Commons

Even though the European Union approved 18 GM crops in 1997, it then went on to introduce an unofficial moratorium the following year which leaves it up to Member States to decide whether or not to ban GM imports. In 2003, the European Union imposed strict rules on the labelling of products containing even small traces (less than 0.9%) of GM ingredients.

Whereas these controls have been relaxed in recent years in Europe, regulations in the USA have always been much less stringent. Today, some 85% of US maize comes from GM crops and there are few requirements to label products with GM ingredients. Transgenic crops have been approved in the USA since 1994, when Calgene, a US company run by scientists, gained federal approval to market its FlavrSavr tomato. A gene had been added to tomato plants to allow the fruit to ripen on supermarket shelves, so that it would keep its flavour without rotting. Although the new tomatoes were a spectacular success, spurring biotechnology giant Monsanto to buy up the patent, the start-up company had not thought through its marketing strategy. As the plants had to be shipped from Mexico, demand soon outstripped supply and the FlavrSavr tomato disappeared from the shelves, never to return.

The advent of DNA profiling

By the end of the 1970s, genes could be isolated from one organism and spliced into another. But no-one knew how many genes a human being possessed, let alone their particular sequences of chemical bases (A,T,G, C), nor indeed, exactly what they did or how they did it.

A further breakthrough came when, in 1977, Frederick Sanger and his colleagues at the UK Medical Research Council Molecular Biology laboratory in Cambridge developed a method of reading complete DNA sequences, leading to the first complete genome, that of the bacteriophage called φX174, a virus that invades and often destroys its bacterial host cells. Its genome consisted of just 5 386 base pairs. Scientists now had all the cards in hand to go for the 'big one,' to determine the exact sequence of the human genome.

In 1981, a discovery offered a crucial next step, while inadvertently paving the way to a procedure that would revolutionize molecular biology once again. Less well-known than the double helix, the polymerase chain reaction (PCR) uses biotechnology to generate thousands, even millions, of copies of a single strand of DNA. Developed in 1981 by Kary Mullis, building on the work of Kjell Kleppe and 1968 Nobel laureate H. Gobind Khorana, PCR, when combined with new genetic sequencing techniques, would go on to form the basis of many of the revolutionary advances in genetics and molecular biology of recent decades, including DNA profiling, cloning and the diagnosis of hereditary diseases.

At this point, we should distinguish between the two different types of DNA found in most eukaryotic cells (the cells making up most complex organisms, such as plants and animals), mitochondrial DNA and nuclear DNA. Once independent cells, mitochondria were incorporated into larger, eukaryotic cells at some point in their evolutionary history to provide the eukaryote with energy. As a consequence of their separate evolutionary path, mitochondria have their own genetic material, separate from the cell's own DNA contained in the nucleus (nuclear DNA). A person inherits mitochondrial DNA from

their mother, as it is only contained in the egg, whereas nuclear DNA is inherited from both parents. It is thus much easier to draw the tree of evolution or trace your ancestry if you follow the mother's DNA.

When it comes to criminal investigations, however, nuclear DNA is the more useful of the two. The DNA profiles of convicted criminals stored in databases by many countries are nuclear DNA profiles. This is because mitochondrial DNA cannot discriminate between people who share a common maternal blood line. The mitochondrial DNA profile of these related individuals will be identical.

Poster from a 1945 US film. A suspect may leave behind a hair, skin cells, blood or saliva at the crime scene. As 99.9% of DNA is common to all human beings, scientists use PCR to identify differences in the remaining 0.1%. They home in on 13 regions of the sample DNA that are repeated numerous times. The number of short tandem repeats, as these regions are known, varies greatly from one person to another, making these regions an ideal target for DNA profiling.

DNA profiling was first used in a criminal case in 1986. Two young girls had been raped and murdered in the British town of Leicester. A DNA analysis of semen taken from both victims proved that the man who had confessed to the crime was innocent.

The human genome… at last

In May 1980, four scientists, writing in the *American Journal of Human Genetics,* published a method of mapping the entire human genome, using a technique called restriction fragment length polymorphism (RLFP). RFLPs are sequences of DNA that can be cut reliably by restriction enzymes at specific points of a genome then sorted and compared. As early as 1981, Frederick Sanger and his colleagues sequenced a short section of the human genome, just 16 000 base pairs long, contained in the mitochondria.

It would be another ten years before the Human Genome Project got under way, in 1990, for the project faced massive technological challenges, as well as doubts about its scientific utility. The project would ultimately sequence several organisms, including the humble fruit fly[3] that had been so crucial to the birth of genetics.

When the Human Genome Project began, it was the largest international collaborative undertaking in the history of science. In the end, it took hundreds of scientists working in labs around the world some 13 years to complete, at a cost of US$ 2.37 billion. UNESCO took a stance early on to promote the open sharing of genomic data and to make sure scientists from the developing world were not excluded.

One fear, even in the scientific community, was that a private lab would claim ownership of the genome or specific genes and patent this knowledge. This prompted UNESCO to hold a symposium, in 1990, on Human Genome Research: Strategies and Priorities, attended by 250 scientists, including Nobel laureates and leaders of national human genome research projects.

Three years later, UNESCO set up an International Bioethics Committee composed of experts and, in 1997, adopted the *Universal Declaration on the Human Genome and Human Rights*. This built on the Bermuda Principles agreed by international partners in the Human Genome Project, whereby sequence data was to be shared publicly within 24 hours of sequencing. Concerned by the potential misuse of human genetic data, the UNESCO experts subsequently drafted an *International Declaration on Human Genetic Data*, which was adopted in 2003, the year the human genome was finally published.

Even before the project started, it was known that the human genome consisted of a unique sequence of 3.4 billion of the four chemical bases that make up the DNA molecule: A, C, T and G. What the project would reveal, however, was the exact sequence of these letters. Printed out in type so tiny that it is almost illegible without a magnifying glass, a copy of the human genome in the Wellcome Collection library in London fills 100 volumes, each 1000 pages long. At a rate of one letter per second, it would take 95 years to read.

Interestingly, the total number of genes in the genome turned out to be just 22 287, although the exact figures[4] are highly contested. Even so, this was far fewer than the 30 000–40 000 that researchers had previously expected and a fraction of the 100 000 estimated when the Human Genome Project started.

From patented plants to the God gene…

Despite the *International Declaration on the Human Genome and Human Rights*, commercial interests are still fiercely defended when it comes to patenting genetic sequences, as the potential for profit can be immense, whether from pharmaceuticals, screening tests or agricultural products.

Until this year, Myriad Genetics, which marketed the test used to screen Angelina Jolie for cancer, held a monopoly over the screening technology. But the US Supreme Court has now ruled that the company could not patent a human gene. This will lower the cost of the test and make it more widely available.

Nevertheless, according to the biological sequence research platform Genome Quest (GQ-Pat), the number of patents on gene sequences in the USA has doubled from 100 000 in 2007 to over 200 000 in 2013. Altogether, the GQ-Pat database currently lists more than 413 000 patents and over 212 800 000 000 sequences. The patenting of crops and animals has met with hostile opposition. Having been granted a patent for basmati rice in the late 1990s, RiceTec subsequently lost the right to call its rice 'basmati', the name of a traditional Indian strain, encouraging other traditional producers to defend the intellectual property rights of local produce.

Since it has become possible to locate, isolate, sequence and clone individual genes, there has been an explosion in research to discover the function of each of the 20 000 or so human genes. The Human Variome Project[5], for example, established by Prof. Richard Cotton in 2006 and officially endorsed by UNESCO since 2011, aims to map the full range of genetic mutations affecting human health, in order to provide doctors and researchers with a comprehensive reference database. The potential benefits for diagnostics and therapies are immense, opening the door to personalized therapies which can, for example, target the exact form of cancer in a given patient.

There is already a move in cancer treatment (oncology) away from focusing on the tissue in which the cancer is established towards the molecular basis of the tumour. This can help doctors pinpoint the best form of treatment. Oncologists can consult an online database like My Cancer Genome to help match the drug treatment to the specific cancer case. A private company called Foundation One offers a US$4290 test to compare a sample of a patient's tumour DNA against a database of 236 sequences of genes known to be directly involved in cancers.

However, for Nobel laureate Werner Arber, speaking at the 60th anniversary of the double helix in June, 'there is a concern that the development of tailor-made treatments for patients could upset a delicate balance' in the body. 'Each human body hosts a microbial world which discreetly fights infection, digests our food and so on,' he said. 'We do not yet know what would happen to this balance if we introduced personalized therapies.'

The quest to understand the role and functions of human genes has also led to a kind of genetic determinism in molecular biology, where everything, including a disposition to be religious, is thought to be due to a specific gene. In 2004, molecular geneticist Dean Hamer published a book entitled *The God Gene: How Faith is Hardwired into our Genes*. He argued that openness to mystical experience was linked to a specific gene, VMAT2, triggering a debate than ran in the columns of the science press for months.

Sharing genetic data, protecting privacy

The ability to sequence – and store – entire genome sequences has opened the door to a proliferation of DNA ancestry screening services, the accuracy of which often falls short of their claims. The relative ease of DNA screening today has also raised the need for regulations to protect privacy and determine who has the right to store these data and who may access them.

In the USA, the Genetic Information Non-Discrimination Act was passed in 2008, making it illegal for health insurers and employers to use the results of DNA screening to refuse insurance or employment on the basis of a genetic defect or hereditary illness. But, when a DNA sample is taken from a crime suspect who is later eliminated from the enquiry, should those data be destroyed? What protection should the individual be given?

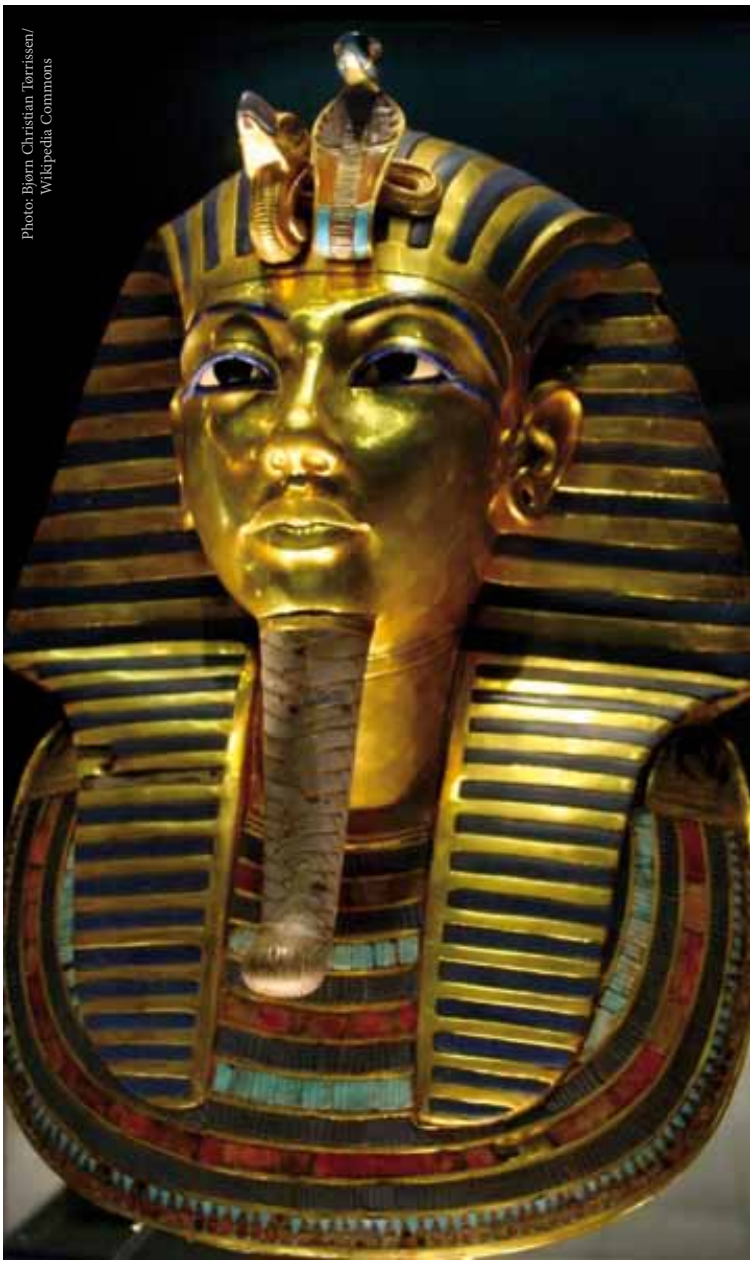


Photo: Bjørn Christian Tørrissen/ Wikipedia Commons

Burial mask of the young Pharaoh Tuthankamen (circa *1341–1323 BCE), on display at the Egyptian Museum in Cairo. In 2010, DNA tests confirmed that he was the son of the Pharaoh Akhenaten.*

Conversely, when DNA data are offered freely for research purposes, shouldn't they be made widely available to the global scientific community?

