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IN THIS ISSUE

EDITORIAL

Seal the deal!

Global carbon dioxide (CO_2) emissions from burning fossil fuels stood at a record 8.4 gigatons in 2006, according to the Earth Policy Institute, '20% above the level in 2000. Emissions grew 3.1% a year between 2000 and 2006, more than twice the rate of growth during the 1990s.'

This shows that we are on a dangerous slide towards runaway climate change. Growth in CO_2 emissions currently exceeds the worst-case scenario in the Intergovernmental Panel on Climate Change's 2007 report of an average 6.4°C temperature rise by the end of the century.

Yet, just when a sense of urgency should prevail, the mood going into the UN climate talks in Copenhagen in December is one of wait and see. Much of the responsibility for our current predicament lies with the wealthy countries. Time and again, they have failed to live up to their promises of international support for poverty reduction and technology transfer to the developing world. Nor can they deny responsibility for most of the increase in global emissions of greenhouse gases since the 1950s, even if much of this growth is now taking place in the fast-growing industrializing world. Developing countries fear that most of the burden for reducing greenhouse gas emissions will rest on their shoulders, as their investment needs for energy swell in coming years.

Yet, it is not a question of choosing between high economic growth and low greenhouse gas emissions, says UN Secretary-General Ban Ki-moon. He argues that the two pathways are complementary, in his preface to the UN's *World Economic and Social Survey* released in September. The *Survey* proposes creating a global investment programme to help developing countries embrace cleaner development pathways.

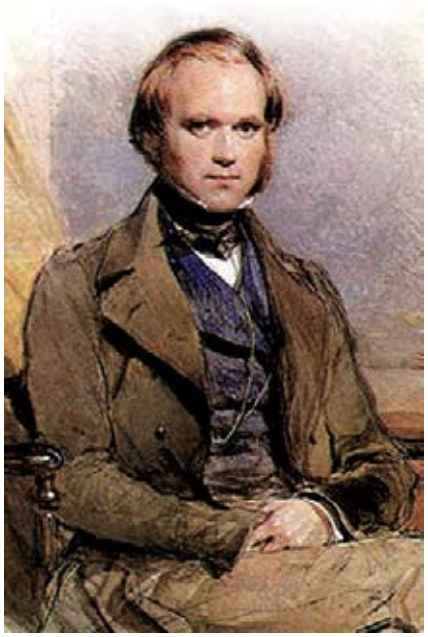
The *Survey* suggests that at least 1% of annual world gross product, or US$500–600 billion, should be invested in adaptation to, and mitigation of, climate change. This compares with an estimated US$21 billion at present in overseas development assistance for climate change. 'The poorest and most vulnerable need significant fast-track funding for adaptation – now!,' warns Ban Ki-moon. You need only look at the case study within these pages of two biosphere reserves in the UK and Kenya to see that, although both are already feeling the effects of sea-level rise, the means at their disposal for adapting to climate change vary greatly.

The onus is on the biggest carbon emitters historically to lead by example by committing in Copenhagen to lower emissions. But no agreement will make sense unless countries with fast-growing emissions also make substantial cuts. Today, just 10 countries emit two-thirds of the world total. In descending order, these are: China, USA, Russia, India, Japan, Germany, UK, Canada, Republic of Korea and Italy. Trailing these countries are Iran, Mexico, South Africa, France, Saudi Arabia, Australia, Brazil, Spain, Indonesia, Ukraine, Poland, Thailand and Turkey.

In the words of Ban Ki-moon, 'our foot is stuck on the accelerator and we are heading towards an abyss.' All of humanity is seated in that car. We are hurtling towards this calamity together and it is only together that we will be able to pull back from the brink.

Copenhagen is the culmination of a three-year effort by the United Nations to have a post-*Kyoto Protocol* agreement in place by 2012. Delegations need to come to Copenhagen prepared to assume their responsibilities. Seal the deal!

W. Erdelen
Assistant Director-General for Natural Sciences



Charles Darwin (1809-1882) aged about 30

Darwin lives!

Charles Darwin turned 200 years old on 12 February 2009. Happily, the 150th anniversary of his book *On the Origin of Species by Means of Natural Selection* falls later in the same year. Darwin's work, which led him to defy respectable convention and develop his own version of 'transmutation' (today called 'evolution'), remains compelling today, as the evidence that he amassed and analysed and the ideas he generated to explain how evolution works still remain at the core of evolutionary science.

Since Darwin's day, of course, the world has moved on. Enormous strides have been made in genetics, developmental biology, palaeontology and anthropology, rendering the case for evolution vastly more detailed and robust. Yet, the essence of Darwin's theory – that all species of life on Earth are related by a process of ancestry and descent, and that the changes we witness in life through time are moulded in large part through the action of 'natural selection' – remain as true today as when Darwin published *On the Origin of Species* in 1859.

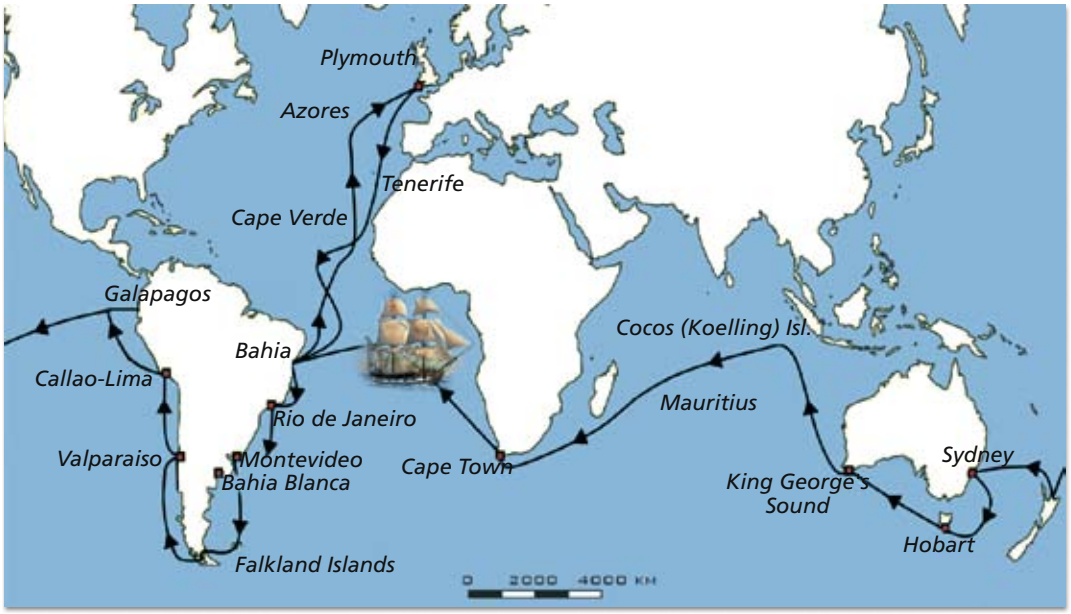
Darwin's formative years

How did a young man with an appetite for outdoor adventures but no real aptitude for formal studies become the great thinker whose ideas challenged the ages-old answers to the questions: 'Who am I?' 'Where did I come from?' 'How do I fit into the world around me?' For although Darwin was not the first to entertain the notion that life has evolved, he was the first to place the idea on a firm scientific footing. Darwin's theory of evolution by natural selection thus ranks as one of the major contributions to thought in the history of humanity.

Darwin's own grandfather, the physician Erasmus Darwin (1731–1802), was England's most renowned proponent of transmutational thinking, refering to the change from one species into another, in the latter decades of the 18th century. It is said that even the great French zoologist, Jean-Baptiste Pierre Antoine de Monet, Chevalier de la Marck (1744 – 1829, "Lamarck" for short), derived some of his inspiration from reading the older Darwin's work. It is Lamarck who has come down to us as the figure who proposed the most convincing ideas of evolution prior to Charles Darwin. Yet Lamarck imagined a world where species graded into one another both through time and even in the modern biota. He felt that, were enough information available, we would see that all the different kinds of bird species visible from one's window, for example, would be seen to meld into other 'species' living elsewhere. In addition, Lamarck had no convincing way of explaining how evolution might occur.

But Lamarck did have his followers, including several of Darwin's teachers after Darwin began his brief stint at medical school in Edinburgh at the tender age of 16 in the mid-1820s. Robert Jameson taught a course in natural history that included lectures 'on the origin of the animal species.' He also founded the *Edinburgh New Philosophical Journal*, which, in 1826, published an anonymous article extolling the virtues of Lamarck's ideas.

Probably Darwin's most important formative experience in Edinburgh was the work he did with Robert Grant (1793–1874), a zoologist trained in Paris (France) and a frank admirer of Lamarck. Grant and Darwin collected primitive animals, such as sponges, coral relatives and 'moss animals',



The **Beagle's** *route around the world*

The emergence of 'deep time'

To understand why *On the Origin of Species* shook conventional wisdom at the time of publication in 1859, we need to slip into the shoes of 19th century Europeans. In the first decades of the century, scientific pursuits are still the hobby of gentlemen and men of the church, rather than established professions. The Geological Society of London has only existed since 1807, when it became the world's first professional society for Earth scientists.

'At the time, the public believed the Book of Genesis in the *Bible* to be literally true,' recalls Randal Keynes, great great grandson of Darwin and author of a book about his illustrious ancestor. As for men of science, 'most believed that individual species had been created by God, with humans being created first and other species immediately thereafter.' As Prof. Edward Derbyshire of the Geological Society of London recalls, 'By now, megafossils such as woolly mammoth, hippopotamus, rhinoceros and cave hyaena had been discovered in Eurasia, Africa and the Americas, and studied by "the father of palaentology" Georges Cuvier (1769–1832) and others. However, for the public, these discoveries seemed only to confirm the reality of the Great Flood as depicted in the *Bible*. In particular, the presence of marine fossil animals and seashells in rocks far from the oceans* was regarded as endorsing this interpretation.'

The Book of Genesis presented the Earth as being only a few thousand years old. Geologists were perplexed, however, by fossils embedded in deep layers of sediments sometimes more than 1 km thick. How could these layers have formed in just a few thousand years, they wondered, and how could the apparent absence of remains of the human victims of the Great Flood be explained? Why were there so many animal fossils but no human fossils?**

'By the time Darwin embarked on his voyage on the *Beagle* in 1831, many geologists had come to agree that the Earth was far older than the known number of human generations,' explains Keynes. 'Most still believed that land forms had been created by sudden events but the evidence for the biblical flood was the subject of debate and Charles Lyell had begun arguing for a gradualist view of the Earth's history.' In his groundbreaking *Principles of Geology* in 1830, Lyell (1797–1875) argued that the different layers of rocks would have required aeons of time to form, what he called 'deep time.' Lyell was a proponent of uniformitarianism, a school of thought dating from the late 18th century which took the view that the slow-moving natural processes we observe have also dominated deep time. For uniformitarians, the rocks of the present were the key to the past.

Captain FitzRoy handed Darwin volume 1 of Lyell's *Principles of Geology* shortly before the *Beagle* sailed and Darwin later received volume 2 while in South America. In a letter to his friend Leonard Horner in 1844, Darwin noted that he had seen rock formations during the voyage 'through Lyell's eyes.'

* *At the time, it was not yet known that fossils of marine animals called ammonites lay buried in the rock 8000 m above sea level in the Himalayas, evidence of the ancient plate collisions which had formed the massive mountain range.*

** *It will not be possible to date rocks or fossils with radiometric dating until the first half of the 20th century, following the discovery of radioactivity in the 1890s.*

along the shores of the Firth of Forth and on at least one occasion Grant surprised Darwin (as he later recalled) by praising Lamarck's ideas. Grant was searching for evolutionary connections between the various animal groups and even between plants and animals. Darwin was not only privy to this work but participated in it directly in his fledgling observations using a light microscope.

But Darwin had neither the heart nor the stomach for medicine, so he enrolled at Cambridge with the (rather vague) notion of eventually joining the clergy. There, he pursued his love of the outdoors and developed an inordinate fondness for beetle collecting. He became attached to the Reverend John Stevens Henslow, whose course in botany Darwin took three times. Henslow was a staunch creationist, denying evolution and believing instead that all species had been separately created by God. But he knew that species of plants showed variation and trained Darwin to collect specimens and keep notes very carefully, the better to document this variation within species.

Darwin also went through a brief but critical training period, learning how to map geological strata on a field excursion with the Reverend Adam Sedgwick, one of England's most distinguished geologists, in the summer of 1831.

When he returned home, Darwin found the fateful letter inviting him to join the HMS *Beagle* on its forthcoming voyage around the world. He was to serve as the ship's unpaid naturalist and gentleman's companion to Captain Robert FitzRoy. Thus began what Darwin called 'by far the most important event in my life.' Although his scientific training had been rudimentary, it was to prove to be more than enough for this ambitious young man.