This is one of the objectives of the Human Variome Project. According to David Abraham, Chairman of the Board of Human Variome Project International, speaking at the 60th anniversary of the double helix, 'seven million children are born each year with a genetic disorder or birth defect. Some 90% of these children are from low-income countries. We need better ways to share our genomic knowledge, so that all people can share in the benefits of our common genetic heritage.'

Next-generation genomics

In the decade since the human genome was sequenced, computing power has multiplied several times over, outstripping Moore's law, which predicts a doubling every two years. Today's popular Apple iPad2 tablet computer is more powerful than a Cray-2 supercomputer, which was the fastest on the planet in 1990, when the Human Genome Project got under way. In 1953, when Watson and Crick published their paper on the double helix, the world's most powerful computer was a wimp compared to the chip in a modern-day washing machine, yet still filled a small room. In the past decade alone, genome sequencing techniques have evolved rapidly, bringing down costs and filling the databases of known gene sequences with fresh human cases almost daily.

At the 60th anniversary of the double helix, Prof. Sir John Burn, Deputy Chair of the Scientific Advisory Committee for the Human Variome Project, recalled that, when Marjolein Kriek, a 34 year-old Dutch clinical geneticist, became the first woman to have her genome sequenced in 2008, it cost €40 000. Just eight years earlier, the same exercise would have cost about €100 million. Today, the cost has dropped to €5 000 and, Burn speculated, could one day be as low as €100.

In Star Trek, the popular TV science-fiction series set in the 23rd century, the spaceship's doctor uses a hand-held 'Tricorder' scanner to detect and diagnose illnesses in his patients. Now, 200 years ahead of time, that device is almost here. Sir John Burn expects a prototype of his own company's version of the Tricorder to be available next year. He anticipates that QuantuMDx's diagnostic scanner willl shrink from the size of a microwave oven

Photo: Wikipedia Commons

Taxidermied body of Dolly, on display at the National Museum of Scotland. She was cloned from an adult cell in 1996. Dolly gave birth to several lambs but had to be put down after developing lung disease and severe arthritis in middle age, suggesting that cloning causes premature ageing.

Photo: Wikipedia Commons

Pyrenean ibex painted by Joseph Wolf in 1898. The extinct ibex was brought back to life in 2009 but the cloned animal only lived seven minutes.

to that of an Apple iPad within a few years. By that time, it should be able to test for the presence of bacteria that cause illnesses like tuberculosis within minutes, in the doctor's surgery. This will bring diagnostics based on genetic screening within reach of even remote areas in developing countries. Also under development is Q-SEC™, a device which will sequence your genome 'while you wait.'

The first human trial in gene therapy began in the USA in 1990. The aim of gene therapy is to deliver the corrected gene to human cells affected by a defective gene. The patient was a four-year old girl with adenosine deaminase (ADA) deficiency, a genetic disease which leaves her defenseless against infection. White blood cells were taken from her then the normal genes for making ADA were inserted into them. The corrected genes were then re-injected into her cells using a virus as carrier. Today, she and a second girl who received the same treatment lead normal lives. Several newborn babies with ADA deficiency have also received normal ADA genes, via immature blood cells (stem cells) taken from the babies' umbilical cord.

Gene therapy remains controversial, though. It is too early to say whether this type of therapy will work over the long term and there are a number of scientific obstacles to overcome before it can become a practical form of therapy.[6]

DNA profiling technologies have improved so much in recent years that it is now possible to sequence tiny, incomplete or even old samples. The facility of genetic testing is opening up new possibilities in fields as diverse as oncology, crime detection and palaeontology. In a study published in *Nature* in July this year, the analysis of the complete genome of a tiny fragment of bone from a prehistoric horse found in Canada in 2003, preserved in permafrost for 700 000 years, showed that the modern horse, donkey and zebra arose over 4 million years ago, two million years earlier than previously thought.

Even more spectacularly, researchers brought the Pyrenean ibex back from extinction in 2009, after a fragment of skin from the body of the last member of the species was cloned and implanted into domestic goat embryos, using the techniques that created the first cloned mammal, Dolly the sheep, back in 1996. However, the life expectancy of these cloned animals can be brief. The resurrected Pyrenean ibex lived for just seven minutes before it was killed by a lung infection. Dolly the sheep, though, lived for over six years, albeit about half the life expectancy of a normal domestic sheep.

Last year, South Korean stem cell scientist Hwang Woo-suk obtained exclusive rights to cloning a 10 000 year-old woolly mammoth. His private laboratory will use tissue samples found in a frozen carcass in Siberia, which spilled liquid blood when incised! If he manages to create an embryo, it will be implanted in an elephant.

This year, a DNA sample kept from a 1964 crime scene in the USA has finally linked a suspected serial killer – the Boston Strangler – to the last of his victims. Although Albert Desalvo had confessed and been imprisoned for other crimes, no conclusive proof was ever found – until 49 years later.

© US government

Although Albert Desalvo confessed to being the Boston Strangler, it took 49 years to obtain conclusive proof that he had murdered one of the 13 victims, thanks to progress in DNA analysis.

DNA analysis is also being used to overturn a number of long-standing convictions, including that of the American Santae A. Tribble in December last year. He was arrested in 1978 at the age of 17 for the murder of a taxi driver. He spent 28 years in prison on the basis of a hair sample which turned out not to be his.

For Sir John Burn, the really exciting emerging field in medicine is epigenetics. Developmental biologist C. H. Waddington coined the term in the 1940s, challenging Charles Darwin's idea that evolution took place through natural selection[7] on the basis of randomly occurring mutations in genes. We now know that, as Waddington had suggested, genes are being switched on and off by environmental factors.

'At present,' said Burn in an interview published this year by *The Naked Scientists*, '300 000 or more people in the UK are carrying genes for cancers, such as breast or colon cancer, that are switched on by environmental factors but the majority are unaware that they are carriers. In each case,' he said, 'we have a very effective intervention that could reduce or avoid them developing cancer. The one I am obviously most interested in is colon cancer because we have shown that two aspirins a day will halve the risk. There are 60 000 people out there in Britain [who are likely to develop colon cancer] and we only know 6 000 of them.' Simple screening by a doctor using next-generation screening devices would multiply that number ten times, potentially saving tens of thousands of lives. If the same simple [genetic] screening were applied to other inherited diseases, globally, the benefits would be immeasurable.'

Peter Coles,[8] with Alessandro Allegra[9]

1 *Some cancers are hereditary and others are not. This is because evolution works through the germline. All animal species have two types of cells: germline cells and somatic cells. A mutation or other genetic change to a germline cell can potentially be passed on to a person's offspring but a change in a somatic cell will not be.*

2 *The new field of synthetic biology can assemble genes into totally new organisms. See A World of Science, January 2013: http://unesdoc.unesco.org/images/0021/002191/219156E.pdf*

3 *The first free-living organism to be sequenced was the bacterium* H. influenza *(1995), 1.8 million base pairs long, followed by the yeast* Saccharomyces cerevisiae *(1996, 12 million), the bacterium* E. coli *(1997, 5 million), the roundworm* Caenorhabditis elegans *(1998, 97 million) and fruit fly* D. melanogaster *(2000, 180 million).*

4 *The human genome contains 19 599 known protein-coding genes and a further 2 188 sections of DNA predicted to be protein-coding genes.*

5 *See* A World of Science, *October 2012: http://unesdoc.unesco.org/images/0021/002180/218053e.pdf*

6 *See: http://history.nih.gov/exhibits/genetics/sect4.htm*

7 *On Darwin, see* A World of Science, *October 2009: http://unesdoc.unesco.org/images/0018/001844/184441E.pdf*

8 *Science writer and editor*

9 *Science historian*

Strategic groundwater reserves found in northern Kenya

An exploration of groundwater resources has identified reserves of water in Turkana County in drought-stricken northern Kenya.

The findings were announced on 11 September at the opening of an international water security conference in Nairobi. They result from a groundwater mapping project, spearheaded by UNESCO in partnership with the Government of Kenya and with the financial support of the Japanese government. The project has been implemented since last year within UNESCO's Groundwater Resources Investigation for Drought Mitigation in Africa Programme (GRIDMAP, see *A World of Science*, January 2012).

Two aquifers – the Lotikipi Basin Aquifer and the Lodwar Basin Aquifer – were identified using advanced satellite exploration technology. Their existence was then confirmed by drilling conducted recently by UNESCO but there is need for further studies to quantify the reserves adequately and assess the quality of the water. The technology combines remote sensing, seismic and conventional groundwater information to explore and map the occurrence of groundwater across large areas in a short space of time.

The Lotikipi Basin Aquifer is located west of Lake Turkana, the world's largest permanent desert lake. On its own, Lotikipi could potentially increase Kenya's strategic water reserves.

The smaller Lodwar Basin Aquifer could serve as a strategic reserve for the development of Lodwar, the capital of Turkana County, provided the reserve is confirmed.

Three additional aquifers have been identified in other parts of Turkana but have not yet been confirmed by drilling; they would also need to be assessed using complementary techniques. More research will need to be done to enable a more accurate assessment of the aquifers and their potential contribution to Kenya's economic development.

Announcing the findings in Nairobi during the opening session of the UNESCO Strategic and High-Level Meeting on Water Security and Cooperation, Judi Wakhungu, Cabinet Secretary of the Ministry of Environment, Water and Natural Resources, said that the results were a critical scientific breakthrough for Kenya.

'The news about these water reserves comes at a time when reliable water supplies are highly needed. We must now work to further explore these resources responsibly and safeguard them for future generations,' she said.

Stressing Kenya's vulnerability and water insecurity, caused by erratic rainfall patterns and the influence of climate change, Judi Wakhungu said more research and investment were now needed to identify and understand groundwater aquifers and improve capacity for monitoring and assessment of these resources. The government announced the launch of a national groundwater mapping programme, which is to be implemented with UNESCO.

Of Kenya's 41 million-strong population, 17 million lack access to safe water and 28 million have inadequate sanitation.

© UNESCO

Water gushing from a borehole in the Napuu region of Kenya

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ICTP releases free App for students' iPhones

The Science Dissemination Unit of UNESCO's Abdus Salam International Centre for Theoretical Physics (ICTP) in Trieste (Italy) has released its new, free iPhone application, EyApp.

EyApp enables users of an iPhone, iPad or iPod Touch to make a video composed of a series of captured images along with a simultaneous audio recording. At the press of a button, the application automatically captures images at intervals ranging from 5 to 20 seconds (or manually by the user) then synchronizes the images with a continuous audio signal.

The resultant recording uses just 10% of the disk space of a traditional video because the still frames can be processed by the highly efficient compression algorithms used by the H264 movie format found in modern mobile iDevices.

The film can be shared immediately, or saved in a device's photo or movie gallery then further edited with other Apps. It can be shared by email and rich-media messaging systems, via YouTube and social networking Apps, or transferred to a computer.

The Unit developed the application with education in mind. 'With EyApp, students can record a lecture at any time for their own purposes, or share with colleagues or friends, instead of losing attentiveness taking notes on paper,' says Unit coordinator Enrique Canessa, who created the application with colleagues Carlo Fonda and Marco Zennaro.

An Android-based version of EyApp, named andrEyA, is currently under development.

Download EyApp from: http://tinyurl.com/ad2qob5; and andrEyA from www.andreya.org; for details: sdu@ictp.it

Global Geoparks Network now counts 100 sites

The Global Geoparks Network now counts 100 members, with the addition of 10 sites in Austria, China, Italy, Japan, the Netherlands, Portugal, Slovenia, Turkey and Uruguay. The sites were inscribed during the 3rd Asia-Pacific Geoparks Network Symposium, which took place on Jeju Island in the Republic of Korea from 7 to 13 September.

The new sites are:

Sennongjia Global Geopark (China), in Hubei Province, is known as the Roof of Central China. The area features six mountains surpassing 3 000 m that blend peaks, glaciers and karst. In 1995, relics of ancient human beings from the Pleistocene, beginning 1.8 million years ago (Ma), were found in a cave 2 100 m above sea level near Hongping. More than 1000 pieces of stoneware and ancient fossils, including rhinoceros, pandas and elephants, were unearthed in the cave.

Yanqing Global Geopark (China) is located northwest of Beijing, in the western part of the Yanshanian Mountains. A characteristic mountain-building process during the Mesozoic (250–65 Ma) time created vertical strata, fractures and huge domes. The site's rich geoheritage includes late Jurassic dinosaur footprints. Some 40–50 000 years ago, humans dug their homes in the granite. These cliff dwellings can be visited today at the site of Guyaju, a housing complex with more than 110 stone rooms carved into the rock, the largest cliff residence in China.

Sesia – Val Grande Global Geopark (Italy) in the northeast of the Piemonte Region stretches over two neighboring Alpine valleys and includes the two sacred sites of Sacre Monte of Varallo and Sanctuary of Ghiffa, part of a UNESCO World Heritage property. Its geology is connected to Alpine tectonics. Hikers can take tours through the Earth's crust, including to the collapsed caldera of a fossilized supervolcano. The pink marble in Ossola was used to build the Cathedral of Milan in the 14th century.

Oki Islands Global Geopark (Japan) is situated off the west coast of Honshu, the main island. The basement of the Oki Islands is a fragment of the Eurasian continent, left behind during the formation of the back-arc basin that eventually led to the creation of the Japanese islands. The Oki basement gneisses contain evidence of their continental origin and the extensive alkali volcanic rocks present here are extremely rare elsewhere in the Japanese arc. The influx of subalpine zone vegetation during the coldest stage of the last Ice Age can still be seen today.

Hondsrug Global Geopark (the Netherlands) is the country's first, in the province of Drenthe. The Hondsrug is a small ridge in a landscape that was overrun by ice, creating typically flat 'Netherlands'. Ridges and valleys formed underneath the ice sheet by glacial meltwater are still clearly visible in the landscape, unique in the European–Asian Pleistocene landscape. Glaciers have brought huge numbers of different-sized rocks, including boulders of 40 tons, from Sweden and Finland. Some of these were used 5 500 years ago to raise Neolithic stone megaliths, the country's oldest monuments.

Azores Global Geopark (Portugal) is situated at the triple junction of the North American, Eurasian and African tectonic plates. Its geomorphology is therefore primarily shaped by volcanic and tectonic forces. There have been 26 volcanic eruptions since the early 15th century when the Portuguese first settled the 16 (polygenetic) volcanic islands, most of them silicic, with some featuring summit caldera subsidence. Nine are still active. All the buildings were constructed using volcanic rocks.

Idrija Global Geopark (Slovenia) is situated about 60 km from Ljubljana. A very pronounced fracture in the Earth's crust, one of the strongest in the southern Alps, runs from Croatia some 120 km across the entire territory of Slovenia and into Italy. This fault allowed mineral-rich liquids from the deep to deposit minerals closer to the surface. The discovery of an exceptional mercury deposit in 1490 led to the development of Idrija's important mining history and, ultimately, to the area's inscription on UNESCO's World Heritage List last year.

Karawanke/Karawanken Global Geopark (Slovenia/Austria) is named after the Alpine mountain chain which forms the border. Mountain-building here is ongoing, as proven by recent seismic activity, even though the collision between the African and European continents culminated 34–5 Ma. The geological history of the site dates back some 500 million years and has left a rich mining heritage, notably from the extraction of iron and coal. Today, these mines attract many visitors.

Kula Volcanic Global Geopark (Turkey) is the country's first, located in Manisa Province in Western Anatolia, 150 km east of Izmir. Volcanic cones and lava flows of the Quaternary age dominate its landscape. The latest eruptions in the site occurred about 12 000 years ago. Some of the volcanic ash layers display fossilized footprints of prehistoric humans. The Kula basalts were formed by the rapid southwestward movement of the Aegean microplate overriding Africa.

Grutas del Palacio Global Geopark (Uruguay) is the country's first, located in the Department of Flores. The crystalline basement rocks of the Rio de la Plata Craton, which underlie most of Uruguay, are only exposed in the south and east of the country, where they make up a characteristic hilly landscape. Elsewhere, the rocks are covered by younger volcanic or sedimentary rocks which form wide and naturally fertile prairies. Some rocks exposed in the geopark are geologically very old (Precambrian). Younger soil features with a typically reddish colour are exposed in the Grutas del Palacio Geosite, a picturesque cave system with almost 100 columns up to 2 m high.

For details and more photos: http://tinyurl.com/new-geoparks-2013

Kula Volcanic Global Geopark in Turkey, the country's first

Elephants photographed in March 2013 in Ngorongoro crater (22.5 km wide), part of the Serengeti–Ngorongoro Biosphere Reserve and a World Heritage site. In 2012, one million tourists brought in record revenue for Tanzania.

Wildlife crime is robbing Africa of its future

Throughout most of sub-Saharan Africa, elephants are now being killed faster than they can reproduce, with 2012 being the bloodiest year in decades.

Elephants enable the reproduction of many tropical tree species and are the 'gardeners' of the ecosystems in which they live. By emptying forests of the animals that inhabit them, poaching is transforming vibrant, living forests into deserted spaces.

UNESCO Director-General Irina Bokova and John Scanlon, Secretary-General of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), sounded the alarm on 30 July in an article published in the magazine *Jeune Afrique*.

'This unprecedented increase reflects a change of scale in the way poaching is conducted,' they wrote. 'It is now no longer done in a 'traditional way' but is conducted by heavily armed groups with a lot of equipment, determined to sell their spoils to the highest bidder in the global market – which is fuelled by soaring prices and demand for ivory and rhino horn, primarily in Asia.'

'In recent years, the massacre of wild species has reached an industrial scale, in particular the poaching of animals for their ivory. In Gabon alone, some 11 000 elephants have been killed illegally since 2004. In 2012, almost 700 rhinoceros were poached in South Africa. Just this past April, an armed militia went into the Sangha Trinational transboundary World Heritage site shared by Cameroon, Central African Republic and Congo, and slaughtered at least 26 elephants in the Central African Republic in the space of a few days.'

UNESCO is currently supporting Cameroon, Congo and Gabon in establishing a trinational Dja–Odzala–Minkébé (TRIDOM) biosphere reserve in an area plagued by mining, illegal logging and poaching. Within this process, UNESCO's Man and the Biosphere programme organized a trinational workshop in Brazzaville on 6 June. Managing the area through a blend of conservation, development and logistical support (training, research, education…) – the three integrated functions of biosphere reserves – has been recognized as a powerful weapon against crime.

'To protect these large mammals, the first step is to protect durably their habitats,' the article explained. 'UNESCO's World Heritage sites and biosphere reserves were created for this reason. At present, they are the highest level of protection and management available for natural sites.'

'This, of course, is not enough,' they acknowledged before going on to outline a two-pronged strategy. 'First, we need to support the national and local agencies that are on the front line by giving them financial support and the appropriate training. Sometimes, rangers are only a handful of men in pick-up trucks, not sufficiently prepared or armed against poachers hunting in helicopters.'

'Secondly, countries need to cooperate in order to fight this illegal ivory trade, to protect these animals, to maintain borders and to sanction criminals and unscrupulous intermediaries. Awareness also needs to be raised in the countries to which the ivory is destined, countries where clients often do not realize the provenance of their purchases.'

CITES and UNESCO have been working together in recent years to publish joint data and share their respective experiences in interrelated domains such as the trafficking of cultural assets and ivory.

Read the full article: http://whc.unesco.org/en/news/1063; on the TRIDOM: n.raondry-rakotoarisoa@unesco.org; http://tinyurl.com/unesco-tridom

Mobile broadband **fastest-growing technology** ever

Mobile broadband is the fastest-growing technology in human history, according to the second edition of the *State of Broadband* report, but people in the world's poorest countries are being left behind.

Released in New York on 21 September at the 8th meeting of the Broadband Commission for Digital Development, the report reveals that mobile broadband subscriptions, which allow users to access the web via smartphones, tablets and WiFi-connected laptops, are growing at a rate of 30% per year. By the end of this year, there will be more than three times as many mobile broadband connections as there are conventional fixed broadband subscriptions.

The Republic of Korea continues to have the world's highest household broadband penetration, at over 97%, far ahead of the USA in 24th place. Switzerland leads the world in fixed broadband subscriptions per capita, at over 40%.

There are now more than 70 countries where over 50% of the population uses Internet. The top ten countries are all located in Europe, with the exception of New Zealand (8th) and Qatar (10th).

UNESCO Director-General Irina Bokova serves as Co-Vice-Chair of the Commission with ITU Secretary-General Dr Hamadoun I. Touré. 'We must not lose sight of those who are being left behind,' said Dr Touré. 'Over 90% of people in the world's 49 least developed countries remain totally unconnected.'

State of Broadband also tracks a new target mandating 'gender equality in broadband access by the year 2020', a target fixed by the Commission at its March meeting in Mexico City. ITU figures confirm that, worldwide, women are less likely to have access to technology than their male counterparts. While the gap is relatively small in the developed world, it widens enormously as average income levels fall.

The *State of Broadband* is the only report to feature country rankings based on access and affordability for over 160 economies worldwide.

Read the report: www.broadbandcommission.org

University of Nigeria hosts **science and engineering fair**

Some 2700 academics, students, school pupils and their teachers converged on the University of Nigeria on 17–21 June for a week of hands-on learning in science and engineering.

Separate workshops targeted university students, university instructors and over 2000 school pupils between 13 and 16 years old, three-quarters of them girls.

The workshops had three core tracks: mobile learning, engineering and microscience.

The mobile learning workshops demonstrated how teachers could work with students to design applications for mobile phones. The course was run by Clement Onime from UNESCO's Abdus Salam International Centre for Theoretical Physics, along with experts from Pakistan, Saudi Arabia and Trinidad and Tobago, as well as UNESCO's own Mark West. Dr Fareeha Zafar from Pakistan designed an application for smartphones which was donated to the university once the workshop was over.

Susanna Ackermann, of Intel, demonstrated an innovative 'eye-patch' lens that transforms the cameras on laptop and tablet computers into a powerful microscope which can be used to detect motion and take time-lapsed imagery. According to Intel, the lens supports up to 60 different experiments and is currently being marketed in South Africa.

Instructors were introduced to augmented reality, a process by which a digital device allows a user to manipulate items that are not in the physical world. Clement Onime demonstrated how students could, for example, create a virtual circuit board by manipulating objects under the web camera of a tablet computer. The objects are moved across a piece of patterned paper but appear on the screen of the tablet as transistors and wires. This technology opens up numerous avenues for learning, particularly in contexts where actual circuit boards and related materials are unavailable or prohibitively expensive.

©EWB (UK)

A student tapes wire coils to a sheet of cardboard to make a stator for his micro-hydro turbine. The four magnets have already been taped to the cardboard. The turbine is made by inserting four 'blades' into a cork to form a propeller. These 'blades' are simply cut out of a plastic cup (below).

The University of Nigeria has a new physics and chemistry laboratory but experimentation in engineering is uncommon for lack of modern equipment. One aim of the fair was to demonstrate that you can perform experiments without expensive equipment and, above all, that you cannot teach science and engineering without hands-on learning.

The engineering workshops were a blend of experimentation and lectures on four themes: shelter, transportation, water filtration and micro-hydro power generation. In one experiment, students were given a plastic bottle and cup, cork, copper wire and magnets and asked to build a micro-hydro turbine. The idea was for the magnet to turn the rotor (copper wire) and turbine, thus generating a small current when water was passed over it (*see photos*). On the second day, one student replaced the cork in his apparatus with the rubber sole of his sandal, an improvement subsequently incorporated into the experiment.

These workshops were run by Yasemin Dogan from Engineers Without Borders (EWB) in the UK and Rovani Sigamoney from UNESCO, who were accompanied by Nigerian representatives of EWB and the Institute of Electrical and Electronics Engineers.

In the microscience workshops, school pupils tried their hand at filtering water and mixing chemicals, under the watchful eye of Imteyaz Khodobux and Osu Otu from UNESCO. The teenagers were shown how to use miniature plastic kits promoted by UNESCO within its longstanding Global Microscience Experiments programme (See *A World of Science*, July 2011).

The week wouldn't have been complete without a talk by Prof. Francisca Nneka Okeke from the University of Nigeria, one of this year's five l'Oréal-UNESCO laureates for Women in Science. Prof. Nneka Okeke studies the ionosphere situated between 50 km and 1 000 km above the Earth's surface. She spoke of her passion for science to a spellbound auditorium.

Participation in the science fair was funded entirely by the International Institute for Biotechnology, which operates under the auspices of UNESCO. Hosted by the University of Nigeria, the institute opened its doors earlier this year.

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Sandwatch comes to **Indonesia, Malaysia and Timor-Leste**

Since December, more than 200 pupils from nine secondary schools have participated in a Sandwatch pilot project in Indonesia. In September, the government decided to introduce Sandwatch into selected schools in coastal parts of Java, as part of its new Coastal Education Project.

The Coastal Education Project (*Sekolah Pantai Indonesia*) is being implemented jointly by UNESCO and the Indonesian Ministry of Marine Affairs and Fisheries, in close collaboration with the Indonesian National Council on Climate Change.

Sandwatch has raised pupils' awareness of the need to take care of their beaches, via targeted lessons favouring a hands-on approach. Pupils have learned how to use the scientific method to monitor and critically evaluate problems and conflicts facing their coastal environment. They have been introduced to environmental advocacy and gained confidence in public-speaking.