The voyage of the *Beagle*, 1831–1836

The *Beagle*'s trip was originally scheduled as a three-year circumnavigation of the world, with a primary emphasis on improving the navigational charts for both the Atlantic and Pacific sides of southern South America. By that time, England had established a presence in Australia, New Zealand and South Africa and had recently seized the Malvinas Islands off the Patagonian coast from Argentina, renaming them the Falkland Islands.

Darwin returned from that journey with a theory of how mountains are uplifted, how coral atolls are formed and with his initial ideas on the formation of new species – his first glimmers of evolution. Darwin was always interested in how things worked and much of his natural history observations and collections were accompanied by intense reflection on what his rocks, fossils, plants and animals might tell him about how the world is assembled and how it works.

In September 1832, the *Beagle* made the first of two visits to Bahia Blanca in the southeastern sector of Buenos Aires province. There, at two coastal locations, Punta Alta (since destroyed) and Monte Hermoso, Darwin collected an assortment of fossil bones and shells. He felt the marine shells belonged to the same molluscan and other invertebrate species still living in the waters of Bahia Blanca but that the mammals were extinct. More important was Darwin's belief that the fossil mammals were related[1] to the mammals still living in South America. The gigantic bony carapace of what came to be called glyptodonts seemed to Darwin to belong to an extinct species of armadillo. The bones of the giant ground sloths likewise belonged to the same group of Xenarthra[2] mammals that also include armadillos and anteaters, all of which are confined to the Americas and mostly South America.

The armoured skull and carapace of the South American armadillo Chorobates *(Dasypodidae family) from the Pliocene in Buenos Aires Province in Argentina. Dasypodidae is the only armadillo family in existence today, the other two families of Glyptodontidae and Pampatheriidae having died out. Glyptodon was one of the largest armadillos – about the size of a car! Glypodonts first evolved during the Miocene in South America before becoming extinct at the end of the last ice age, along with giant ground sloths and other megafauna.*

However, the giant extinct mammals seemed like only distant cousins of the living armadillos and sloth species. More exciting were the much smaller fossil bones from Monte Hermoso that Darwin took to belong to a species very closely related to the living Patagonian cavy, the third-largest species of rodent in the world after the South American capybara and North American beaver. Here, at Monte Hermoso, Darwin came across evidence that not all mammal genera become extinct at the same time: the glyptodonts and giant ground sloths belonged to different genera than the living species but not so the extinct fossil and living species of cavy, which Darwin thought must belong to the same genus.

With the Monte Hermoso fossil cavy, Darwin had direct evidence of the existence of an extinct species that had been replaced by a close relative still alive today. There can be no way of concluding with certainty that Darwin had by then become a 'transmutationist' but it is clear from his notes that he was actively contemplating the possibility as early as late 1832. Thus, I cannot help but think of Bahia Blanca as being as important to the development of Darwin's thinking as his much more famous visit to the Galapagos Islands three years later! For this reason, the geological strata of Monte Hermoso, with their richly productive fossil remains, deserves to be inscribed on UNESCO's List of World Heritage sites every bit as much as the Galapagos, which has already been given that important designation.

Darwin was seeing discrete species replacing one another in time. He was soon to extend this thinking to living species themselves. As he says in his *Origin of Species* published years later, he saw that species tend to replace one another as one travels south within the South American continent. His best examples were the two species of rhea, the ostrich-like birds of South America. At Bahia Blanca and elsewhere on the pampas, Darwin saw, collected and even ate specimens of the *nandu*, or greater rhea; to the south, in Patagonia proper, Darwin heard of another, slightly smaller and browner species, the 'choique,' for a time known as 'Darwin's rhea.'

Darwin knew the ranges of these species overlapped at the Rio Negro, the informal dividing line between the pampas to the north and Patagonia to the south. But he became convinced as the trip wore on that the two species did not blend into one another, as Lamarck might have supposed. Rather, they remained as distinctly, recognizably different when adjacent to one another as they were in remote parts of their ranges.

Darwin made similar observations of geographic replacement in other groups of birds. When the *Beagle* visited the Falkland Islands (especially the second time, in early 1834), Darwin extended these observations, seeing for the first time that species on islands off the South American coast were distinct, albeit retaining a distinctive South American character. Specifically, Darwin thought the Falkland Island Fox to be distinct from any mainland species. Even better, the foxes appeared to be slightly different from each other on the East and West Falkland islands: an example of replacement of one variant by another of the same species.

Photo: Wikipedia Commons

One of the fossils Darwin came across in Punta Alta was that of a Megatherium. *Unlike its living relatives, the tree sloths,* Megatherium *was a giant. When it stood on its hind legs, as here, it was about twice the height of an elephant. This sloth lived during the Pleistocene epoch.*

The first binomial scientific classification system

Swedish botanist and zoologist Carl Linnaeus (1707–1778) was not the first to attempt a scientific classification of living things but he made a major contribution to taxonomy by establishing a binomial nomenclature and hierarchy for nature. At the highest level, he placed two kingdoms: Animalia for animals and Vegetabilia for plants. A third kingdom, Mineralia, was reserved for minerals.

The animal kingdom (Animalia) was divided into Phyla (singular: phylum). The Phyla were in turn divided into Classes, the Classes into Orders, the Orders into Genera (singular: genus) and the Genera into Species (singular: species). For example, *Homo sapiens* is part of the animal kingdom, in the phylum of Chordata,* the class of Mammalia and the order of Primates. *Homo* refers to the genus and *Homo sapiens* to the species.

More than 200 years later, the scientific classification system is still being refined.

* *Chordata encompass the vertebrates and several invertebrates. They have in common, at some point in their life cycle: a notochord (later to become the spine in vertebrates), dorsal neural tube (later to become the spinal cord in vertebrates), pharyngeal slits (later to become part of the throat or, in fish, gills), a tail that extends beyond the anus and an endostyle (in the pharynx). [Wikipedia definition]*

©Stefan Laube/Wikipedia

*Brown-throated tree sloth (*Bradypus variegatus*) in Panama.*

In February 1835, the *Beagle* was anchored downstream from the Chilean city of Valdivia. On 20 February, Darwin was ashore when he experienced a violent earthquake that terrified him. Possibly as a result of that frightful event, Darwin wrote a brief essay, entitled simply *February 1835*. The essay is now housed in the Earthquake Portfolio at Cambridge University Library in the UK, along with Darwin's extensive field notes from the *Beagle* voyage. In this essay, Darwin recalls the cavy from Monte Hermoso and discusses patterns of extinction and, for the first time, 'births' of species that replace one another. Here, Darwin comes very close to embracing transmutation, although he does not explicitly say so. Captain FitzRoy had the right to examine everybody's notes and had already done so once with Darwin's. Darwin's reluctance to reveal his growing convictions on transmutation, a habit that persisted well into the 1840s and which was not truly broken until he published his *Origin of Species* in 1859, had clearly begun while he was first forming his evolutionary thoughts on the *Beagle*.

I have come to see the Galapagos, which the *Beagle* reached in August 1835, not so much as the beginning of Darwin's evolutionary thinking, as the *coup de grace* to any lingering doubts about evolution that Darwin may have still held. Although he is famous for not seeing the importance of the confusing *mélange* of little black and brownish birds that have since become famously known as 'Darwin's finches,' he did indeed find what he had come to expect: that the animals were basically South American in their affinities and that some of them appeared to vary from island to island (he was not so sure of the plants initially). This pattern, already familiar from the Falklands, jumped out at him as soon as he observed the mockingbirds on several of the islands in the Galapagos chain.

Sketch of a Falkland Island Fox, Dusicyon culpaeus*, shortly before it was hunted to extinction. Darwin gave him the name of* Canis antarcticus

The Governor of the Galapagos, a Spanish penal colony at the time, then told him that anyone familiar with the Galapagos could tell 'at once', as Darwin later recalled, which island the shell of a dead tortoise must have come from. As the journey was nearing its end and Darwin was organizing and rewriting his notes, he came to the Galapagos mockingbirds. As he wrote about how the mockingbirds seemed to be different from island to island – he thought there were a total of three or four 'varieties,' or perhaps distinct species – he recalled the Falkland foxes and Galapagos tortoises he had seen. It was then that he penned his famous remark, 'If there is the slightest foundation for these remarks, the zoology of Archipelagoes will be well worth examining; for such facts [would] undermine the stability of Species.' Nearly all scholars now agree that, by mid-1835, while still aboard the *Beagle*, Darwin had, albeit cautiously, declared himself a transmutationist.

Darwin's theory evolves: 1837–1859

Sketch of a rhea which, for a time, was known as Darwin's rhea.

The *Beagle* finally returned to England in late 1836. It was not until early the next year, however, that Darwin was free to pick up his notes and jot some of his final thoughts on the *Beagle*'s journey in his so-called *Red Notebook*, opened while still at sea. Here, he is – at long last! – an avowed transmutationist, essentially rewriting the gist of his February 1835 essay in explicitly evolutionary terms. For example, Darwin writes that there is no 'progressive change' within either species, as the geographic ranges of the two rhea species converge. The replacement is abrupt and Darwin says "…if one species does change into another, it must be *per saltum*." Not only does Darwin openly speculate about one species changing into another but he also specifies that it must be an abrupt 'jump' from the ancestral species to the descendant.

Then things change. In the *Red Notebook*, Darwin is a 'saltationist' (from the Latin word *saltus* for leap), believing that new species arise in sudden bursts from ancestral species. But when he opens the first of his 'transmutational notebooks' in late 1837, references to the *Beagle* are few and far between. Darwin is now off on a different evolutionary track, probing the principles of inheritance and patterns of variation. So we ask: why did he change direction?

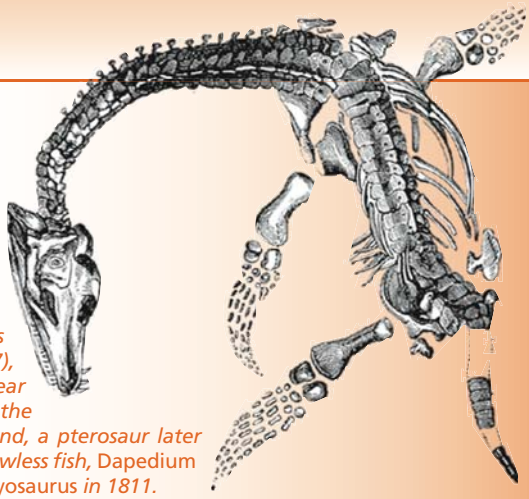
*Patagonian cavy (*Dolichotis patagonum*) like that observed by Darwin in Monte Hermoso.*

It is often said that Darwin did not become 'converted' to evolution until after he arrived home and heard the opinions of experts on the identities of all his specimens. Although we have seen that that is not literally the case, I do think that finding out from the ornithologist John Gould that the confusing array

A walk through time

©Peter Coles/UNESCO

On the English Riviera, the raised beaches visible in cliffs are tell-tale signs of past sea level change.



Sketch of a Plesiosaurus macrocephalus, *a marine reptile from the Early Jurassic (circa 190 Ma). This 3 m-long fosssil was found on a beach at Lyme Regis in 1823 by Mary Anning (1799–1847), one of the first fossil-hunters. A year later, she would come across a fossil of the first flying reptile ever found in England, a pterosaur later named* Dimorphodon, *and, in 1828, a jawless fish,* Dapedium politum. *Her first big find was an* Ichthyosaurus *in 1811.*

In Darwin's day, geology and palaeontology were still in their infancy. Darwin would have been aware, however, of the growing number of fossils being discovered on England's southern coast at sites that today belong to UNESCO networks.

The Jurassic Coast

Commonly known as the Jurassic Coast, the Dorset and East Devon Coast World Heritage site stretches over 150 km along the coast and encompasses one of the most spectacular geological sequences in the world, spanning the Triassic, Jurassic and Cretaceous periods. These geological sequences bear testimony to the area's shifting climate over time. The rocks reveal evidence of deep oceans, shallow warm seas, dense forests, swamps, lagoons, salt lakes and even hot deserts: in East Devon, where the Triassic rocks are 250 million years old (Ma), the red cliffs used to be part of a desert landscape similar to that of Namibia today.

William Buckland was the first to recognize fossil excrement in the Lias around Lyme Regis, which he termed coprolites. Buckland thought that the large valleys of the Axe and Char were evidence of the biblical flood, as he argued that the rivers were too small to have cut the valleys. Today, we interpret the Ice Age as being the time when the rivers were large enough to cause that erosion. In 1822, Buckland published *On the Excavation of the Valleys that intersect the South Coast of Devon and Dorset*.