In June this year, UNESCO extended the Sandwatch project into Timor-Leste, where two schools are involved in monitoring beaches in the Liquica District.

In both Indonesia and Timor-Leste, pupils are studying their region's local and indigenous knowledge in relation to coastal management and climate change adaptation. In Indonesia alone, the knowledge of the Bajo (Wakatobi Province) varies greatly from that of the Awig-awig (Bali Province) and Panglima Laot (Aceh Province), for example.

Next year, UNESCO's Jakarta office plans to re-introduce Sandwatch into Malaysia, using funds in trust provided by the government. One aim will be to strengthen cooperation in environmental education between Indonesia, Malaysia and Timor-Leste.

Sandwatch was launched by UNESCO in the Caribbean in 1999 and has since spread to Africa, Asia, Europe and the Pacific and Indian Oceans.

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First World Heritage sites for **Fiji, Lesotho and Qatar**

On 22–23 June, the first sites in Fiji, Lesotho and Qatar were inscribed on the World Heritage List. In all, 19 sites were added by the World Heritage Committee, which met first in Phnom Penh then in Siem Reap (Cambodia).

The new properties in Fiji and Qatar are both cultural sites. Levuka Historical Port Town (Fiji) was the first colonial capital of Fiji, ceded to the British in 1874. Al Zubarah Archaeological Site (Qatar) is a walled coastal town which flourished as a pearling and trading centre in the late 18th century before being destroyed in 1811 then abandoned in the early 1900s.

Lesotho's first site has been inscribed as an extension to uKhalamba Drakensberg Park in South Africa to form Maloti–Drakensberg Park, a mixed natural and cultural site. Two other sites received extensions this year: Mount Kenya National Park/Natural Forest (Kenya) and the Wieliczka and Bochnia Royal Salt Mines (Poland).

The other 12 cultural sites inscribed are: Red Bay Basque Whaling Station (Canada), the Cultural Landscape of the Honghe Hani Rice Terraces (China), Historic Monuments and Sites of Kaesong (Dem. People's Republic of Korea), Bergpark Wilhelmshöhe (Germany), the Hill Forts of Rajasthan (India), Golestan Palace (Iran), the Medici Villas and Gardens in Tuscany (Italy), Fujisan, Sacred Place and Source of Artistic Inspiration (Japan), the Historic Centre of Agadez (Niger), the Wooden *Tserkvas* of the Carpathian Region (Poland/Ukraine), the University of Combra – Alta and Sofia (Portugal) and the Ancient city of Tauric Chersonese and its Chora (Ukraine).

© Paul van Schalkwyk

The Namib Sand Sea covers more than 3 million hectares. Home to endemic invertebrates, reptiles and mammals, it is the only coastal desert in the world to include extensive dune fields influenced by fog, the site's primary source of water.

Five natural sites were inscribed in Cambodia: Xinjian Tianshan (China), Mount Etna (Italy), El Pinacate and Gran Desierto de Altar Biosphere Reserve (Mexico), the Namib Sand Sea (*see photo*) and Tajik National Park (Tajikistan).

The additions bring the number of sites on the World Heritage List to 981 in 160 countries, 759 of which are cultural, 193 natural and 29 mixed properties.

In June, the site of Bam and its Cultural Landscape was removed from the List of World Heritage in Danger, whereas East Rennell (Solomon Islands) was inscribed on the same list, along with all six Syrian sites.

In Bamako on 7 June, a Malian team of experts had met with a UNESCO mission to analyse the damage done to the city of Timbuktu, after both teams had inspected the city and consulted local authorities.

'The destruction caused to Timbuktu's heritage is even more alarming than we thought,' said Lazare Eloundou Assomo of UNESCO's World Heritage Centre, who led the international mission. 'We discovered that 14 of Timbuktu's mausoleums, including those that are part of the UNESCO World Heritage sites, were totally destroyed, along with two others at the Djingareyber Mosque. The emblematic El Farouk monument at the entrance to the city was razed. We estimate that 4 203 manuscripts from the Ahmed Baba research centre were lost and that another 300 000 were exfiltrated – mainly to Bamako – and are in urgent need of conservation.'

For details: http://whc.unesco.org

ICTP has **big ideas for small science**

At the Hands-On Research in Complex Systems School hosted by UNESCO's Abdus Salam International Centre on Theoretical Physics (ICTP) in Trieste (Italy) on 1–12 July, 68 scientists from mainly the developing world used simple, inexpensive apparatuses that fit on a tabletop to research the intricacies of such complex phenomena as fluid dynamics, cell migration, turbulence and nonlinear optics.

The school was run by eminent scientists who have conducted frontier tabletop research themselves. Harry Swinney, director of the Center for Nonlinear Dynamics at the University of Texas (USA), is one of the school directors and a leading figure in the world of 'small science' – science done in a small laboratory with simple equipment.

'These kinds of experiments can be done anywhere in the world,' says Swinney. 'This is not expensive science and this is not big science but these experiments help us investigate many phenomena in nature.' Swinney's own foray into the world of small science started with tabletop experiments to study systems in thermodynamic equilibrium in the 1960s.

Since then, there has been such a tremendous leap in technological advances that the experiments have become more accessible than ever before. 'The kind of camera we are using in the lab today costs €60–65; the same camera would have cost tens of thousands of euros in the 1990s. The camera is connected to a laptop computer that is more powerful than the most powerful supercomputer of the 1990s,' explains Swinney. 'This has opened to the entire world the quantitative study of phenomena that was only possible for very wealthy labs just 20 years ago.'

Another school director, Rajarshi Roy, director of the Institute for Physical Science and Technology at the University of Maryland (USA), recalls that 'the idea behind small science is try to do experiments that cost less than €1000 but still do absolutely cutting-edge science.' For Roy, getting the school to the ICTP has proved to be a great success because the global reach of the centre meant that participants came from all over the world.

For details: www.ictp.it

Green chemistry project 'investment in planet'

A call for research proposals will be launched in November by UNESCO and the largest producer of phosphate-based fertiliser in Europe, PhosAgro, within a joint Green Chemistry for Life project which will be providing annual grants worth a total of US$1.4 million over the next five years.

Scientists aged 35 years or less will be invited to compete for grants of up to US$30,000 each to implement innovative projects that respect the 12 principles of 'green chemistry'. The successful projects will be selected by an international scientific jury.

The 12 principles of green chemistry were defined by Paul Anastas from Yale University (USA) in 1998, seven years after he coined the term. The first of these principles dictates that 'it is better to prevent waste than to clean up waste after it has been created.' Other principles advocate finding harmless alternatives to toxic chemicals and solvents, more energy-efficient chemical processes, the use of renewable feedstocks, safer chemicals, biodegradable chemicals and waste, and so on.

Green chemistry has become a target for cutting-edge research into sustainable technologies that eliminate or reduce the generation or use of hazardous substances in mining and in the design, manufacture and application of chemical products. Projects may encompass biochemistry, geochemistry, biotechnology and applied microbiology, giving young scientists ample opportunity to demonstrate their inventiveness.

The Green Chemistry for Life project was officially launched on 29 March with the signing of a partnership agreement in Paris between UNESCO Director-General Irina Bokova and Maxim Volkov, Chief Executive Officer of PhosAgro. The project is being implemented jointly by UNESCO's International Basic Sciences Programme and PhosAgro, in close cooperation with the International

Union of Pure and Applied Chemistry, UNESCO's partner in the International Year of Chemistry in 2011.

At the signing, Maxim Volkov remarked that the project was the first of its kind to be sponsored by a Russian company. 'We view the Green Chemistry for Life project as an investment in the whole planet,' he enthused, 'and a successful example of how science and business can unite under the auspices of UNESCO to create new knowledge aimed at protecting the environment. I also believe this project will help to improve the prestige of chemistry and lead to more young scientists choosing to study the topic.'

For details: m.nalecz@unesco.org; http://tinyurl.com/unesco-ibsp

UN sets its sights on **protecting the open ocean**

The open ocean covers almost half of the Earth's surface. A UN working group has just asked the 68th UN General Assembly, which got under way in New York on 17 September, to explore the feasibility of developing a new instrument to protect marine biodiversity in the open ocean, the area beyond national jurisdiction.

The issue at stake is whether the UN Convention on the Law of the Sea should include a new agreement covering implementation, in order to protect marine biodiversity in areas beyond national jurisdiction, or whether a better implementation of existing instruments would be sufficient.

If the UN working group on the conservation and sustainable use of marine biodiversity beyond areas of national jurisdiction obtains its mandate, it will submit its recommendations to the 69th UN General Assembly in September 2014.

Today, 60% of the world's major marine ecosystems have been degraded or are being used unsustainably. We are now exploiting fish stocks farther away from the coasts and deeper into the ocean. Marine litter is becoming a huge problem, especially for sea birds and marine mammals, as is the warming, increasingly corrosive ocean – the consequence of absorbing so much of the CO_2 emitted into the atmosphere.

There is overall consensus that we ought to protect our precious living resources better and manage them sustainably. However, agreeing on how this should be tackled is far from easy. Regulating activities that have an impact on biodiversity affects many economic sectors, including fishing, mining, drilling, oil and gas exploitation, wind farms, aquaculture, tourism and basic research, including prospection for bio-active compounds. At this time, there is no central database to record all these activities.

One of the most difficult tasks will be to agree on what tools and mechanisms are needed and on who should implement these and control and monitor economic activities in the open ocean.

Some countries argue that we must respect the freedom of the seas. Others, notably the G77/China and the European Union, consider the resources in the open ocean as the common heritage of humankind. For them, the open ocean belongs to everyone and we are all responsible for taking proper care of it, including when it comes to sharing the fruits of research and the benefits of exploitation among all nations.

On 22 August, the UNESCO-IOC organized a side event with Tara Expeditions on scientific cooperation and data-sharing, while the working group was meeting at UN headquarters in New York. A panel of experts presented the IOC's Ocean Biogeographic Information System (OBIS), a global database on marine life, and a number of programmes which collect samples from the least explored parts of the ocean, including the International Network for Scientific Investigation of the Deep Sea, the Deep Ocean Stewardship Initiative and the schooner *Tara (see interview overleaf)*. All the collected data are being stored and made available in global open-access information systems like OBIS.

For details : w.appeltans@unesco.org; j.barbiere@unesco.org; www.slideshare.net/OBIS-IOC

Climate communication centre opens in Indonesia

On 3 September, the Climate Communication Centre (*Pusat Komunikasi Iklim*) opened in the Indonesian province of Central Kalimantan.

The centre will give local communities access to online discussions on climate change and enable them to exchange information on sustainable ways of reducing greenhouse gas emissions. Courses in related areas will also be run from the centre.

Central Kalimantan is home to the Dayaks, the indigenous inhabitants of Borneo. Deforestation was encouraged by President Suharto until his fall in 1998 and, today, illegal logging remains an acute problem.

The burning of peat forests is responsible for about 70% of Indonesia's CO_2 emissions. In 2009, President Susilo Bambang Yudhoyono committed to cutting Indonesia's CO_2 emissions by 26%. A year later, Indonesia imposed a two-year moratorium on the exploitation of its peat and natural forests.

Indonesia can obtain compensation for the revenue it loses from limiting deforestation via REDD+. The plus sign refers to the implications for indigenous people and local communities of projects funded by the UN Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries (REDD). Once earmarked for widespread rice cultivation, Central Kalimantan is now a pilot province for REDD+.

As part of UN support for the Indonesian REDD+ initiative, UNESCO's office in Jakarta helped to develop the community-learning centre in Central Kalimantan. The project was launched in October last year, in

tandem with the UN Office for Project Services, which built the centre, and the UN Office for REDD+ Coordination in Indonesia.

At the launch of the centre in September, Shahbaz Khan, Deputy Director and Programme Specialist for Water and Environmental Sciences at UNESCO's Jakarta office, presented UNESCO's contribution, which had focused on preparing the community to use the centre. UNESCO helped local villages prepare a community action plan centred around environmental protection and the development of sustainable livelihoods like ecotourism. The plan was distributed to the provincial and district authorities, as well as to NGOs, to help them identify practical ways of supporting the community. The ecotourism project has since got under way with local government support and that of womens' and youth groups.

In August, UNESCO ran a series of training workshops for 46 participants from four villages. These focused on ecosystem restoration, agroforestry and community-based carbon accounting.

Over the past year, UNESCO has also sponsored research by the Forestry Research and Development Agency, attached to the Ministry of Forestry. These studies assessed the impact of deforestation on climate change in Central Kalimantan and on the population's living standards. They also evaluated the efficacy at village level of forest regulations and identified forest ecosystem services of use to local villages. The findings have been communicated to the local government and deposited in the community centre's library.

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IPCC confirms **widespread warming**

The Intergovernmental Panel on Climate Change (IPCC) released its fifth report in Stockholm (Sweden) on 27 September, more confident than ever that global warming is 'unequivocal' and largely human-driven.

The evidence for this has grown since the release of the IPCC's previous report in 2007, thanks to better observations, a deeper understanding of the climate system and more refined climate models.

'Since the 1950s, many of the observed changes are unprecedented over decades to millennia', states the approved *Summary for Policymakers* on the physical science basis for climate change, produced by Working Group I. 'Each of the last three decades has been successively warmer at the Earth's surface than any preceding decade since 1850.' Taken together, global land and ocean temperature data show an increase of 0.85–1.06°C over the period 1880–2012.

'The atmospheric concentrations of CO_2, methane, and nitrous oxide have risen to levels unprecedented in at least the last 800 000 years,' the report states. CO_2 concentrations have increased by 40% since pre-industrial times, primarily from fossil fuel emissions and secondarily from land-use changes. The ocean has absorbed about 30% of CO_2 emissions, causing ocean acidification.

More than 90% of the energy accumulated between 1971 and 2010 has been stored in the ocean, 60% alone in the upper ocean (0–700 m), which warmed from 1971 to 2010.

The extent of Arctic sea ice very likely decreased by between 3.5% and 4.1% per decade between 1979 and 2012. Summer sea ice shrank by as much as 9.4–13.6% per decade over this period.

'The rate of sea-level rise since the mid-19th century has been larger than the mean rate during the previous two millennia,' state the authors. Global sea-level rise was very likely 2.0 mm per year on average between 1971 and 2010 and 3.2 mm per year between 1993 and 2010. Glacier mass loss and ocean thermal expansion from warming since the early 1970s together explain about 75% of this sea-level rise.

The report makes projections based on a set of four new scenarios. 'Global surface temperature change for the end of the 21st century is likely to exceed 1.5°C relative to 1850–1900 in all but the lowest scenario considered,' said IPCC Co-Chair Thomas Stocker in Stockholm, 'and is likely to exceed 2°C for the two high scenarios.' The IPCC considers likely a temperature rise of up to 4.8°C and sea-level rise of 0.82 cm by 2081–2010, if the world follows the most carbon-intensive development scenario.

'Heat waves are very likely to occur more frequently and last longer,' Stocker added. 'As the Earth warms, we expect to see currently wet regions receiving more rainfall and dry regions receiving less, although there will be exceptions.' Globally, it is likely that the area encompassed by monsoon systems will increase over the 21st century.

The global ocean will continue to warm during the 21st century, with heat penetrating from the surface to the deep ocean to affect ocean circulation.

'The IPCC can say a lot about the ocean this time around because of scientific advances, not least the 3000-strong flotilla of Argo floats now patrolling the globe,' observed José María Figueres, Co-Chair of the Global Ocean Commission and former president of Costa Rica, on 19 September in the *Huffington Post*. Coordinated by the UNESCO-IOC within its Global Ocean Observing System (GOOS), the Argo floats record ocean temperature and salinity. In the past four years, they have collected more ocean data than ships and moorings did throughout the 20th century. GOOS enables much of the climate science assessed by the IPCC, informing national and global policy on climate change.

The second volume of the IPCC's 5th Assessment Report on Climate Change, that on *Impacts, Adaptation and Vulnerability*, is due to be released by Working Group II in March 2014. Through its Local and Indigenous Knowledge Systems programme, UNESCO has led inter-agency efforts to include indigenous knowledge alongside science in this volume. As part of this effort, UNESCO and UNU organized an experts' workshop with Working Group II in Mexico City in July 2011. Last year, UNESCO and UNU also published *Weathering Uncertainty: Traditional Knowledge for Climate Change Assessment and Adaptation*, which they made available to the IPCC authors.

Read the report: www.ipcc.ch

Romain Troublé

Sailing the seas for science

From May to December this year, the *Tara* schooner (*pictured*) is circumnavigating the Arctic Ocean via the Northeast and Northwest passages, which are only accessible to shipping in the summer months. Throughout this 25 000-km expedition, the scientific crew is analysing the impact the melting ice pack is having on marine life. Scientists are keen to compare what is happening in the Arctic with the impact of climate change on marine biodiversity elsewhere.

This is not *Tara*'s first ocean expedition but it *is* the first time that UNESCO's Intergovernmental Oceanographic Commission (IOC) has been 'on board', following the signing of a partnership agreement between UNESCO and the French NGO Tara Expeditions on 27 June. The two partners are complementary, with *Tara* collecting scientific data from its expeditions which the IOC will then share with the global scientific community via both its Global Ocean Observing System and the Ocean Biogeographic Information System (OBIS), a global database on marine life. But *Tara* has another string to its bow: raising public awareness. The IOC has been looking for a means of interacting more closely with civil society, in order to alert the public to the dangers facing the oceans. *Tara* can help make that vital link. Here, executive director Romain Troublé brings us up to speed on some of *Tara*'s recent expeditions.

The route taken by the current Tara Oceans Polar Circle expedition

What is the purpose of your Arctic expedition?

The current mission, Tara Oceans Polar Circle, is taking samples of marine life. We are trying to understand how ice melt and an acidifying Arctic ocean are affecting the microscopic plankton ecosystem and the higher echelons of the marine food web.

Once the ice pack melts in the spring, the extra sunlight falling on the ocean triggers an algal bloom. For the past 20 years, the melting season in the Arctic has begun two days earlier every year. The question is: is the bloom now occurring too soon in the spring, before the animals which feed on these algae are mature? If so, these animals could starve or show stunted growth, in turn depriving species higher in the food chain of adequate sustenance.

Another factor which may be affecting the Arctic food web is that, for each of the past 10 years, the extent of summer sea ice cover has been consistently lower than prior to 2003.

Can you walk us through the voyage?

During the six-month expedition, *Tara* is stopping almost every day to take extensive measures and samples. In July, the crew established a first sampling station on the edge of the ice in the Kara Sea, just before Cape Tchelyouskine (Russia).

Another sampling station was established in August above the slope separating the Laptev Sea from the Nansen Basin (Russia). The waters here are particularly deep, with the seabed dropping from less than 100 m on the continental shelf to about 2 500 m. The zone can only be accessed in summer by boat. Here, the scientists took water samples at three different depths to test for the presence of plankton: 300 m, 20 m and at the surface. In the Nansen Basin at a depth of 300 m, you find warm saltwater masses transported by the Gulf Stream from the Atlantic to the Arctic.

We also found freshwater in the ocean during much of the ship's crossing of the Laptev and East Siberian Seas but for different reasons. Many large Siberian rivers, like the Lena River, flow across this area into the central Arctic, bringing nutrients and warmth in the summer which contribute to plankton growth.

We set up our third sampling station in the East Siberian Sea, in very shallow water less than 25 m deep that was chosen for its low salinity and warmer temperatures – more than 1.4°C. This water showed a high content of sediments and coloured, dissolved organic matter, confirming the heavy influence of fresh river water.

The crew then passed Wrangel Island, which separates the East Siberian Sea from the Chukchi Sea. It has the richest biodiversity in the northern Arctic, with 100 000 walruses from the Pacific Ocean and hundreds of polar bears gathering there, among other species. Wrangel Island was also the last refuge of the woolly mammoths about 4 000 years ago. This jewel of biodiversity was inscribed on UNESCO's World Heritage List in 2004.

Off Wrangel Island on 9 September at precisely midnight, the GPS arrived at 180° East then suddenly began to count the minutes backwards: 179° 59' West, 179° 58' West. It was then that we knew *Tara* had changed time zones and that the crew would be experiencing 9 September twice!

Next, in the Chukchi Sea, the scientists on board took water samples from the surface and 40 m beneath the surface, both on the edge of the ice. The first samples revealed rich planktonic life, with lots of seaweed. The crew captured large quantities of *Nichtia,* very long, thin diatoms (microalgae), as well as *Sea Angels*, so-named because they float gracefully in the ocean.

Later the same month, the team spotted some walruses and a solitary male polar bear while taking samples from an ice floe in the Beaufort Sea between Pevek (Russia) and *Tara*'s next destination, Tuktoyaktuk (Canada). The bear climbed onto the ice after probably swimming several kilometres – polar bears are great swimmers and can cover up to 120 km at a stretch.

Tara's next scientific objective will be to explore the waters of the Beaufort Sea and those of Barrow Canyon, located offshore from Point Barrow, the northernmost tip of the USA. The deeper layers of this 'small' sea (450 000 km^2) come from the North Atlantic and are therefore particularly interesting for our scientists on land.

This will take *Tara* one step closer to the Northwest Passage, which will then take *Tara* to Greenland. The schooner is expected to lay anchor in Ilulissat on 15 October, before sailing to Quebec on 10 November then on to the French island of St Pierre-et-Miquelon on 20 November. If all goes according to plan, *Tara* should reach Lorient by 6 December.

The crew is now engaged in a race against time, as it must sail north along the Northwest Passage before thickening ice floes block the passage in the autumn.

How did your first Arctic expedition differ from this one?

Whereas, this time, we have tried to sail around the sea ice pack, during our previous Arctic expedition from September 2006 to February 2008, we deliberately let *Tara* drift across the Arctic Ocean until it became encased in frozen sea ice.

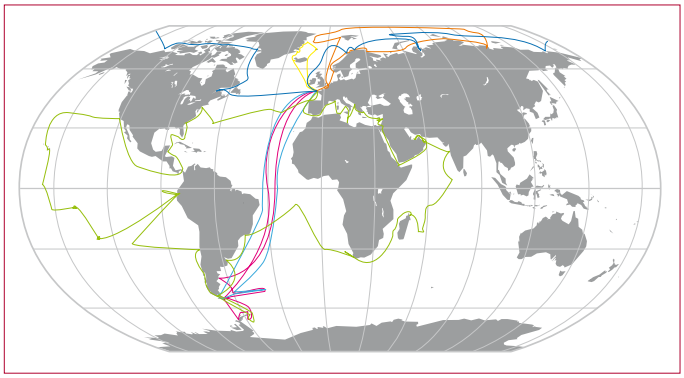
While the vessel was trapped, the scientists on board documented how much heat was being exchanged at an altitude of 1000 m above the sea ice, using a tethered balloon, as well as through the ice itself. They did the same in the ocean, using a device called a CTD that was daily lowered down to 3 000 m by a winch. The instruments on board provided by the Damocles programme of the European Union confirmed that heat travels to the Arctic from the south. These ocean currents and winds are noticeably warmer than before, a phenomenon which is largely responsible for the reduction in sea ice extent and thickness being observed in the Arctic. Sea ice is thinning quite significantly not only because the summer is lasting longer but also because the winters are milder, producing less thick ice.

To our surprise, we discovered that *Tara* had drifted twice as fast as the predictions made by the most up-to-date models: 10 km per day on average, mainly due to wind patterns and to the thinning ice cover. We made this information public, via the blogging done by our on-board journalist, to show the public just how far short of reality our knowledge fell.

Didn't one expedition last more than two years?

Yes, *Tara* set sail from the French port of Lorient in September 2009, with scientists on board from the French National Centre for Scientific Research (CNRS), the European Molecular Biology Laboratory and other labs. They collected plankton and environmental data from 154 different sites and three depths around the world during the 115 000-km voyage, which ended in March 2012.

Findings from this expedition are now being published and the bulk of the data are being made available to the public. The main objective of this quest was not so much to discover what lives in the world's oceans but rather how these species behave,



The various Tara expeditions since 2004. The green route corresponds to the voyage between 2009 and 2012.

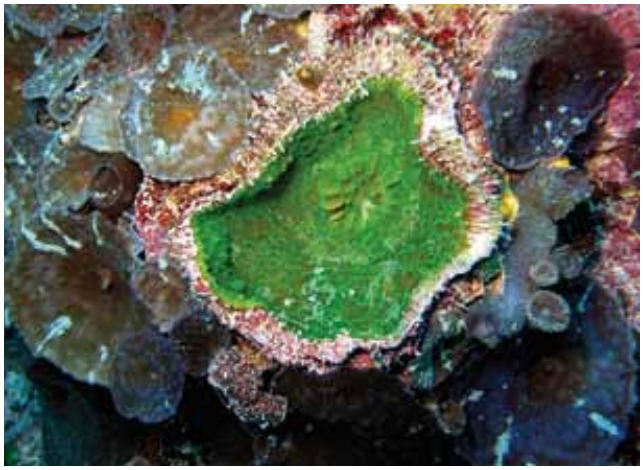
whether this carbon pump is still as effective as we think and what fate might lie in store for plankton as the oceans warm and acidify. You can imagine the quantity of physico-chemical data that accompanies the 30 000 samples we gathered. It will take us years to sequence genomes and digest this massive dataset – but what are a few years in the history of science!

Has a new species really been named after *Tara*?