In about 1830, Sir Henry De la Beche produced the first-ever illustration of a past environment, *Duria antiquior*, depicting an ancient Dorset based on the fossils found by Mary Anning in Lyme Regis. De la Beche and the Reverend William Conybeare were the first to describe the ichthyosaurs, giant fish-like reptiles which thrived in the Mesozoic Era.

Reverend Osmond Fisher studied the small quarries in the Bincombe area of Dorset. His studies led to the first textbook on theoretical geophysics, *The Physics of the Earth's Crust*, in 1881. It anticipated ideas that 70 years later would become the modern theory of plate tectonics.

Today, the best places to find fossils are the beaches around the towns of Charmouth and Lyme Regis. Dinosaur footprints uncovered by quarrying and fossilized specimens can also be admired in local museums. Some of the fossils on the beaches and cliffs along the Jurassic Coast give clues as to the region's past climate.

The English Riviera Geopark

About 375 Ma, the English Riviera Geopark lay under the sea, south of the equator. Warm seas teamed with creatures now extinct and massive corals grew. Over millions of years, shells and bones from marine organisms accumulated in layers to form hard limestone rock. These layers were folded and broken as tectonic movements thrust the Earth's crust northwards. By 280 Ma, the geopark lay just north of the equator and was part of a vast desert. This is when the area's distinctive red sandstones were formed. A series of ice ages and warmer, interglacial periods, starting about 2.5 Ma, hollowed out the caves in the geopark, providing shelter for animals and early humans.

One of these caves, Kents Cavern, is open to the public. It 'has an uninterrupted sequence of human occupation going back half a million years,' says the cavern's owner, Nick Powe. Between 1865 and 1880, William Pengelly led excavations here by candlelight. Pengelly dug away two stalagmite floors of the cave, formed after each ice age, turning up evidence of human occupation 500 000 years ago, alongside bones from cave bears, cave lions, mammoths, woolly rhinoceroses and hyaenas.

Charles Darwin dwelled on the final chapters of *On the Origin of Species* while staying nearby at Meadfoot Beach in Torquay. Darwin was in regular correspondence with Pengelly, whose discoveries shook the orthodox scientific community in London at the time.

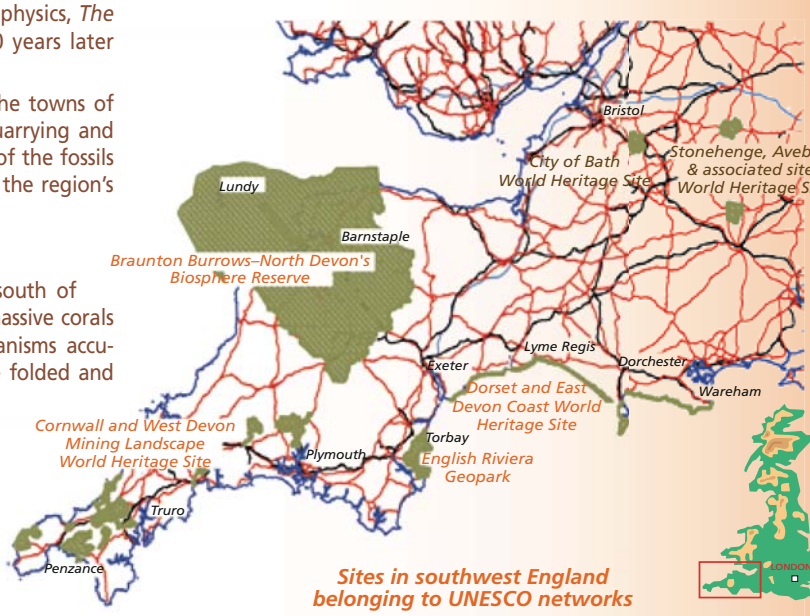
©Courtesy of Nick Powe

The original jawbone found in Kents Cavern, which may turn out to be that of a Neanderthal.

A fragment of human jawbone found in the cave, recently estimated to be 35–40 000 years old, is one of the oldest records of modern humans (*Homo sapiens*) in Europe. DNA from the fragment is being studied by the UK's Ancient Human Occupation of Britain Project led by Prof. Chris Stringer at the Natural History Museum in London. For the moment, the results are inconclusive but the jawbone may yet turn out to be from a Neanderthal skull, thereby proving that Neanderthals and modern humans once coexisted here. Meanwhile, archaeological research continues, with the first dig inside Kents Cavern in 80 years having got under way in September. The team from Sheffield and Durham Universities is searching for new, undisturbed evidence of the Neanderthal occupation of the cavern.

Source: personal communication from Nick Powe, Mel Border and Richard Edmonds; Coles, P. (2008) Neanderthal man at the seaside. UNESCO Courrier*; www.kents-cavern.co.uk ; www.jurassiccoast.com/.*

For details of the Braunton Burrows–North Devon's Biosphere Reserve, see page 20.



Sites in southwest England belonging to UNESCO networks

Map produced by the Devon County Council with the assistance of the UK National Commission for UNESCO, based on information under licence from the Ordnance Survey (LA 100019783)

of small birds from the Galapagos islands actually formed a closely related group of finches was in all likelihood a watershed moment for Darwin. For now, instead of needing a theory to explain the replacement of one species by another in space and time, he needed an explanation for the variation between closely related species, differences exemplified by the different shapes and sizes of the beaks of these Galapagos finches.

In other words, Darwin needed a theory of adaptation. It took him roughly a year to come up with his idea of natural selection.

Darwin already knew that there was some process of inheritance that made offspring look like their parents. As he was to put it in *Notebook E.*, 'grandchildren like grandfathers.' He knew not why, only that it was so.

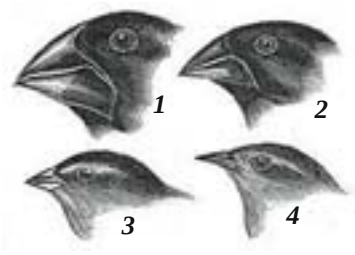
Likewise, Darwin knew there was variation, a 'tendency to small change', as he put it in *Notebook E*. He also knew those variations to be heritable. The final link in the logical chain came when he read the article by English pastor Thomas Malthus (1766–1834), *An Essay on the Principle of Population*. He realized for the first time that the process of sexual reproduction quickly led to exponential growth of populations, unless some factors intervened to regulate the size of populations. Think of it this way: let's say one set of parents produce two offspring; if these two offspring each produce two, that means there are four offspring in the next generation. And so forth. Darwin said that the world would be 'standing room only' in elephants, even with their slow reproductive rates, if you started with a just a single pair of elephants and watched the reproductive process unfold over a few thousands years. Yet the world is not standing-room-only in elephants – or anything else for that matter (with the alarming exception of human beings). Something must hold population growth in check. From Malthus, Darwin learned that food supplies are a cardinal limiting factor to population growth, even if a host of other factors, like disease and predation, are at work as well.

Thus, Darwin came to see that, as a rule, those individuals with the 'most favourable' variations would survive and tend to reproduce, more so than others in the population with less advantageous characteristics. So here, Darwin had defined a process analogous to the 'artificial selection' of breeders, who consciously allow the individuals in the fields (plants) and barns (livestock) with the best developed characteristics, like milk yield in cattle, to produce offspring that will perhaps yield even more milk. *Voilà*: natural selection!

Darwin wrote his thoughts up in a little essay entitled the *Pencil Sketch* in 1842. He then expanded his thoughts in a much longer *Essay* in 1844. Both manuscripts have the same organization of ideas and contain similar language to that which finally appeared in his *Origin of Species* in 1859.

But instead of publishing, Darwin turned to other projects, still reluctant to announce his ideas to the world, even though he had begun telling friends and relatives by 1844. It was only after his beloved daughter Annie died at the age of 10 in 1851 that he was finally prompted, a year or so thereafter, to begin compiling his notes for his 'big species book' to be entitled *Natural Selection*.

Darwin did have a revelation of sorts in the mid-1850s, when he began to see how natural selection could lead to the modification of species in different geographic regions. With isolation, discrete 'varieties' and perhaps also discrete species would eventually emerge, a view of the process of 'speciation' very similar to the modern concept.



Sketch of 'Darwin's finches' from the Galapagos islands, Geospiza magnirostris *(1),* Geospiza fortis *(2),* Geospiza parvula *(3) and* Certhidea olivacea *(4)*

He wrote these thoughts up under the term 'principle of divergence' in the manuscript for his big species book but, alas, these thoughts never made it completely to publication in Darwin's lifetime. Instead, prompted by the receipt, in the summer of 1858, of a letter and manuscript from the naturalist Alfred Russell Wallace (1823–1913) announcing his own, independent discovery of evolution through a process that Darwin was calling 'natural selection,' Darwin was forced to drop everything and dash off an 'abstract' of his views. That 'abstract' was itself a hefty tome and the book that shook the world: *On the Origin of Species by Means of Natural Selection*, published just a little over one year after Wallace's manuscript had arrived.

None of the nuances of Darwin's 'principle of divergence' ever made it into the *Origin of Species*. These ideas effectively reconciled his early focus on the replacement of discrete species in time and space with his later concentration on the adaptive modification of the characteristics of organisms through natural selection. Instead, the world inherited a view of evolution centred on the gradual modification of the features of organisms through natural selection, a process that, somewhat ironically, calls to mind the Lamarckian 'smear' of variation for which Darwin had initially found no evidence.

Evolution since Darwin

Since Darwin, there have been three themes in evolutionary biology:

- the restoration of some of the issues that had ended up on the floor of the cutting room of Darwin's editorial mind, such as isolation and the emergence of discrete species in space and time;
- the clarification of what were 'black boxes' to Darwin, such as the science of heredity, genetics and its further development into molecular biology, as well as the attendant insights into how genetic information is expressed during the development of organisms – in the case of vertebrate animals, from a fertilized single egg cell to an adult body of billions of cells of hundreds of different types; and
- the enormous amount of new examples, knowledge of the history of life that confirm, over and over again, the fundamental truth of Darwin's evolutionary insights.

I will consider each of these three briefly, in reverse order. Lest there be any rational lingering doubt over the basic truth of the simple proposition that life has evolved, for Darwin himself had heaped example upon example, it is staggering to compare what we know now about the history of life on Earth, from the fossil record and the diversity of life still present on Earth, with what was known in Darwin's day. The 'tree of life,' where biologists use molecular (DNA and RNA) data to supplement older-style analyses of the relationships of organisms has revealed the complex network of relationships between all of the millions of species now living on Earth. Instead of the crude, simple trees Darwin was sketching in notebooks, computers are constantly refining the depiction of the details of the tree of life.

Photo of fossil from Berlin Museum of Natural History

Fossil of an Archaeopteryx *(circa 150 Ma) showing the imprint of wings.* Archaeopteryx *is thought to be the missing link between dinosaurs and birds.*

So, too, palaeontologists have compiled a breathtaking array of examples of transitional fossils. To give just three examples, there is the 360 million-year-old 'fish-with-legs' *Tiktaalik*, providing a connection between fish and amphibians; there are primitive whales which clearly bear the stamp of their artiodactyl ('cloven-hoofed') terrestrial mammalian ancestry; and the famous *Archaeopteryx* so clearly linking reptiles and birds.

But my favourite example of the definitive proof of evolution comes from the very source of all the resistance that remains to accepting Darwin's evolutionary answers to the questions: Who am I? and Where do I come from? The fossil record of human evolution is stunningly dense and becoming more so with each passing field season in Africa, Europe and Asia. The record shows our 'descent' from very ape-like australopithecines in Africa living between 6 and 1.5 million years ago. Our own lineage branched off from some of these precursors, marked from the beginning by an increase in brain size.

Several phases of the evolution of new species, each with larger brains, culminated in the appearance of our own species in Africa, somewhere between 150 000 and 200 000 years ago. Newcomers on the evolutionary scene, we nonetheless proudly come from a very long line of ancestors, none of whom Darwin had any direct knowledge of, though of course, in principle, he knew they must be there. Darwin predicted correctly that it would someday be shown that our own species evolved in Africa. We did and the molecular evidence agrees with the fossils on that point.