Yes, in 2011, Dr Francesca Benzoni described this new shallow-water coral species while participating in the Tara Oceans expedition. It was discovered in the Gambier Islands in French Polynesia. The species is neither rare, nor hard to detect underwater, thanks to its bright colours, yet it had never been described before. This just goes to show how little we still know about the diversity of corals, despite all that has been written about them. It also shows that scientific expeditions to remote locations still have a contribution to make to taxonomy. The distribution of *Echinophyllia tarae* sp. n. has since been entered in OBIS. In fact, it was one of ten new coral species discovered during that expedition, mainly in the Gambier Islands.

How are scientists selected for a Tara expedition?

The *Tara* expeditions are generally the result of a bottom-up process, with scientists from all disciplines and origins coming together to tackle a scientific query with the *Tara* team. The laboratories involved propose their students and researchers, who then join the expedition along part of the route taken by *Tara*. This approach only works if you have a robust team of engineers like those from the CNRS to make sure the highest-quality data are collected.



The colourful reef-building coral species named after Tara, Echinophyllia tarae sp. n.

How long has *Tara* been travelling the oceans?

The schooner was built in 1989 to cross the Arctic by drifting in the frozen sea ice but she didn't actually see her first Arctic crossing until 2008, as *Tara*. She is also known in France and in the English-speaking world, thanks to her prestigious owner Sir Peter Blake, a renowned New Zealand sailor who was committed to building environmental awareness. He was killed tragically in the Amazon in 2001 after trying to defend his men from thieves who had boarded the schooner.

Over the past two decades, *Tara* has sailed 400 000 nautical miles. Her original mission of public outreach has not changed but we have added a scientific focus. Based on this experience, Tara Expeditions has decided to bring its network and knowledge into the policy debate on high seas governance with the launch of the *Paris Appeal for the High Seas* in April this year. The basic message is that the high seas belong to no-one and must be managed in the interests of the public good, as a shared common heritage for all humanity. By mid-September, about 10 000 people had signed the appeal,[10] which we launched together with the Economic, Social and Environmental Council, a French parliamentary body. More than 70 French parliamentarians from both houses have signed it so far.

How do you convey your findings to the public?

We share developments on each expedition via daily videos and a ship's log that can be followed online. Once the expedition is over, we take the most comprehensive findings from the articles published by the scientists who travel on *Tara* and share them with our followers; these include children, through the Tara Junior programme for classrooms.

Communication is the hardest nut to crack in our multicultural, multilingual world. To reach out to as many people as possible and show just how wild and fragile the oceans are, we share our adventures with the public through documentaries, festivals, television and web television, radio, social networks, exhibitions, books, the *Tara Journal* and so on.

What do you expect from UNESCO?

Our partnership with UNESCO is a great opportunity to take *Tara*'s messages to a broader audience. It will also speed up the connections between the scientific work done in the laboratories and the OBIS database.

The IOC is helping us to make the most of our collaboration with its Member States. I believe we have all it takes to build up a small but strong capacity-building programme on marine biology with these states. We plan to submit a proposal to existing funding programmes, as I can see that, in multilateral gatherings, everyone talks about capacity-building but without proposing clearly how to go about it.

Interview by
Susan Schneegans

For details: www.taraexpeditions.org; tarajunior.org

10 See: www.lahautemer.org

Protecting a land of fire and ice

Cape Horn is the southernmost biosphere reserve in the world. Located just 1 000 km north of Antarctica in the Chilean Antarctic Province, this sparsely populated archipelago is a unique patchwork of mountains, fiords, islands, glaciers, forests and moorlands. One of the planet's last wildernesses, it is also extremely fragile.

View from Navarino Island of the Beagle Channel, named after the vessel in which Darwin travelled to Chile in the 1830s. High Andean cushion plants and scattered carpets of mosses cover the stony foreground. In the distance lies the Argentinian part of Tierra del Fuego.

Since becoming a biosphere reserve in 2005, Cape Horn has shown remarkable ingenuity in tackling threats to its pristine environment which range from retreating glaciers to invasive species, mass tourism and the extinction of indigenous languages that have thrived for 7 000 years. One novel idea has been to package tours of the region's miniature forests to stimulate sustainable tourism and teach young and old about a world that grows barely taller than their fingernail.

In April 2007, park rangers patrolling the Magallanes subantarctic ecoregion just north of Cape Horn Biosphere Reserve were astounded to discover that a four-hectare glacial lake they had visited a month earlier had completely disappeared. Glaciologist Andres Rivera from Chile's Centre for Scientific Studies (CECS) immediately travelled to the isolated area to ascertain what had happened to the water. He noticed signs that melting glaciers had put pressure on the wall of ice which, by acting as a dam, had allowed the lake to form. When the pressure became too great, the wall would have given way, sending water cascading through the breach. The momentum of the rushing water would have then emptied the lake into a nearby fiord.

This tale is symptomatic of a wider phenomenon. Warmer temperatures are causing glaciers to melt, a process exacerbated by the increase in precipitation falling as rain rather than snow. According to the CECS, almost 90% of the 100 glaciers being monitored in the Patagonian Ice Fields are in retreat. Shared by Argentina and Chile, the Patagonian Ice Fields cover about 14 000 km^2 and are the world's third-biggest frozen landmass after Antarctica and Greenland. In 2011, the CECS released more than 1 400 time-lapse photos showing that Jorge Montt Glacier in the Southern Patagonian Ice Field had retreated by almost 1 km between February 2010 and January 2011. Historical photos of the same site show that the glacier had only retreated by about 20 km over the entire previous century, with most of this retreat taking place in the 1990s.

The rapid rate of glacier melt is raising sea level and producing a large number of icebergs. Tourists flock to the fiords to observe these floating giants. If the glaciers retreat too far, though, icebergs will cease to carve off into the fiords, eliminating a precious reservoir of freshwater and one of the region's biggest tourist attractions.

One of the last wildernesses on Earth

Cape Horn Biosphere Reserve straddles the Chilean Antarctic Province and southwestern Tierra del Fuego Province. Tierra del Fuego means literally Land of Fire, a reference to the fires made by the Fuegian indigenous people which captivated Portuguese explorer Ferdinand Magellan when he came across the area in 1520. The biosphere reserve protects the austral archipelago south of Tierra del Fuego in the Magellanic subantarctic ecoregion, one of the 24 most pristine wildernesses in the world.

The biosphere reserve is covered by evergreen and deciduous forest, dominated by the endemic southern beech trees, *Nothofagus betuloides* (evergreen) and *Nothofagus pumilio* (deciduous). Cape Horn is home to the world's southernmost forests. Part of the South American temperate forest biome, they represent the largest expanse of temperate forest in the Southern Hemisphere, with 13.6 million hectares in Chile and 2 million hectares in Argentina.

Darwin's encounter with the Amerindians of Tierra del Fuego

On the northern coast of Navarino Island lies the capital of the Chilean Antarctic Province, Puerto Williams, with its 2 200 inhabitants. The province extends to the South Pole and is the least populated area in the world, with just 0.000072 inhabitants/km^2. A single dirt road leads into town. To get around the rest of the biosphere reserve, you have the choice between sailing and trekking.

Most of the members of the indigenous Yaghan community, or Yamana, live in Ukika, near Puerto Williams. They can lay claim to being the southernmost ethnic group on Earth. Over 1 000 archaeological sites in the biosphere reserve testify to their presence in the region for more than 7 000 years.

The Yaghan and other neighbouring Fuegian Amerindians can also claim to have inspired Charles Darwin's theory of evolution as concerns our own species. Darwin's encounter with the Fuegian people in Cape Horn and Tierra del Fuego shook his belief in the gulf between humans and animals. In his diary, Darwin described the arrival of the *Beagle* in Tierra del Fuego on 17 December 1832 as follows:

> While entering [the Bay of Good Success], we were saluted in a manner becoming the inhabitants of this savage land. A group of Fuegians partly concealed by the entangled forests was perched on a wild point overhanging the sea; and as we passed by, they sprang up and, waving their tattered cloaks, sent forth a loud and sonorous shout. The savages followed the ship and just before dark we saw their fire and again heard their wild cry.... It was without exception the most curious and interesting spectacle I ever beheld. I could not have believed how wide was the difference between savage and civilized man; it is greater than between a wild and domesticated animal, inasmuch as in man there is a greater power of improvement.

© Ricardo Rozzi

A Yaghan artisan presents two replicas of bark canoes she has made to sell to tourists.

Although Darwin's judgment of the Fuegian native people is irritatingly eurocentric, it is difficult to imagine how a scientist of his day would ever have arrived at the conclusion that *Homo sapiens* belonged to the Animal Kingdom and was related to other primates, had he never left the confines of genteel 19th century English society.

Nowadays, most Yaghan are engaged in fishing, handicrafts, construction and ecotourism. Both the culture and language of the native people Darwin met in Cape Horn and Tierra del Fuego are extremely endangered; only small communities of their descendants remain and today the Fuegian Ona, Alacaluf and Yaghan languages are spoken fluently by fewer than ten people.

Ice and moss in the Patagonian Ice Fields

© Ricardo Rozzi

Nine's company, ten's a crowd

If you were to ask the Yaghan to name the region's most charismatic bird, they would no doubt opt for the colourful Magellanic woodpecker (*Campephilus magellanicus*). The largest woodpecker in South America, this endangered bird is a close relative of the extinct imperial woodpecker (*C. imperialis*) and ivory-billed woodpecker (*C. principalis*). There are at least 100 bird species in the biosphere reserve.

The climate is too cold to appeal to reptiles and amphibians. At the height of summer in January, the air temperature averages just 9.6°C, compared to 1.9°C in the depth of winter. Sea temperature varies little throughout the year, from 5°C to 7°C. Marine mammals flourish in these waters. For thousands of years, sea otters have provided the Yaghan with fine furs and sea lions with their main source of calories.

There are nine native terrestrial mammal species: three species of rodent (*Euneomys chinchilloides*, *Oligoryzomys longicaudatus* and *Abrothrix xanthorhinus*); the Andean fox (*Lycalopex culpaeus*), which is the largest in South America; two bat species (*Histiotus montanus* and *Myiotis chiloensis*); the guanaco (*Lama guanicoe*), a relative of the camel; and two species of otter (*Lontra feline* and *L. provocax*).

A tenth mammal species is a visitor to the region which has overstayed its welcome. In the 1940s, 50 North American beavers (*Castor canadensis*) were introduced into the area by the Argentine government to kickstart a fur industry. In the absence of predators, their numbers have since swelled to about 100 000. These cuddly aquatic rodents have invaded the endemic forest, felling trees to make dams on the river. The destruction is so widespread because South American trees do not regenerate, unlike their North American counterparts.

The colourful Magellanic woodpecker

A hotspot for miniature forests

South of Navarino Island, the landscape is dominated by peatlands, bogs and evergreen forests. It is here that you find one of the world's biodiversity hotspots – but you may need a magnifying glass to spot it. The Magellanic subantarctic ecoregion represents less than 0.01% of the Earth's surface area but hosts more than 5% of the planet's known species of bryophyte, half of which are endemic.

Bryophytes are non-vascular plants, meaning that they lack the series of tubes found in vascular plants such as conifers and flowering plants which transport water and nutrients over a distance. Plants without a vascular system have stunted growth. Mosses, lichens and the even simpler liverworts rarely grow more than 2 cm in height. They tend to stick together, forming lush green carpets. As they have no roots, they grow in moist areas, in order to absorb the necessary water and nutrients.

A team from Omora Ethnobotanical Park on Navarino Island has inventoried more moss (450) and liverwort (368) species in the biosphere reserve than vascular plant species (773), making the region a hotspot for bryoflora. In most parts of the world, there are about 20 times more vascular plants than bryophytes, as vascular plant species are far more common worldwide (300 000) than bryophyte species (15 000).

A sanctuary for biocultural diversity

After it was founded in 1999, Omora Ethnobotanical Park became increasingly concerned about the threats facing both biodiversity and indigenous languages and cultures in the ecoregion. Scientists from the research centre decided that a biosphere reserve would provide an ideal framework for the development of education, research and long-term biocultural conservation in the ecoregion. They rapidly convinced the authorities and local community to support the idea. In collaboration with the regional government, an interdisciplinary team from Omora Park and the University of Magallanes then set about collecting the requisite data and zoning the future biosphere reserve, incorporating traditional ecological knowledge provided by members of the Yaghan community.

Upon its designation by UNESCO in June 2005, Cape Horn became the largest biosphere reserve in the Southern Cone of South America, with a surface area of 4.9 million hectares (or 48 843 km^2), including just under 3 million hectares of marine areas.

Within two months, a Biosphere Reserve Management Committee had been set up. Chaired by the Government of the Magallanes Region, the committee also comprises the Chilean Antarctic Province Government, the Municipality of Cape Horn

© André Künzelmann (beaver) and Elke Schüttler (valley)

Left, a boy fondles his pet beaver and (right) the less appealing side of this invasive species, a valley on Navarino Island after a couple of beavers have finished doing some ecosystem engineering

and the Chilean Navy. The scientific committee chaired by the Omora Ethnobotanical Park fulfils an advisory role but does not have the right to vote.