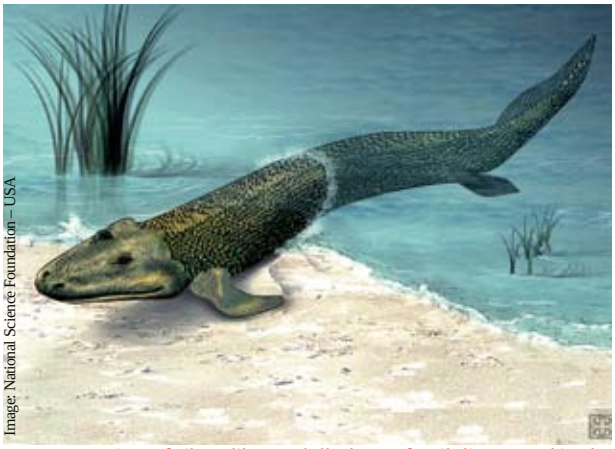


Image: National Science Foundation – USA

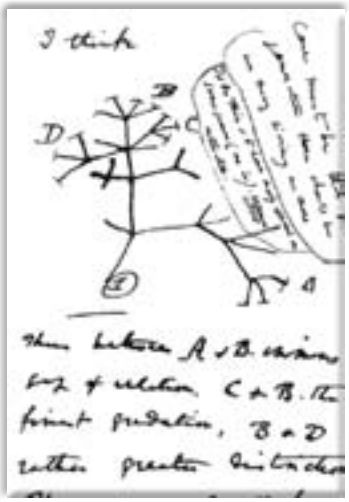
Reconstruction of Tiktaalik, *modelled on a fossil discovered in the Canadian Arctic in 2006.* Tiktaalik *illustrates the transition from fish to amphibian. Technically, it is a fish but with the flattened head of a crocodile. It could also prop itself up on its sturdy fins.*

Rediscovery of the experimental work done by Austrian monk and botanist Gregor Mendel (1822–1884) led to an explosion of knowledge of genetics from the turn of the 20th century. In his thirst for knowledge, Mendel had grown as many as 29 000 varieties of pea in the monastery garden to learn how hybrids formed. This led to what is known as Mendel's Laws of Inheritance, earning him the unofficial title of 'father of modern genetics.'

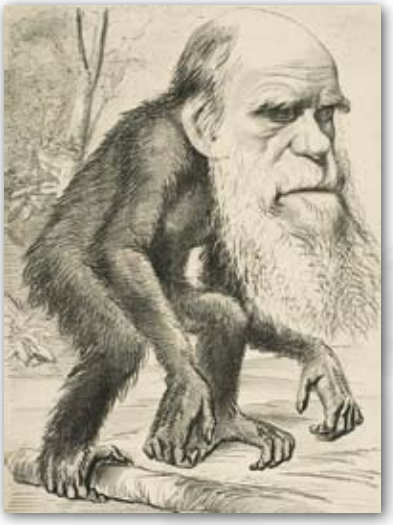
Genes were discovered and, eventually, the chemical structure of RNA and DNA ushered in the new world of molecular biology. The data from these fields, as already remarked, completely confirm the evolutionary pedigree of all living species. But now we know so much more: why organisms resemble their parents; how and why mutations occur; and how that genetic information can be translated into an adult organism from a fertilized egg. We understand, too, much more about how natural selection works, how organisms can co-evolve to their mutual benefit, such as when plants and insects evolve structures that enable fertilization of the plant and feeding behaviour of the insects. We understand how adaptations can be modified into other structures that may assume additional roles and functions: how, for example, the fins of a fish, used by some ancient species to clamber around a lake bottom then perhaps to waddle around on shore, can become modified in the evolutionary–developmental process into true legs. These legs may then, in some descendant species, be further modified into wings for flight. All of these amazing insights come from the new world of molecular biology; they reveal the secrets of how life evolved to a level that Darwin himself would find absolutely amazing. The essence of his theory holds but our grasp of exactly how the process works is infinitely more complex than the newly emerging science of biology could demonstrate back in Darwin's day.

Lastly, there is my own bailiwick as a palaeontologist, one who has spent his entire career trying to forge closer ties between patterns in the fossil record of life's history with our ideas on how life evolves. Presented with the modern version of Darwin's theory of slow, steady gradual evolution under the guidance of

natural selection, I searched the rocks in vain to find an example of progressive, gradual adaptive change. Instead, species tended to look to me as though they remained pretty much the same after they first appeared, sometimes undergoing virtually no change for millions of years. New species which sometimes differ only slightly from their ancestors appear from time to time, usually fairly abruptly, implying rapid evolutionary change. These observations, coupled with modern theories of species formation through geographic isolation, were the basis of my early ideas on 'punctuated equilibria', which I published under that name with Stephen Jay Gould in 1972.



The crude 'tree of life' Darwin sketched in one of his notebooks in 1837.



Caricature of Charles Darwin as an ape, published in a magazine in 1871. The Origin of Species *sparked a sometimes heated international debate, particularly as concerned the ape ancestry of humans. Charles Lyell himself was troubled by this. Darwin teased him in a letter dated 10 January 1860 that 'Our ancestor was an animal which breathed water, had a swim bladder, a great swimming tail, an imperfect skull and undoubtedly was a hermaphrodite! Here is a pleasant genealogy for mankind'[3].*

Until recently, I had no idea that Darwin initially saw evolution as the origin of discrete species replacing one another over time and geographically. I had been taking exception to his later mature ideas – when he ignored the stability of species after acknowledging it in his notebooks and began to downplay the importance of isolation in evolution. Modern ideas of the role and importance of geographic isolation in evolution – ideas essential to the development of punctuated equilibria – were not reformulated until the 1930s, mostly through the work of Ukrainian geneticist Theodosius Dobzhansky and German ornithologist Ernst Mayr.

In other words, many of the patterns in the history of life that Darwin saw as a young man, but which he factored out as he developed his theory of evolution as almost wholly a matter of adaptation through natural selection, have, by fits and starts, been re-appreciated and, by degrees, incorporated back into a richer picture of the nature of the evolutionary process.

Much remains to be done in all three categories and there are no doubt more important discoveries to come. Most exciting to me is the fairly recent realization that most evolution seems to occur after spasms of extinction drive away many pre-existing species, triggering the evolution of new species at about the same time. Darwin, once again, knew about extinction patterns and appended a note to the manuscript of his 1844 *Essay*. There, Darwin writes, 'Better begin with this: if species really, after catastrophes, created in showers over world, my theory false.' Yet it is clear that the pattern of extinction followed by species 'created in showers over world' *is* true, just as it is clear that Darwin's general evolutionary ideas are also true. For example, the great extinction at the end of the Cretaceous Period some 65 million years ago finally wiped out the terrestrial dinosaurs and many other land-living groups, as well as marine animals like the ammonites.[4] Mammals had been around as long as the dinosaurs but it was only after the final extinction of the large dinosaurs that mammals evolved into a great array of sizes and ecologically diverse species, in effect emulating the roles that dinosaurs had once played. These new adaptations of mammals assuredly evolved through the same mechanisms of variation and natural selection that Darwin had first proposed.

Prior to the rediscovery of the importance of extinction in the history of life, the last prominent biologist to consider the problem was the great French anatomist and palaeontologist Georges Cuvier, an anti-Lamarckian creationist. My goal over the past few years has been to see how the evolutionary process, including adaptive change through natural selection and the importance of environmental change and isolation in the emergence of new species, can be reconciled with these spasms of extinction and evolutionary proliferation. My theory of the 'Sloshing Bucket' sees that, the greater the environmental disturbance, the greater the degree of extinction (including global extinction events) and thus the greater amount of expected evolution. Just how this process operates in detail is in itself work in process. Evolutionary thinking is still evolving. Darwin lives!

Niles Eldredge[5]

The Boxes and illustrations in this article have been compiled by the Editor.

1. *They used the term 'closely allied' back in those pre-evolutionary days.*
2. *Xenarthra means 'strange joints'. This group of placental mammals is unique in that it has extra articulations on its vertebral joints. Xenarthra encompass anteaters, armadillos and sloths, today extant only in the Americas.*
3. *See: www.darwinproject.ac.uk/darwinletters/calendar/entry-2647.html*
4. *For a brief history of evolution, see* A World of Science *of October 2007 and January 2008*
5. *Division of Palaeontology, American Museum of Natural History, New York city, USA*

Albania approves science strategy

On 29 June, the Council of Ministers approved the *National Strategy for Science, Technology and Innovation in Albania* covering the period 2009–2015.

The document was coordinated by the Department of Strategy and Donor Coordination of the Prime Minister's Cabinet, in co-operation with the Ministry of Education and Science and with UNESCO assistance. It fixes five strategic goals to 2015:

- to triple public spending on research and development (R&D) to 0.6% of GDP;
- to augment the share of gross domestic expenditure on R&D from foreign sources, including via the European Union's Framework Programmes for Research, to the point where it covers 40% of research spending;
- to create four or five Albanian centres of excellence in science which will be equipped with dedicated laboratory equipment and workspaces that could be used for pre-incubation, testing, certification and so on of new technology-based firms;
- to double the number of researchers, both through 'brain gain' incentives like a returning researchers grant scheme and through the training of new researchers, including 500 PhDs: this will entail establishing up to three new doctoral programmes in Albanian universities;
- to stimulate innovation in 100 companies, either via investment in local R&D or via consortia with academic research institutes or foreign partners.

An Action Plan detailing the operational aspects complements the *Strategy*. The *Strategy* is to be implemented in synergy with other sectoral strategies and taking into account *Albania's Higher Education Strategy* adopted in 2008 and the *National Strategy for Development and Integration* (2007–2013). The latter underlines the importance of modernizing economic sectors such as the agro-food industry and tourism. It also underscores the strategic importance of energy, environmental and water resource management. Stakeholders have proposed prioritizing fields of research such as agriculture and food, information and communication technologies (ICTs), public health, Albanology and humanities, natural resources, biotechnology, biodiversity, defence and security. A more detailed sectoral analysis is to be conducted using a bottom-up approach, in order to set research priorities.

One of eight pilot countries for the One UN Programme, Albania is a small country, both physically and in terms of population (3.6 million). Even after two decades of growth, annual GNP per capita remains modest, at about US$3,912 (2008). Economic competitiveness and exports are low, with the economy still heavily skewed towards low technology. Agriculture absorbs more than 50% of the labour force.

The European Union (EU) has set clear objectives for research and innovation as part of its Lisbon Strategy for becoming the most competitive economy in the world. Like other Western Balkan countries aspiring to join the EU, Albania is trailing behind in the development process, having focused in recent years on laying the foundations for economic growth.

Deputy Prime Minister Genc Pollo acknowledges that 'the high rates of socio-economic development required in the process of Albania's membership of the North Atlantic Treaty Organization (NATO)[6] and EU accession necessitate strengthening the role of science, technology and innovation in our society.' In August, the government approved the establishment of the Albanian Agency of Research, Technology and Innovation, to improve policy implementation.

In 2006, the Albanian government undertook a deep reform of the scientific research system. The Academy of Sciences was re-organized along the model of many other European countries; it now operates through a selected community of scientists and no longer administrates research institutes, these having been integrated into the higher education system. Two new faculties have been set up: the Faculty of Information Technology at the Polytechnic University of Tirana and the Faculty of Biotechnology and Food at the Agricultural University of Tirana. The University of Tirana has also gained an Applied and Nuclear Physics Centre and Biotechnology Department. Twelve government agencies and centres for technology transfer have also been created.

Until recently, R&D and innovation statistics were not collected in Albania to OECD, Eurostat or UNESCO standards. A first survey of public and academic institutes was launched earlier this year and a business R&D and innovation survey is currently under way, both with the support of UNESCO.

Read the Strategy*: www.dsdc.gov.al/; for details: i.nechifor@unesco.org www.unesco.org/science/psd/thm_innov/albania_science.shtml;*

UN adopts climate services

When you turn on your radio or television set, you may be able to tune in to a climate forecast in the not too distant future. It could tell you that heavy rains are expected in three months' time or to prepare for a heatwave next summer. Climate forecasts are one of a range of climate services approved in Geneva (Switzerland) on 4 September at the UN World Climate Conference.

The Global Framework for Generating Climate Services will provide early warnings of extreme weather and promote data exchange between scientists and governments. Forewarned and thus forearmed, farmers, water managers, city and coastal planners, national legislators, municipalities and so on will thus have time to plan ahead. If a prolonged drought is predicted, for example, a farmer will know not to plant water-thirsty crops.

Whereas weather forecasts tend to be reliable for up to seven days, climate forecasts will ultimately be looking months or

6. *Albania became a member of NATO earlier this year.*

even decades ahead. It is hoped that, within a couple of years, there will be a framework in place for delivering these climate services in a coordinated way, to make sure a broad range of stakeholders in developed and developing countries have rapid access to this information.

UNESCO organized two fora in Geneva, one on gender and climate and the other on capacity-building, education and training. 'Capacity-building through education and science' was retained as a key element of the Global Framework for Generating Climate Services.