Omora Park's strategy is to blend interdisciplinary scientific research with educational programmes and the promotion of sustainable tourism.

Researchers and graduate students from the centre are also collaborating with the Livestock and Agriculture Service and the regional government on a programme to control invasive species, including the mink (*Neovison vison*) and wild pigs and dogs. In 2008, Omora Park collaborated with the regional government on a feasibility study for the eradication of all 100 000 beavers from the biosphere reserve over several years. No decision has yet been made as to whether to go ahead with the project. In the meantime, Argentina and Chile are using traps and other methods to control the beaver population.

Extending the tourist season beyond the summer

Omora Park runs a long-term bird monitoring programme. Scientists study migratory patterns and bird ecology within a programme which also registers indigenous Yaghan knowledge. They have also helped local tour operators to introduce bird-watching tours and design cruise itineraries which mimic the maritime route Darwin followed in Cape Horn 180 years ago.

Taking a closer look at liverworts, mosses and lichens on the trail of Omora Park's miniature forests

© Adam Wilson

The cruises and birdwatching can only take place in summer, however. A team of scientists, philosophers and artists have come up with an innovative alternative which appeals to tourists all year round. Participating tour operators send their clients to explore the 'Miniature Forests of Cape Horn' in the interpretive trails of Omora Ethnobotanical Park. The visitors are given a magnifying glass to help them observe the intricate beauty and diversity of the tiny lichens, mosses, mushrooms, insects and other invertebrates they would usually walk past without noticing. Signs placed along the trail provide information on the ecology of each bryophyte and other plant species in several languages, including Yaghan.

The first science education programme for preschoolers

The visit to the miniature forests has even been adapted to young children, within the first science education programme for preschoolers. The Small Explorers of Cape Horn Miniature Forests tour is supported by the Chilean National Commission for Scientific and Technological Research (CONICYT). A dictionary for children has also been developed that incorporates Yaghan ecological knowledge.

Courses on bryophytes, Yaghan ecological knowledge and Yaghan language and culture have also been introduced at Puerto Williams School.

The team at Omora Park has also designed the first graduate programme in Patagonia, together with the University of Magallanes. Graduate students work with members of the Yaghan community, local schools and tour operators to integrate ecological sciences and environmental ethics into biocultural conservation.

Strength in numbers

By pooling its experience with other research centres and biosphere reserves in the Americas, including the Charles Darwin Station in the Galapagos Biosphere Reserve, Omora Park has become part of a dynamic network which is using new scientific knowledge to develop sustainable tourism and enrich school and university curricula.

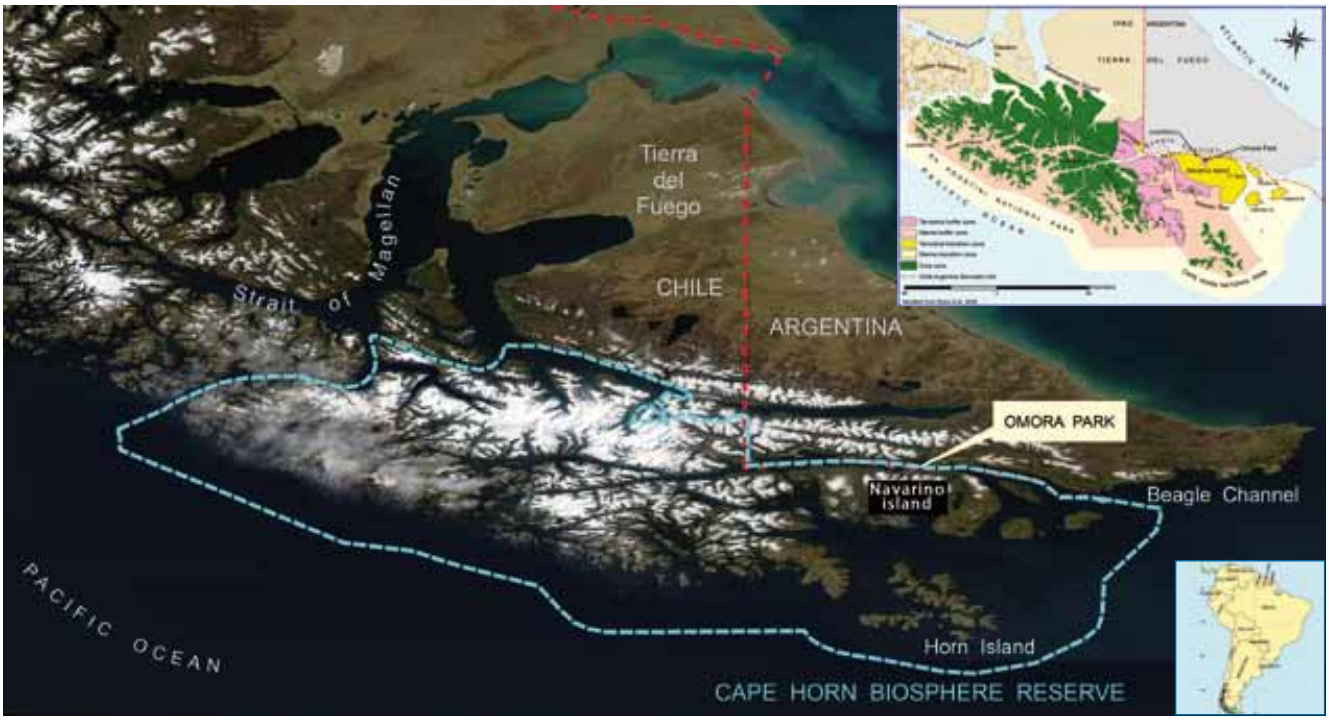
The centre participated in the creation of the Chilean Long-Term Socio-Ecological Research Network in 2008, financed by CONICYT, which has allied science and tourism at other Chilean sites, including the Fray Jorge Biosphere Reserve and Chiloe National Park. Omora Park also participates in the Millennium Scientific Initiative coordinated by the Chilean Institute of Ecology and Biodiversity, which brings together researchers from the Universities of Magallanes, Concepción and La Serena, as well as the Pontifical Catholic University of Chile.

More recently, Omora Park has established a Subantarctic Biocultural Conservation Programme in partnership with the University of North Texas (USA), which hosts the world's leading centre in environmental ethics.

Ricardo Rozzi[11], *Elke Schüttler*[12]

11 *Department of Philosophy and Religion Studies, University of North Texas, USA*

12 *Department of Conservation Biology, Helmholtz Centre for Environmental Research, Germany*



Source: Modified from Ricardo Rozzi *et al.* (2008) Changing lenses to assess biodiversity: patterns of species richness in sub-Antarctic plants and implications for global conservation. *Frontiers in Ecology and the Environment*, 6: 131–137

The Cape Horn Biosphere Reserve. The core zone *(dark green) is dedicated to strict preservation; in* buffer zones *on land (bright pink) and in the ocean (pale pink), sustainable, low-impact activities like ecotourism are permitted; in the* transition areas *on land (bright yellow) and in the ocean (pale yellow), higher impact activities are allowed, including the construction of infrastructure.*

A garden in the desert

There are signs that vegetation is recovering in some parts of Qatar, a UNESCO survey has found, but most desert rangelands and coastal areas remain in poor condition. Camel farming could be a way to restore these rangelands, by preventing overgrazing.

Vegetation ecologist Benno Böer from UNESCO's Doha office came to this conclusion after criss-crossing the small Gulf state for six months between December 2012 and May 2013.

Avicennia marina mangroves thrive in Al-Khor in northeast Qatar. These mangroves once provided key fodder for camels in prolonged droughts. Qatar's mangroves are generally in good condition, although some habitat in Al Wakra and Umm Saeed has been lost to coastal development.

Dr Böer is UNESCO's Ecological Sciences Advisor for the Arab Region. He travelled around Qatar to assist Pergola Contracting and Greenhouses, a Qatari company specializing in landscaping and construction, in collecting and breeding a maximum of native plant species. Benno Böer was assisted in this task by UNESCO intern Chanthy Huot, a horticulturalist from Cambodia, UNESCO volunteer Patricia Bannier, a geographer from the Netherlands who compiled the species distribution maps, and by Mark Sutcliffe, a UNESCO Project Officer from the UK.

Whereas UNESCO's interest was purely scientific, the Qatari company had a more practical motivation, the quest for Qatari plants for gardens and green spaces in Qatar's cities. The two partners shared the same overarching goal, however, to contribute to the *ex situ* conservation of indigenous and native plant species. Article 9 of the Convention on Biological Diversity is devoted to *ex situ* conservation. Reducing biodiversity loss also happens to be one of the targets of the Millennium Development Goal of environmental sustainability.

The survey mapped at least 164 plant species out of the almost 400 species recorded so far in Qatar. The geographical location of each native plant species collected was recorded by the UNESCO team, to ensure that they could be revisited by botanists, horticulturists, landscape architects, plant-breeders and others in the future.

Encroaching urbanization

It rains mainly in winter in Qatar, although the country did witness heavy downpours this year in the spring months of April and May. With the exception of a few temporary *wadis*, the only sources of water are fossil groundwater and the water recovered from desalination plants. Just 2.5% of the territory is

*Staff from Pergola and UNESCO collecting wild seeds and cuttings during the survey. On the right is a Sidr tree (*Ziziphus nummularia*).*

devoted to agriculture, with some Qataris also raising camels, goats and sheep.

Many of the areas visited by the survey team were in very poor condition, dominated by thorny, salt-tolerant (halophytic), or poisonous plant species. The team found only small numbers of edible species, owing to the combination of a hyper-arid climate with long-term overgrazing, groundwater depletion and urban encroachment.

'Coastal development and urban encroachment into natural ecosystems have caused serious habitat loss,' observes Böer. Between 2004 and 2010, Qatar's population grew by 128%, to 1.7 million, according to the Qatar Statistics Authority, with immigrant workers making up about two-thirds of the total population. Over the same period, the number of houses doubled in Qatar, while apartments jumped by 146%.

Overgrazing has decimated desert plants

'In desert rangelands,' laments Böer, 'plants have been decimated by decades of overgrazing by camels, goats and sheep'. This has prevented the rejuvenation of palatable species like *Acacia* trees and allowed opportunistic thorny, toxic and halophytic plant species to proliferate.

'Some areas which have banned livestock have shown good signs of recovery,' he adds. In the area to the west of the Dukhan–Umm Bab Highway, for instance, palatable *Panicum turgidum* grasses flourish and, between Shahaniyah and Rawdat al Farras, the absence of grazing livestock has enabled a good rejuvenation of *Acacia* trees.

Finding the right balance

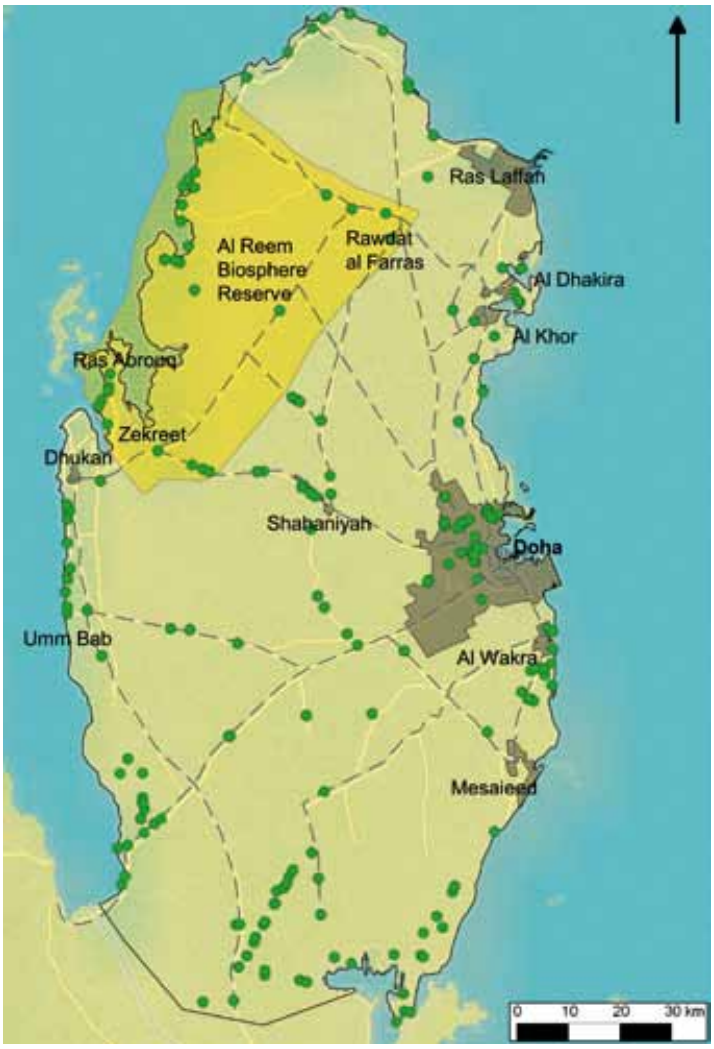
Camels contribute greatly to the health of desert ecosystems by redistributing nutrients through their faeces.. Perfectly adapted to arid environments, they cause much less damage to the soil and vegetation than sheep or goats. They also continue to be an important source of meat, milk, wool and other products in the Arabian Peninsula.

Camels are also part of the region's cultural heritage. For thousands of years, Bedouins and their camels lived in a harmonious, symbiotic relationship with their environment. In antiquity, the Arabian Peninsula was an important route for trade with India and Abyssinia, modern Ethiopia. Bedouins travelled through the desert in caravans, or camel trains, to protect themselves and their merchandise from attack by bandits.

The survey helped scientists to estimate the right balance between rangeland vegetation and grazing camels, so that camels can be reintroduced in sustainable numbers. This will not only enhance biodiversity conservation but also reduce wind-born soil erosion and, with it, the amount of dust particles in the atmosphere.

More vegetation will mean more wildlife

'Once the vegetation cover exceeds 8% of the soil, there is basically no more erosion,' says Böer. 'Currently, we have less than 1% in most places. Better vegetation cover will make the rangelands more productive and, by providing food for herbivores,



Sites from which plant samples were taken (green dots) during the survey. Towns are shaded in grey and the Al Reem Biosphere Reserve is in yellow.

Lycium shawii *bushes after winter rains in an area where grazing is banned*

Halopeplis perfoliata *grows in the salt marshes between the sea and the dunes. It is one of the most salt-tolerant plants in the Gulf.*

Calotropis procera *is a poisonous plant when fresh but its leaves can be consumed by livestock once they have dried.*

The beach lavender Limonium axillare *occurs on the landward side of the mangroves and salt marshes.*

This Leptadenia pyrotechnica *is showing clear signs of soil erosion. Its roots should not be visible above the surface.*

Edible fruits of the Sidr tree, Z. nummularia

This Acacia tortilis *tree is over 125 years old. It may have been shaped by the north–northwesterly Shamal winds which blow here in the Dukhan heights in the southwest. In this part of Qatar, there is less than 1% vegetation cover.*

A previously unrecorded species discovered during the survey, Tetraena mandavillei, *in the red sands of southern Qatar*

Rumex vesicarius *can be eaten as a salad.*

Palm trees are rare in Qatar. These specimens of Phoenix dactylifera *grow in western Qatar in Umm Bab.*

will allow for the controlled re-introduction of captive-bred species that are either rare or extinct locally.'

This includes flagship conservation species, such as the desert hare (*Lepus capensis*), spiny-tailed lizard (*Uromastix aegyptiaca*), various species of gazelle (*Gazella* spp.) and the houbara bustard (*Chlamydotis macqueenii*), a migratory bird that is of great importance for the Arab art of falconry. Protected by UNESCO's Convention for the Safeguarding of Intangible Cultural Heritage, this ancestral art has great potential for the development of recreational, photographic and educational outdoor tourism.

In the northwest, the Arabian Oryx (*Oryx leucoryx)* and various species of gazelle are being bred in captivity in the country's only biosphere reserve, designated by UNESCO in 2007. Al Reem Biosphere Reserve sports some of the most interesting landscapes of the Qatar peninsula. Stretching over 1 100 km^2, it occupies about 10% of Qatari territory. The biosphere reserve combines desert landscapes with a long coastline. The limestone cliffs extending from Zekreet to Ras Abrouq are unparalleled in the country.

The surveyors found that the main plant species in the biosphere reserve were similar to those found elsewhere in Qatar. In addition to the *Acacia* tree (*Acacia tortilis*), *Lycium shawii* and *Limonium axillare* grow there, as well as *Senna italica, Halopeplis perfoliata* and *Panicum turgidum* grasses.

There are plants growing in the biosphere reserve and beyond which are perfectly palatable for camels, oryx and gazelles, including *Rhanterium epapposum*, *Panicum turgidum* and *Pennisetum divisim*. These native species do not need much irrigation water, as studies by the Kuwait Institute of Scientific Research have shown, unlike the thirsty alfalfa plant and Rhodes grass, commonly used as fodder for livestock.

'During our time in the biosphere reserve, we did not observe any camels. This is a positive sign, as their absence will allow the vegetation and habitat structure to recover', says Boër, before adding that 'we did see large numbers of grazing sheep and goats, however.'

Towards camel farming?

UNESCO's Doha Office developed a proposal in 2007 to establish camel farms,[13] in order to reduce the number of camels on desert rangelands and thereby combat desertification. The idea was to encourage camel owners to transfer part of their growing herds from degraded rangelands to farms geared to feeding camels with native desert plants. The herdsmen would benefit from the scheme, since each farm would be able to produce a large volume of commercial products.

These farms could be tested in Al Reem Biosphere Reserve, within a wider management plan to restore plant species and soils. Once the flora and vegetation had been restored, the biosphere reserve would then be able to re-introduce oryx, gazelles and other animals into the wild.

Mark Sutcliffe[14] and Bonnie James[15]

For details: b.boer@unesco.org; www.unesco.org/new/en/doha/natural-sciences/

13 *See: www.unesco.org/new/uploads/media/The_Camel_From_Tradition_To_Modern_Times.pdf*

14 *Project Officer in UNESCO's Doha office*

15 *Deputy News Editor of the* Gulf Times, *Qatar*

Diary

30 September – 4 October
IHP Southeast Asia and Pacific
Steering committee, during Intl Forum on Water Cooperation and World Water Forum, Nakdong River Intl Water Week. Gyeongju City (Rep. Korea): s.khan@unesco.org www.nariiww.com

2–5 October
Science communication
School organized by UNESCO Venice Office during 1st regional conf. on science promotion. Belgrade (Serbia): m.scalet@unesco.org; r.santesso@unesco.org

3 October
Renewable energy in the service of humanity
40th anniversary of intl project on The Sun in the Service of Humanity. Traces industrial development since. UNESCO, ADEME, CNRS, French Perm Del to UNESCO. Room II, 6 pm. UNESCO Paris: o.benchikh@unesco.org

24–26 October
Biosphere reserve partnerships for a green economy
Southeast Asia Biosphere Reserve Network. UNESCO Jakarta, Philippines Nat. Comm. For UNESCO Palawan Biosphere Reserve (Philippines): s.khan@unesco.org

28–31 October
Seismicity and earthquake engineering
in the extended Mediterranean region. 33rd intl workshop cosponsored by UNESCO and USGS: 70 senior scientists from 20 countries expected. Sessions on data exchange, seismotectonics, etc. Malaga (Spain): j.torres@unesco.org; http://tinyurl.com/seismo-meeting-europe

29–30 October
Blue carbon
Scientific workshop of Intl Blue Carbon Initiative. UNESCO-IOC and Conservation Intl. On remote sensing and mapping of wetlands. UNESCO Paris: jl.valdes@unesco.org

29–31 October
Youth and social inclusion
Civic engagement, dialogue and skills development. 8th youth forum. UNESCO Paris: www.unesco.org/new/en/youth-forum-2013; m.goucha@unesco.org; m.kypriotou@unesco.org

5–7 November
The role of African universities in enhancing STI capacity
In response to emerging industrial and socio-economic needs. 5th African Regional Conf. of Vice-Chancellors and Deans of Science, Engineering and Technology. With German Exchange and ANSTI. University of Botswana, Gabarone: p.oti-boateng@unesco.org; www.ansti.org

10 November
World Science Day For Peace and Development:
www.unesco.org/science/pcb

11–13 November
Ecohydrology: sustainable management for a sustainable world
1st Congress on ecohydrology in Latin America. UNESCO, Govt. Chile, University of Santiago,etc (Chile): zmay@unesco.org.uy; www.celacphi2013.cl

18 November
Ocean acidification: the other CO_2 problem
Side event during COP 19, 11–22 November. UNESCO-IOC, with IAEA, SCOR, Plymouth Marine Laboratory, WMO. Warsaw (Poland): jl.valdes@unesco.org

20–22 November
Impact of global climate change
On snow, glaciers and water resources in the Andes. Expert workshop. UNESCO, ACCIÓN, CONDESAN. Quito (Ecuador): a.mishra@unesco.org

24–27 November
Science for global sustainable development
6th World Science Forum. Govt of Brazil, UNESCO, Brazilian and Hungarian Academies of Science, with ICSU, AAAS, EASAC. Rio de Janeiro (Brazil): www.sciforum.hu; l.brito@unesco.org

25 November
Applying ocean sciences and knowledge for societal benefit
Demands after Rio+20. UNESCO-IOC roundtable during World Science Forum (see previous entry). Rio de Janeiro (5:30 pm): jl.valdes@unesco.org

2–13 December
Ecohydrology under climate change
23rd UNESCO-IHP training course for South Asia on river basin management. UNESCO co-organizer. Held along Kizu River and at Disaster Prevention Research Institute, Kyoto University (Japan): s.khan@unesco.org; www.ihpnagoyaforum.org

9–13 December
IndiSeas II
Hosted by UNESCO-IOC. IndiSeas evaluates the effects of fishing on the health of marine ecosystems. IndiSeas is cofunded by UNESCO-IOC, European Network of Excellence Euroceans, French IRD and European MEECE project. UNESCO Paris: Valdes: jl.valdes@unesco.org

9–14 December
2nd IPBES plenary
UN partners: UNEP, UNDP, UNESCO, FAO. Antalya (Turkey): www.ipbes.net/plenary; s.arico@unesco.org

New releases

International Glossary of Hydrology

3rd edition, prepared by UNESCO/WMO Standing Committee on Terminology, Multilingual in English, French, Russian and Spanish, 144 pp.
Agreed terminology is essential for communication, shared research and joint action, especially at the international level. Hence the need for this glossary, which succeeds the first (1974) and second (1992) editions. Download: http://unesdoc.unesco.org/images/0022/002218/221862M.pdf

World Map of Biosphere Reserves

Produced by UNESCO-MAB with support of German, Austrian, Swiss and Luxembourg National Commissions for UNESCO. Multilingual in English, French, Spanish and German.
Recto verso map showing all 621 biosphere reserves in 117 countries, as of September 2013. Includes overview of the functions and structure of biosphere reserves. For details: m.clusener-godt@unesco.org; download: http://unesdoc.unesco.org/images/0022/002229/222915M.pdf

Free Flow
Reaching Water Security through Cooperation

UNESCO Publishing/Tudor Rose Publishing, ISBN 978-92-3-104256-0, English only, 328 pp.
Begins with an overview of UNESCO's International Hydrological Programme. Chapters follow on water diplomacy, transboundary water cooperation, water education and institutional development, financing cooperation, national and regional legal frameworks, etc.
Download: http://unesdoc.unesco.org/images/0022/002228/222893E.pdf

Science Policy Information Network (version 2.0)

New version of free online information provider launched in 2010 by UNESCO's Montevideo office for Latin America and the Caribbean in English, French and Spanish.
Features new and updated information on STI policies, operational STI policy mechanisms, STI legal frameworks, indicators, national STI systems' organizational charts and STI priorities in the region. Incorporates new sections on gender equality, mainstreaming indigenous knowledge systems, science education and popularization, etc. Provides linkages to other key databases, allowing direct access to country profiles from the UNESCO Institute for Statistics, WIPO, Agricultural Science and Technology Indicators, etc. Visit SPIN at http://spin.unesco.org.uy

Tsunami Preparedness, Civil Protection
Good Practice Guide

Published by UNESC-IOC, with support of European Commission Directorate General for Humanitarian Aid and Civil Protection. Manuals and Guides, No.65, English only, 64 pp.
Targets civil protection authorities in Mediterranean, Northeastern Atlantic and connected seas. *Download:* http://unesdoc.unesco.org/images/0022/002208/220802e.pdf

IOC Strategic Plan for Oceanographic Data and Information Management (2013–2016)

Published by UNESCO-IOC. Manuals and Guides, No 66. Multilingual in English, French, Russian and Spanish, 54 pp.
Provides standard and best practices in sharing, accessing and evaluating oceanographic data and information under agreed governance criteria, within UNESCO-IOC Oceanographic Data Exchange Policy (2003).
Download: http://unesdoc.unesco.org/images/0022/002230/223030M.pdf

Tsunami Glossary

Published by UNESCO-IOC. Technical Series, No.85 rev. French and Spanish edition of report first published in English and Arabic, 48 pp.
Download: http://unesdoc.unesco.org/images/0018/001882/188226f.pdf
(Replace the 'f' with an 's' for Spanish version)

Now available in French and Spanish