UNESCO's Intergovernmental Oceanographic Commission (IOC) helped to prepare the session on meeting the information needs of coastal populations. The experts pointed out that ocean observations were the backbone of any climate service and that the provision of climate services would thus be dependent on having a comprehensive, perennial Global Ocean Observing System (GOOS). Coordinated by the UNESCO-IOC, GOOS feeds information and data to the Global Climate Observing System.

The side event on groundwater and climate organized by UNESCO's Division of Water Sciences underscored that groundwater would play a major role in society's ability to adapt to future change, particularly in light of an increasing number of extreme weather events, such as floods and droughts. Despite this, groundwater is not well represented in global climate models at present. This is partly due to the difficulty in assessing groundwater resources and the scarcity of data, and partly due to a lack of recognition that groundwater is part of the hydrological cycle and thus part of the global climate system.

Whereas the Geneva conference focused on climate services as a way of helping countries to adapt to climate change, the UN-sponsored climate talks in Copenhagen in December will be thrashing out a deal between developing and industrialized countries to reduce global carbon emissions.

The first World Climate Conference in 1979 launched the Intergovernmental Panel on Climate Change and the World Climate Research Programme. The second in 1993 led to the adoption of the UN Framework Convention on Climate Change and the Global Climate Observing System.

For details: www.wmo.int/wcc3/page_en.php

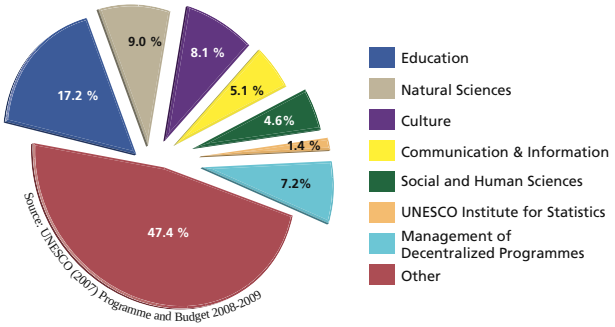
OECD reassesses **UNESCO's development aid**

On 18 June, UNESCO Director-General Koïchiro Matsuura welcomed the decision by the Organisation of Economic Co-operation for Development (OECD) to revise its assessment of UNESCO's contribution to overseas development assistance (ODA) from 25% to 44% of its activities. The decision takes effect as from the current year reporting on ODA flows in 2008.

Mr Matsuura had hoped that the Working Party on Statistics of the OECD's Development Assistance Council would accept his proposal to raise the coefficient to 'at least 75%.' He also regretted that the Working Party had excluded the entire range of UNESCO's normative work, as well as its activities in the field of culture and social sciences. The Working Party considered that UNESCO's ODA was provided by its activities in education, natural sciences and communication and information. UNESCO's programme activities represent just over half its regular budget (*see graphic*).

UNESCO's revised status is also an acknowledgment of the importance of long-term development assistance, as opposed to emergency assistance where UNESCO, with its modest biennial budget of US$631 million, cannot compete.

UNESCO was one of several international agencies under review at the Working Party's meeting in May. It has agreed to reconsider UNESCO's ODA coefficient at its next meeting in June 2010, as an exception to the rule under which coefficients remain valid for a minimum of five years. Any recalculation is important, as it may have an impact on allocations decided by Member States in the area of development.



Distribution of UNESCO's regular budget, 2008–2009

Strong growth in student mobility

In 2007, over 2.8 million students were enrolled in institutions of higher learning outside their country of origin, a 53% increase over 1999. So says the latest edition of UNESCO's *Global Education Digest*, launched in Paris on 6 July at the World Conference on Higher Education.

Data on student mobility compiled by the UNESCO Institute for Statistics show that sub-Saharan Africa has the highest outbound mobility rate: 5.8% in 2007, compared to the world average of 1.8%. In real terms, however, it is China which accounts for the greatest number of students living abroad (about 421,100). China is one of 10 countries which account for 38% of the world's mobile students. The other nine countries of origin are India, the Republic of Korea, Germany, Japan, France, USA, Malaysia, Canada and the Russian Federation.

Mobile students are expanding their range of destinations. In 1999, one in four students chose to study in the USA, a proportion down to one in five students in 2007. Australia, Canada, France, Italy, Japan and South Africa not only remain popular destinations but have seen their shares of mobile students grow.

Countries that have emerged among the top host countries include China, the Republic of Korea and New Zealand.

Another trend revealed by the report is that students are increasingly staying within their region of origin. In Latin America and the Caribbean, for instance, the percentage of mobile students remaining within the region has risen from 11% in 1999 to 23% in 2007. In East Asia and the Pacific, 42% of mobile students remained within the region in 2007, compared to 36% in 1999. Western Europe (77%) and North America (39%) show little change in comparison to 1999.

For policy-making, knowing what types of programme are in demand globally is important. In 2007, 23% of mobile students were enrolled in Business and Administration programmes. Science is the second most-popular field, attracting 15% of mobile student enrolment, followed by Engineering, Manufacturing and Construction (14%) and Humanities and Arts (14%). Broad trends in preferences by region may suggest a link to the needs of the labour market in students' countries of origin. Students from Latin America and the Caribbean, for example, show a preference for Business and Administration.

The number of mobile women students has grown even faster than that of men. However, as most countries do not report data on mobile students by sex, these estimates are based on a small group of host countries. Reported data on tertiary education generally show an improvement in the position of women globally but there are still clear divisions by field of study. Women are under-represented, for example, in Science and Engineering.

The report includes an overview of the financing of higher education.

For details: www.uis.unesco.org/publications/GED2009

Invest more in higher education, conference urges

The UNESCO World Conference on Higher Education wound up in Paris on 8 July with a call to governments to increase investment in higher education, encourage diversity and strengthen regional cooperation.

The communiqué stresses that 'higher education must pursue the goals of equity, relevance and quality simultaneously,' underlining the importance of regulatory and quality assurance mechanisms and the need to enhance 'the attractiveness of the academic career.' It notes that ICTs should be more fully integrated throughout higher education to meet increasing student demand and ensure the results of scientific research are shared.

The communiqué emphasizes the need for stronger regional cooperation in areas ranging from the recognition of qualifications to quality assurance, governance, research and innovation. It highlights the importance of establishing regional areas of higher education and research.

Reflecting the conference's special focus on the revitalization of higher education in Africa, the communiqué calls for differentiated approaches to meet rapidly increasing demand; more attention to areas of expertise such as agriculture, the environment and natural resource extraction; and the mobilization of private financing. Brazil, China and the Republic of Korea were among those countries which expressed their commitment to strengthening higher education in Africa, a sentiment echoed by private partners present.

Drawing attention to the global teacher shortage, the communiqué calls for higher education 'to scale up pre-service and in-service teacher training with curricula that equip teachers to provide individuals with the knowledge and skills they need in the 21st century.'

The conference drew 1000 participants from around 150 countries. Ministers, university rectors, faculty, students and key representatives of the private sector, as well as regional and multilateral institutions, debated issues that included the impact of globalization on higher education, social responsibility, academic freedom, research and financing.

Read the communiqué: www.unesco.org/en/wche2009/

UNESCO assesses damage to Babylon

UNESCO's *Final Report on Damage Assessment in Babylon* was presented to the press in Paris on 9 July. Produced by the Sub-Committee on Babylon of UNESCO's International Coordination Committee for Safeguarding of the Cultural Heritage of Iraq, it provides an exhaustive technical evaluation of present conditions at the renowned archaeological site and a list of recommendations.

The archaeological site of Babylon was used as a base by coalition forces from 2003 to 2004, an encroachment a 2005 British Museum report called 'tantamount to establishing a military camp around the Great Pyramid in Egypt or around Stonehenge in Britain.' Substantial damage was caused to the archaeological city, the report notes, by 'digging, cutting, scraping and leveling.' Key structures harmed 'include the Ishtar Gate and the Processional Way.'

Babylon is the capital city of two famous kings of antiquity: Hammurabi (1792–1750 BC), who introduced one of the world's first law codes; and Nebuchadnezzar (604–562 BC), who built the Hanging Gardens of Babylon, one of the Seven Wonders of the World. The city is located 90 km south of Baghdad. Much of ancient Babylon remains to be discovered.

As the *Final Report* recapitulates, the Iraqi government's ambitious 1978–1987 Archaeological Restoration of Babylon Project rebuilt ancient buildings, introduced modern facilities and undertook major landscaping, in part for a new palace for Saddam Husssein, 'to the great detriment of the site.' Subsequently, the archaeological city was plundered during the war in 2003. Contents of the Nebuchadnezzar

and Hammurabi museums and of the Babylon Library and Archive were stolen and destroyed. Finally, after serving as a camp for the Multinational Force Iraq between April 2003 and December 2004, Babylon was handed back to the Iraqi State Board of Antiquities and Heritage.

It is 'gratifying,' the latest mission noted, that 'there are no signs of malicious or accidental damage to the site of Babylon since December 2004. 'The major problems now arise from neglect and lack of maintenance. The restored buildings at Babylon are all in poor condition, particularly the Ninmakh Temple, Nabusha-Harre Temple, Ishtar Temple, the Babylonian Houses and the Southern Palace of Nebuchadnezzar.'

Read the report:
http://unesdoc.unesco.org/images/0018/001831/183134E.pdf

Lecture notes go public

UNESCO and the International Institute of Seismology and Earthquake Engineering (IISEE) in Japan are making the institute's lecture notes freely available online.

The lecture notes cover seismology, earthquake engineering and tsunamis. They are used in international training courses run by the IISEE for researchers and engineers from developing countries. These courses are supported by UNESCO and the Japan International Cooperation Agency.

The IISEE has been organizing these courses since its inception in 1960. To date, more than 1300 scientists and engineers from almost 100 countries have passed through its doors. The current lecture notes are in English but the IISEE welcomes translation into other languages to increase their dissemination.

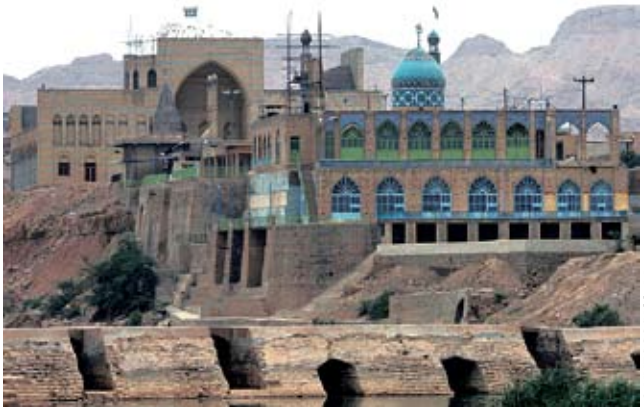
The IISEE–UNESCO Lecture Notes project is an output of the International Platform for Reducing Earthquake Disaster launched by UNESCO in June 2007, in cooperation with the IISEE, Japanese Ministry of Land, Infrastructure, Transport and Tourism and the Japanese Building Research Institute.

To access the lecture notes: http://iisee.kenken.go.jp/lna/;
for details: b.rouhban@unesco.org

Thirteen sites join World Heritage

On 28 June, the World Heritage Committee inscribed two new natural and 11 cultural sites on UNESCO's World Heritage List. For Burkina Faso, Cape Verde and Kyrgyzstan, this is a first. Since the committee also withdrew one site, in light of the construction under way of a four-lane bridge in the heart of Germany's Dresden Elbe Valley, the List now numbers 890 properties.

The two new natural sites are: the Wadden Sea, comprising the Dutch Wadden Sea Conservation Area and the German Wadden Sea National Parks of Lower Saxony and Schleswig-Holstein, one of the last remaining large-scale, intertidal ecosystems where natural processes continue to function largely undisturbed; and the Dolomites, comprising a mountain range in the northern Italian Alps. It is of international significance for its geomorphology marked by steeples, pinnacles and rock walls, glacial landforms and karst systems. The property features one of the best examples of the preservation of Mesozoic carbonate platform systems, with fossil records.


© UNESCO/Yalda Moaiery

Band-e Mizan dam in the city of Shushtar in Khuzistan Province. The historical hydraulic system of Shushtar in Iran can be traced back to Darius the Great in the 5th century BC. It involved the creation of two main diversion canals on the river Kârun, one of which, Gargar canal, still provides water to the city of Shushtar today via a series of tunnels that supply water to mills.

The 11 new cultural sites are: Stoclet House (Belgium); the Ruins of Loropéni in Burkina Faso; Cidade Velha, the Historic Centre of Ribeira Grande (Cape Verde), the first European colonial outpost in the tropics; Mount Wutai (China), a sacred Buddhist mountain encompassing 53 monasteries and the Ming Dynasty Shuxiang Temple; Shushtar, a Historical Hydraulic System in Iran (*see photo*), Sulamain-Too Sacred Mountain (Kyrgyzstan); the 5000 year-old Sacred City of Caral-Supe (Peru); the Royal Tombs of the Joseon Dynasty built from 1408 to 1966 (Republic of Korea); the Tower of Hercules, a Roman lighthouse at the entrance to La Coruña harbour in northwestern Spain, dating from the late 1st century AD; and La Chaux-de-Fonds/Le Locle watchmaking town-planning (Switzerland); and Pontcysyllte Aqueduct and Canal (UK), situated in northeastern Wales, a feat of 19th century engineering.

Meanwhile, Tubbataha Reef Marine Park triples in size with the approval of an extension encompassing Tubbataha Reefs Natural Park (Philippines).

Three sites have been inscribed on UNESCO's List of World Heritage in Danger: Belize Barrier Reef Reserve System, mainly because of mangrove-cutting; Los Katios National Park (Colombia), threatened by deforestation; and The Historical Monuments of Mtskheta (Georgia) because of the serious deterioration of the stonework and frescoes at the site. One site has been removed from the Danger List, the Walled City of Baku with Shirvanshah's Palace and Maiden Tower (Azerbaijan).

For details: http://whc.unesco.org/en/news/536;
Photo gallery: www.unesco.org/en/whc/photos

Beatriz Barbuy

The life and death of stars

We see them sparkling in the night sky but how much do we really know about the stars above us? Beatriz Barbuy has studied different stellar populations in the Milky Way using modern telescopes which allow us to penetrate the secrets of the Universe more deeply than ever before. These include the Hubble Space Telescope and the Very Large Telescope of the European Southern Observatory in the Chilean desert. Most of the stars visible to the naked eye are 10–100 light-years[7] away. The nearest star to Earth after the Sun is Alpha Centauri. As Alpha Centauri is 4.3 light-years away, we see it as it was four years ago. With modern telescopes, astronomers are able to travel *billions* of years back in time; they can observe distant galaxies as they were just a few billion years after the Big Bang.

Full Professor at the Institute of Astronomy, Geophysics and Atmospheric Sciences at the University of São Paulo in Brazil, Beatriz Barbuy was awarded one of this year's five L'OREAL–UNESCO prizes for her work on the life of stars from the birth of the Universe to the present time. Here, she explains how to determine the approximate age of a star, among other secrets.


Image: Hubble Space Telescope

In January 2002, a star suddenly flashed to at least 4000 times its previous brightness. For several weeks, the red supergiant Star V838 Moncerotis was the most brilliant star in the Milky Way. The brightness faded but, as the light from the flash travels through space, it progressively illuminates the dust surrounding the star in what is called a 'light echo.' A star which occasionally brightens is called a nova. Nova flashes usually occur when the gravity of a dense white dwarf pulls enough material from a nearby red supergiant star to cause a reaction on the dwarf's surface.

What do we know about the formation of galaxies?

The Big Bang occurred 13.7 billion years ago. Three minutes after the Big Bang, hydrogen and helium formed and, 400 000 years later, the nuclei of hydrogen and helium and their electrons recombined into neutral atoms. Only from this period onwards did the structures of the Universe begin converging locally by the force of gravity, even as the Universe continued to expand. Massive stars seem to have been the first objects to form. The most distant such star, which exploded 13 billion years ago, was detected recently by the Swift satellite. Later on, small galaxies formed and began merging with each other to form bigger galaxies.

Today, we can create computer models of how spiral and elliptical galaxies formed. Observing stars within galaxies also tells us a lot about how galaxies form.

How is a star born and why does it die?

Even though the Universe is expanding, stars are still able to form, since gravity is the dominant force within local groups of galaxies and within galaxies themselves. Stars are formed essentially by the gravitational contraction of gas clouds. A star is born when it starts igniting hydrogen then transforms this hydrogen into helium, in a process called nucleosynthesis. By this stage, it is a so-called dwarf star, like our own Sun.

Massive stars will go through several phases, burning first hydrogen then helium then carbon then neon then oxygen then silicon. As they go through these different stages of nucleosynthesis, they are effectively in a state of permanent nuclear fusion. This powers the star for the duration of its lifetime and accounts for the extreme heat and light it projects.

After the formation of the iron group elements, the core of the star will keep contracting for a few million years until it ends up either as a compact neutron star or as a black hole, depending on the star's mass. The rest of the star will be ejected in a supernova explosion. After the explosion, only the neutron star or black hole will remain.

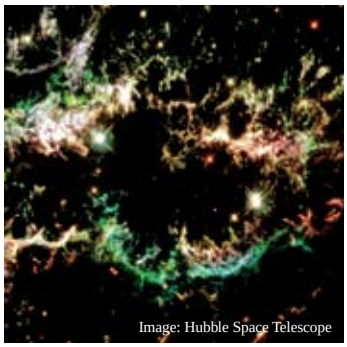


Image: Hubble Space Telescope

Cassopeia A is a supernova remnant of a massive star that exploded. It lies 10 000 light-years from Earth and is 13 light-years across. The compact core of an exploded star is called a neutron star. No neutron star is visible here but sometimes a pulsar will betray its presence. Pulsars are rotating neutron stars that emit a strong beam of electromagnetic radiation.

Neutron stars are hard to see; they are very hot and the densest objects known to us. They are only about 16 km in diameter, yet are more massive than our Sun!

Low mass stars like our Sun will not go through most of these phases, nor will they explode. Rather, they are born when hydrogen begins burning at the core. Later, helium starts burning, mostly in the shell around the nucleus. Low mass stars will go through a phase of being a planetary nebula, by ejecting layers of gas that are illuminated by the star itself, before ending up as a white dwarf.

Both neutron stars and white dwarfs will remain as compact remnants of their star, in principle forever.

Where in our own spiral galaxy is the Sun located and what is it made of?

The Sun is about 25 000 light-years from the centre of the Milky Way. It is located on one of the outer arms, the Orion Arm.

The Sun is made up entirely of gas. It has a core with a central nucleus and this core is surrounded by several layers of gas. The outer layer is the solar atmosphere that we can observe. In terms of mass, the solar atmosphere is composed of about 70% hydrogen, 28% helium and 2% various metals. Oxygen is the most abundant element after hydrogen and helium: 0.06% of the solar atmosphere. At the core where nuclear fusion takes place, the composition of the Sun is very different. Here, the hydrogen is gradually being converted to helium.

When will the Sun die?

The Sun is a relatively young star, about the same age as the Earth: 4.5 billion years. The Sun has been a dwarf star since birth and should continue as such for another 4.5–5 billion years. It is, however, getting progressively hotter. The central nucleus has already been transformed into helium and this will continue to grow in size over the next 5 billion years. Once about 10% of the Sun's core has been transformed into helium, the Sun will expand to become a red giant. Less than 1 billion years or so later, it will become a white dwarf and slowly fade. As a white dwarf, it will be cooling for 70 billion years at least, until it becomes a crystal (a diamond star) with very little energy.

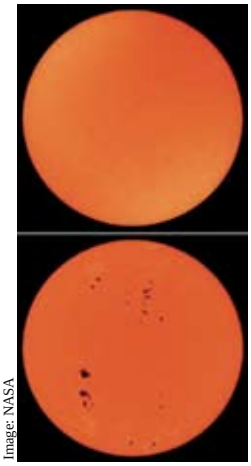


Image: NASA

A photo taken on 27 September 2008 (top) showing a blank Sun with no sunspots and the Sun photographed on the same day in 2001, dotted with giant sunspots and solar flares. Sunspots are cooler regions on the Sun's surface which can affect weather in space. The Sun departed from its usual 11-year cycle for sunspots from 1645 to 1715 in what is known as the Maunder Minimum. Over this period, virtually no sunspots were visible on the Sun's surface and average global temperatures dropped on Earth. Astronomers say 2008 was the 'blankest year' for sunspot activity in 50 years. Sunspots have, however, been visible again this year.

As the Sun ages, what will happen to the Earth?

In about 500 million years' time, the Earth will be too hot to sustain human life and all the surface water will have evaporated. So, this is the timeframe we have for moving to another planet! About 5 billion years from now, when the Sun becomes a red giant, its radius will expand and it will engulf the Earth.

How do we know the age of the Sun?

The age of the Sun has been determined from radioactive elements found in meteorites that have landed on Earth. Astronomers measure the amount of elements like uranium relative to the product of the element's decay. In the case of uranium, lead is produced as it decays. Other elements used include samarium, rubidium, rhenium and osmium.

These meteorites originate in regions of the Solar System where matter was unable to create a planet from space rubble. The debris collide with one another, forming a meteoroid. Once the meteoroid enters the Earth's atmosphere, we call it a meteorite.

Image: Hubble Space Telescope

The Cat's Eye Nebula was created when a dying star ejected its outer layers of gas into space. This planetary nebula will be visible until its gas dissipates into space over the next 10 000 years or so. It lies in the Draco Constellation 3000 light-years from Earth and is 1.2 light-years wide.

How else do you determine the age of a star?

A first rough indicator of a star's age is its metallicity. The amount of metals it contains indicates whether the star was formed from gas that was previously enriched by many generations of stars or, as in the case of the oldest metal-poor stars, by very few stars.

In astronomy, the term 'metal' refers to any element heavier than hydrogen or helium but it tends to refer to iron in particular, or else to oxygen. Hydrogen and helium were the only two elements produced in abundance during the Big Bang. All the heavier elements (metals) were subsequently produced by nuclear fusions in stellar cores. With each new generation of stars, the metallicity of the gas out of which new stars will form increases.

Image: Hubble Space Telescope

A cluster of young stars known as NGC 346 in the Small Magellanic Cloud galaxy

Weren't you the first to demonstrate that metal-poor stars in the galactic halo – the outer edge of a galaxy– were formed in early times?

I didn't discover this phenomenon but I was probably the first to demonstrate clearly a consequence of this, namely the overabundance of oxygen in stars in the galactic halo, known as halo stars. We know that metal-poor stars in the galactic halo have an overabundance of oxygen relative to iron. I should point out here that, when astronomers speak of an overabundance or excess of oxygen or any other element, this is generally in relation to the Sun, which we take as the reference.

What does this overabundance tell us? Quite a lot actually, as the amount of oxygen relative to iron is a second rough indicator of a star's age. Massive stars[8] have a low iron content and high oxygen content. When massive stars explode as supernovae, they eject their metals, mainly the elements oxygen, magnesium, silicon, calcium and titanium. Iron only comes later from less massive stars. Therefore, stars rich in oxygen which formed just after the first massive stars show a high ratio of oxygen to iron, indicating they are old. This is the case of all the stars in the galactic halo. Halo stars must thus have formed in early times from gas enriched from the explosion of massive stars.

However, there are also metal-rich stars in the centre of galaxies that are old because, in the centre, several generations of stars can form more rapidly than in other regions due to the large amount of gas.

There are other, more precise ways of determining the age of stars. You can use spectroscopy to measure radioactive elements such as thorium and uranium. By determining the abundance of these radioactive elements and their probable initial abundance when the stars formed, we can infer how much of this element has decreased due to radioactivity then deduce from this the age of the star. Uranium has only been used for three old stars so far, due to difficulties in detecting the line. The line is faint, so can only be seen in stars with an excess of heavy elements.

The best and most common method is to observe the brightness of stars belonging to a given cluster. The same stars are measured in two colours, for example visible and infrared light.[9] For the first observation, a filter allows only visible light to pass through and, for the second observation, only infrared light. The difference in brightness is plotted on a diagram. This diagram can then be compared with detailed calculations of where stars of slightly different masses are located in the same diagram. We can thus derive the age of the cluster from the distribution of brightness of the stars within it.

Image: European Southern Observatory

The Small and Large Magellanic Clouds are dwarf galaxies that are among the Milky Way's closest neighbours. They are separated by about 75 000 light-years and can be viewed with the naked eye in the Southern Hemisphere. Persian astronomer Al Sufi called the Large Magellanic Cloud the White Ox in his Book of Fixed Stars *(964 AD).*

Why do very aged stars form a cluster?

All stars are born in clouds of gas. Clusters of stars gradually form within these gas clouds. Clusters can contain a handful of stars if the gas cloud is small or they can form so-called globular clusters in the case of clouds the size of about 1 million solar masses. These gas-rich clouds are present when galaxies are young but, as more and more stars form over time, there is less and less gas left.

In our own galaxy, there are no more gas clouds of 1 million solar masses. This means that the old globular clusters we can observe in our galaxy formed a long time ago when the Milky Way was gas-rich and starting to form stars.

However, irregular dwarf galaxies like the Magellanic Clouds, which are satellites to our own galaxy, started to form stars much later than the Milky Way because the gas was too sparse; this is why there is still a lot of gas in these galaxies. The Magellanic Clouds are presently forming numerous globular clusters of young stars.

Interview by Susan Schneegans

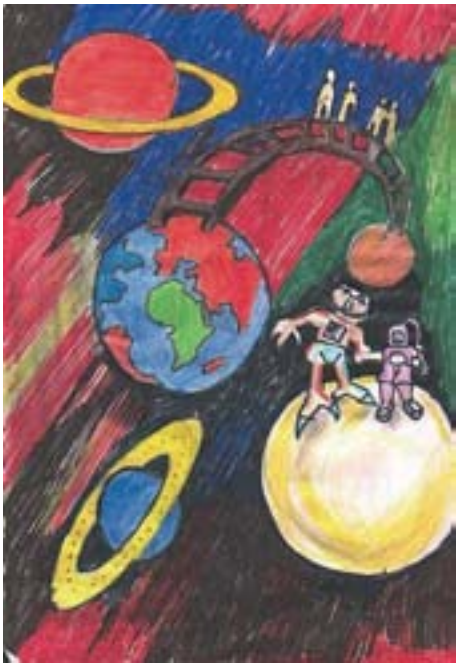
To view many of these photos and others: www.hubblesite.org/gallery

7. One light-year = *9.46 trillion km, the distance light travels in a year. The distance to the boundary of our Solar System is about 1.6 light-years.*
8. *A massive star has a mass above 10 solar masses, typically between 10 and 60 solar masses. Again, the Sun is the reference here: we use the unit of 1 solar mass = the mass of the Sun. The Sun is about 109 times the diameter of Earth and 330 000 times its mass.*
9. *Infrared light has a longer wavelength than visible light. The cooler the star, the brighter it will appear in infrared.*

Captivate them young!

'Is it true that you become sterile after travelling in outer space?' asked the teenager. With a smile, former astronaut Jean-Jacques Favier reassured him that zero gravity had no direct effect on either a person's hormones or their reproductive organs. Other hands shot up. 'How do you sleep and bathe in a space ship?' one girl wanted to know. 'And what does it feel like to go through so many time zones so quickly?'

Workshops like this one in Tanzania in 2008 are a key feature of UNESCO's Space Education Programme. Jean-Jacques Favier from the French Centre national d'études spatiales is one of a team of experts who devote part of their time to lecturing secondary school pupils and their teachers on topics such as space exploration, astronomy, rocket science and remote sensing. Mindful of the declining interest among youth for scientific careers, Favier tries to motivate his young audience by sharing his first-hand experience of human spaceflight.



'I have drawn a picture that shows friends going planet to planet for a holiday.' This is how 7 year-old Dilan Thakrar from Kenya described his entry in the Living in Space *art contest for 6–10 year olds organized by UNESCO, the Norwegian Space Centre and EURISY. His was one of the winning entries which featured in a special UNESCO calendar for 2005.*

'I never fail to remind pupils that their dream can always come true, as long they are focused and tenacious,' says Favier. 'If a pupil is interested in becoming an astronaut, he or she needs to be prepared academically and, once selected for the astronaut programme, very patient, as the waiting time between selection and the first mission assignment can take 8–10 years.'

'The criteria for selection of astronauts has broadened, though,' he adds, 'and is no longer limited to pilots.' An engineer and physicist himself, he was the first French scientist to travel in space. He recalls that, on his first mission in 1996, 'the crew included a medical doctor and a veterinarian, who, like me, were performing experiments. Even if most pupils will never have the opportunity to fly,' he concludes, 'they should bear in mind that science gives them a lot of exciting career prospects.'

Colombian pupils building rockets out of plastic bottles at a UNESCO workshop in 2005. Water is used in this exercise as a 'boosting fuel', as it is perfectly safe. The pupils will then launch their rockets at a nearby open field using air pumps.

Space is part of our daily lives

Whereas outer space was initially explored for military purposes, predominantly by the USA and the ex-Soviet Union, today it is the realm of national space agencies and private companies for the purpose of socio-economic and technological development. Navigation and communication satellites have revolutionized the way we live. Human travel to the Moon and the exploratory missions of robots and spaceships have deepened our knowledge of the Solar System; sophisticated instruments like the Hubble Space Telescope[10] are deepening our understanding of the wider Universe.

What many people do not realize is that much of the technology designed for these missions is now being adapted for public use. Mobile phones and satellite transmissions are all spin-offs of space research. Even such mundane items as disposable nappies, microwave ovens, lightweight track suits and adhesive velcro patches are all spin-offs of earlier space missions.

We have reached the point of no return. We can no more erase the discoveries of the Space Age over the past 50 years than turn our backs on further use and exploration of outer space. The question is, are we ensuring the work of today's scientists will be pursued when they retire?

UNESCO is doing its fair share of preparing the next generation of space scientists. Since 2002, its Space Education Programme has been promoting the teaching of space-related studies in schools and universities in developing countries in particular. It is also encouraging countries to incorporate these subjects in the school curriculum. The programme focuses on three disciplines: space science; space and aeronautic engineering; and applications of space technology.

Although most of the workshops have so far targeted secondary school pupils, teacher training is equally important.

Within the current International Year of Astronomy, UNESCO and the International Astronomical Union have run two pilot teacher-training workshops on astronomy for teachers in Ecuador and Peru. The workshops introduced a new methodology for teaching astronomy in the classroom.

A full one-day programme

Since 2004, UNESCO has organized space workshops for schools in Colombia, Ecuador, Nigeria, Peru, the Philippines, Vietnam and Tanzania. Others are planned for Syria in December 2009 and other Arab countries next year. UNESCO's field offices play an important role in preparing these workshops.

After an inspirational talk on human space exploration to kick off the workshop, pupils are bewitched by the lecture on basic astronomy. They learn that astronomy is the world's oldest science and strewn with mathematics and physics. When experts from the Armagh Planetarium in the UK or the Planetario de Bogotà in Colombia give talks on exploration of the Moon and Mars, pupils see other scientific disciplines enter into play, such as biology, chemistry and geology.

The pupils then get their first taste of rocket science. The workshop introduces the basics of aerodynamics, structural mechanics and propulsion, and reviews Newton's Third Law (that of Action and Reaction) and the Law of Conservation of Momentum. The pupils then learn how to build a water rocket. The approach of applying theory immediately to practical exercises seems to work, as the information rapidly sinks in.

This exercise is carried out in cooperation with the Space Education Centre of the Japan Aerospace Exploration Agency (JAXA), which organizes numerous activities with water rockets for primary and secondary pupils in the Asia–Pacific region in particular. Experts from the centre say they have been struck by the level of comprehension and concentration pupils demonstrate when doing this exercise, which also fosters a spirit of teamwork.

The fundamentals of remote sensing are also introduced at these workshops. Remote sensing is the acquisition of information about an object or phenomenon without entering into physical contact with it. Once satellites have captured images of the Earth, these raw data need to be processed before they can be used to study different terrains and earthquake faults, monitor volcanoes, gauge watersheds and quantify groundwater resources. Pupils and their teachers come to realize that satellite images can also be used to develop a map of a city or country showing the streets, highways, rivers and lakes. Once the lecture is over, teachers are given an educational module which uses the Spring image processing software of Brazil's Instituto Nacional de Pesquisas Espaciais.[11]

The workshop ends with a water rocket launching contest followed by a session of night sky observation, weather permitting. The star-gazing session makes use of the telescopes donated by UNESCO to the schools participating in the workshops, in cooperation with the National Space Society's Permission to Dream programme and Meade Instruments. Schools are encouraged to use these telescopes for astronomy roving courses, especially in rural areas. Before the end of the year, UNESCO will be receiving donated telescopes from Explore Scientific via a cooperation agreement. Low-cost, easy-to-assemble telescopes are also available through the Galileoscope Cornerstone project of the International Year of Astronomy.[12] In addition, Japan distributes 'You are Galileo' telescopes to school children in Asian countries.

The space education workshops are held in several cities within a country, in order to reach the maximum number of teachers and their pupils. Once the last workshop is over, the national organizers devise a pilot national space education programme with UNESCO and the team of experts. This will serve as a blueprint for the development of space education in the country.

Taking it a step further

Several countries have taken steps to integrate space science and technology in the school curriculum. Here, we take a closer look at the strategies of three of them: Ecuador, Nigeria and the Philippines.

Ecuador provides the Pro Tempore Secretariat for the Fifth Space Conference of the Americas (2006–2009). This mechanism was initiated by the UN Committee on the Peaceful Uses of Outer Space, in cooperation with space agencies, to develop and coordinate activities across the region in space science and technology as they relate to disaster management, education, health and environmental monitoring.

Vietnamese boys trying out their school's new telescope, donated by UNESCO in March 2006

World Space Week

World Space Week is a global celebration which takes place from 4 to 10 October every year. The objective is to increase awareness among decision-makers and the general public of the benefits of the peaceful uses of space science and technology for sustainable development.

World Space Week was officially declared an annual event by the United Nations General Assembly in 1999. The week's start and end dates commemorate the launch of the first human-made satellite, Sputnik 1, on 4 October 1957 and the signing of the Outer Space Treaty on 10 October 1967.

For details: www.worldspaceweek.org/

Countries with a government space agency*

ALGERIA
ARGENTINA
AUSTRALIA
AUSTRIA
AZERBAIJAN
BANGLADESH
BELGIUM
BRAZIL
BULGARIA
CANADA
CHILE
CHINA
COLOMBIA
CZECH REPUBLIC
DPR KOREA
DENMARK
EGYPT
FINLAND
FRANCE
GERMANY
GREECE
HUNGARY
INDIA
INDONESIA
IRAN
ISRAEL
ITALY
JAPAN
KAZAKHSTAN
MALAYSIA
MONGOLIA
MOROCCO
NETHERLANDS
NIGERIA
NORWAY
PAKISTAN
PERU
POLAND
PORTUGAL
REP. KOREA
ROMANIA
RUSSIA
SAUDI ARABIA
SOUTH AFRICA
SPAIN
SWEDEN
SWITZERLAND
SYRIA
THAILAND
TUNISIA
TURKEY
UK
UKRAINE
URUGUAY
USA
UZBEKISTAN
VENEZUELA
VIET NAM

** or a space commission, a space office, a space research institute or organization, an institute for space science and technology or a remote sensing centre. Mexico is expected to formalize a national space agency this year. Ecuador has a civilian space agency.*

Since 2007, Ecuador has been organizing national and regional space education workshops with UNESCO to raise awareness among pupils and their teachers of the importance and relevance of space science. These workshops complement the efforts by the Ministry of Education to stress the study of natural and social sciences at the secondary school level, in order to prepare youth better for the pursuit of higher education. The Ministry of Education is currently revising the school curriculum within a *Decadal Plan in Education* (2006–2015). Space science is one of the areas included in the *Plan*.

© UN Affiliated Centre for Space S.&T. Education in Africa

Nigerian pupils learning to identify the different parts of a rocket launcher, at a workshop run by the UN-affiliated space centre in Africa

Nigeria is the third African country after South Africa and Algeria to have a presence in space. In 2003, it launched NigeriaSat-1, with the assistance of Russia, as part of the Disaster Monitoring Constellation. NigComSat-1 followed in 2007, in cooperation with China, to offer Africa better telecommunications.

In parallel, the government is taking steps to build capacity in space science and technology. Nigeria hosts the UN-affiliated Centre for Space Science and Technology Education in Africa, which offers postgraduate courses. The centre also runs biannual workshops for primary and secondary schools. These offer pupils an opportunity to watch or participate in on-the-spot experiments and to view mock-ups of rockets, launchers and satellites, as well as films on the Solar System and other topics.

The centre has taken steps to introduce space science curriculum into the country's schools, in cooperation with UNESCO. In May 2007, teachers, content providers and curriculum revisers from across the country attended a national workshop on Sustaining the Future of Space Science and Technology Development in Nigeria: the Need for Space Education in Schools. The curriculum is being tested this year, prior to being submitted to the Ministry of Education for a pilot implementation phase.

Under the leadership of the Science Education Institute of the Department of Science and Technology, the **Philippines** set up a National Advisory Committee on the Space Education Programme (NACPSEP) in 2005. A series of workshops and outreach activities have been conducted annually ever since in different parts of the country.

In 2007, a planning workshop was organized to develop a national space education curriculum and teaching resources that would meet international standards; to plan an outreach programme promoting space science and technology, coupled with more widely disseminated public information on the benefits of space; and to design short- and long-term activities for World Space Week. The proceedings of this workshop are serving as a road map for NACPSEP in developing and implementing a national programme on space education. Meanwhile, Rizal Technical University in Manila has introduced a Masters degree in astronomy this year, the first in the country.

Preparing for tomorrow's world

It is obvious from the enthusiasm generated by the workshops over the past five years that space fascinates both young and old. Learning about space develops critical thought, participatory problem-solving and decision-making skills, all benchmarks of quality education. By using space as an entry point, UNESCO's Space Education Programme brings an exciting new dimension to science-teaching.

In the longer term, space science and technology help us to understand our place in the Universe and how our planet functions. They provide information on such problems as climate change, environmental degradation or deforestation, both at local and global levels. By equipping youth with the skills and knowledge that space education provides, we can ensure they will be able to take up the challenges of tomorrow's world.

Yolanda Berenguer[13]

For details: www.unesco.org/en/earth/space-education

10. Due to be replaced by the James Webb Space Telescope in 2013

11. This module can also be downloaded from the website of the Committee on Earth Observation Satellites (CEOS). UNESCO chaired the CEOS Working Group on Education from 2005 to 2007: www.ceos.org

12. For details, go to : http://www.galileoscope.org

13. Coordinator of UNESCO's Space Education Programme and UNESCO Focal Point for International Year of Astronomy: y.berenguer@unesco.org

Taking **a step back**

Malindi Watamu Biosphere Reserve in Kenya and Braunton Burrows–North Devon's Biosphere Reserve in the UK have a lot in common. They may be thousands of kilometres apart with very different climates but they share similar problems. Although one coastline is dotted with coral reefs, sandy beaches and mangroves and the other with marshlands, dunes and popular surfing beaches, both are in the frontlines of the battle being waged against the elements. Sea-level rise and erosion are eating into their beautiful coastlines, threatening the economy and people's livelihoods. The wildlife habitats and beaches that are a draw for tourists are being threatened not only by these natural phenomena but also by unsustainable development. Last year, the communities of Malindi Watamu and North Devon decided to engage in an experiment. By twinning their biosphere reserves, they hope to learn from one another how best to adapt to their changing world.

Clovelly, a typical north Devon fishing village, clinging to the eroding cliffs. Around 60 000 of the biosphere reserve's 150 000 inhabitants live within 1 km of the coast and estuary.

Sea level is rising around the world. It will be impossible to stop this phenomenon, yet in north Devon in the UK, that is exactly what some residents are still hoping to do.

Research done in the UK indicates that there is a risk of losing 20% of important intertidal habitats to sea-level rise over the next 20 years. These salt marshes will need to be replaced because they provide important defences against flooding. If you have a salt marsh in front of a sea wall, the sea wall doesn't have to be nearly as big or resilient because the salt marsh actually takes the energy out of the waves and the tide, as they beat against those defences.

In North Devon, the biosphere reserve team worked with Professors John Pethick and Julian Orford to identify what specific changes might occur to the estuary and its flanking coastline in the next 100 years. Residents were involved in the process to ensure an essential mix of local knowledge and scientific understanding. The results of the study were alarming. They shot down previously held theories of how the coastline had formed, the causes of existing problems and the way in which these should be managed. The shape of the coastline was likely to undergo a radical change, the study revealed.

To come up with these new conceptual models – which will need further testing –, the scientists produced a dataset for the current shape of the estuary and coast using LiDAR (Light Detection And Ranging), coupled with bathymetric studies to develop a single digital elevation model of the estuary basin in 3D. Pethick's particular approach to the model uses the expected change in the volume of water entering the estuary as a result of rises in sea level as the main factor in altering the geomorphology of the estuary. Since the models of both the Intergovernmental Panel on Climate Change (IPCC) and the UK Met Office suggest there may be more intense

The beach at Instow, where the Taw and Torridge rivers converge into one estuary system before heading out to sea. The coast of the biosphere reserve is composed of a large bay that incorporates this estuary flanked by two large spits. One of these spits is the 1300 ha Braunton Burrows Dune system. The other is Northam Burrows (250 ha), which has less sand accretion and includes large areas of low-lying marsh fronted by a pebble ridge.

winter rains in future which would in turn increase river flow, Pethick's model also builds in these phenomena. It is obvious from this 100-year model that it is time to take a step back and let the natural processes take their course along the North Devon coast.

Image: Video still from Rising Tides

Pupils from Bideford College taking measurements of the pebble ridge. Sophie Bosworth is holding the clipboard. The girl facing her is holding a clinometer, a standard geography field device for measuring the angle of inclination of a slope. The girls in the background are holding calipers; these are used to measure the size and flatness of the pebbles both along the ridge and up and down the face.

Flooding farmland

As with many estuaries, the Taw–Torridge estuary in North Devon is characterized by development around the periphery and agricultural land-use behind some of the flood defences. A number of exemplary salt-marsh habitats and exposed mudflats stretch in front of these flood banks. We have a classic case here of 'coastal squeeze', where rising sea levels will reduce the intertidal area in front of the defences. These areas provide services such as fish nurseries and wave energy dissipation. Their loss will have a knock-on effect in financial terms and pose a threat to property.

The biosphere reserve team has begun replacing some of the salt marshes. This has entailed reflooding riverside farmland, a project that has gone ahead uncontested. However, the recommendations for abandoning the mouth of the estuary to the sea have provoked the local ire.

Giving up pebble ridge

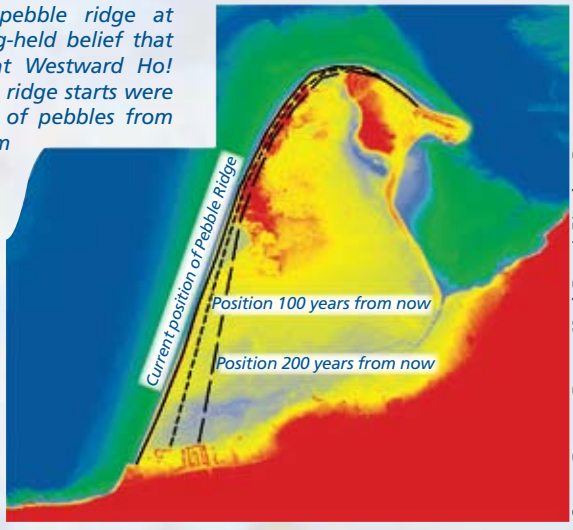
The south side of the estuary is protected by a huge ridge of grey pebbles. In recent years, during storms at high tide, the waves have moved pebbles on quickly at certain points, creating a gap in the ridge. The waves have also begun pummelling the dunes behind the beach. In the past, the council would repair the ridge by moving pebbles into the gaps with heavy machinery. But in the past few years, this costly and damaging policy has been dropped, allowing the sea to flood the land behind, known as Northam Burrows. Local councillor Andrew Eastman thinks this is wrong, a point of view shared by many disgruntled residents. 'We need to rebuild the ridge now,' Eastman says, 'to prevent the water from inundating the coast and buy us more time.'

However, this expensive solution is simply not sustainable. This is clear from the modelling done for the next 100 years using LiDAR data and other geomorphological indicators like the ancient raised beaches left behind from when sea levels were much higher in previous interglacial periods. As local geologist Peter Keene recalls, Northam Burrows has disappeared many times in the past – sea level rose by 8 m some 125 000 years ago – and will do so again. One of the casualties of the changing nature of the pebble ridge is likely to be the local golf course, an eventuality that sorely chagrins the community's golfers. On advice from the biosphere reserve team, the golf club has begun reconfiguring its course to accommodate the encroaching sea.

Getting people to decide with their heads

For many people living in a developed nation, the term 'climate change' evokes accelerating desertification in the Sahel or stronger monsoons in India. They perceive the likely severest effects of climate change as being too remote and too slow-moving for there to be any urgency to act closer to home.

Getting people to understand that 2.5 mm of sea-level rise per year actually means a lot when you total that up over the years is no easy task, especially when you tell them that it will accelerate over the coming years. People often react with their hearts rather than their heads when it comes

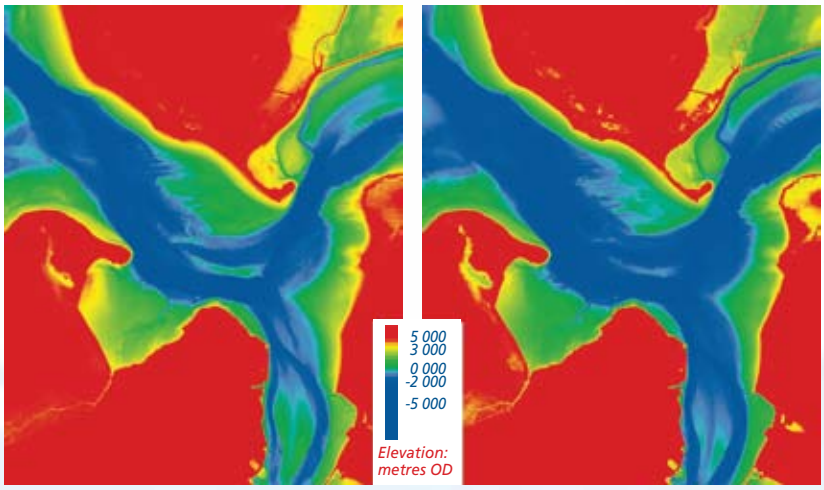


Source: Braunton Burrows-North Devon's Biosphere Reserve

Expected future positions of the pebble ridge at Northam Burrows. It has been a long-held belief that old coastal defences put in place at Westward Ho! immediately to the west of where the ridge starts were preventing the long-shore migration of pebbles from forming the ridge fronting Northam Burrows. The new thinking is that this supply of pebbles comes from a landslide that occurred several hundred years ago and that the supply has simply dried up. This has coincided with development of the coastal village of Westward Ho! The ridge will change its orientation over time to face the most common waves directly.

to making difficult decisions like whether or not to abandon land to the sea. Placing the time horizon for the impact just beyond the life expectancy of the current community depersonalises the issues and can give people the space they need to develop an adaptation policy that their children or grandchildren might appreciate.

It is the young who seem best able to think ahead. Pupils from Bideford College have launched a school project to measure the extent of sea-level rise on their local beach and at the pebble ridge. They take photos and have designed a website they call The Big Climate Thing,[14] to inform the public. The project 'has made me aware of how climate change is affecting our local area,' says teenager Sophie Bosworth, a pupil at Bideford College. 'Especially by the river and by the beaches. We've been looking at the pebble ridge and how it has been retreating, how the sea is eroding it and causing this change and what effects it will have on the land behind it.'



Source: Braunton Burrows-North Devon's Biosphere Reserve

These two images show the loss of foreshore after 1 m of sea-level rise alone, not accounting for any increased erosion. Left is the situation today.

Trouble in paradise

Meanwhile, in tropical Malindi Watamu Biosphere Reserve on the Kenyan coast, all eyes are turned towards the mangroves and beaches. In the reserve, embayments with large mangrove forests provide the same functions as the temperate salt marshes in north Devon: fish nurseries and the dissipation of wave energy. The Sabaki River discharges into this part of the coast but carries with it sediment from the soils eroding in the catchment behind, stifling the corals. This source of stress comes on top of a rise in sea temperature and the threat of acidifying oceans. Sea-level rise combined with possible over-abstraction of freshwater along the coast has also led to reports that some of these wells are increasingly saline due to seepage of the sea through the permeable limestone.

Coastal squeeze from both directions

Kenya benefits from legislation that safeguards a 30-m strip of the beach above the mean high-water mark for preservation. It is in this area that sea turtles nest. The strip also provides a good buffer against any increase in monsoon storms in the Indian Ocean.

However, we are witnessing the erosion of this strip. This is being caused both by the sea and by a worrying increase in unregulated development on land which is encroaching on the beach. The same symptoms of 'coastal squeeze' are happening here but from both directions!

Steve Trott, Chairman of the Watamu Marine Association, observes that erosion on Watamu's Marine Park beach, one of Kenya's main sea turtle nesting beaches, has been especially rapid since 2004. 'So now the turtles are forced to nest in this ever-narrowing part of the beach that gets flooded,' he says, 'where the nests are in danger of being washed away and destroyed.'

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The community now takes protecting turtles seriously. When disaster strikes and one is found drowned in a fishing net, like here, it is given a dignified burial on the beach.

Just like in Britain, feelings run high when it comes to protecting the coastline and wildlife. The Malindi Watamu Biosphere Reserve Organisation has joined forces with the Watamu Marine Association to ensure that the law safeguarding the 30-m strandline is upheld. The Association has already successfully pleaded its case to a National Environmental Tribunal to prevent the development of tourist villas at Blue Lagoon, an exquisite natural bay.

Enlisting the help of the population

It is not just the impact of sea-level rise that has the biosphere reserve management committee worried in Malindi. The main problem is poverty. It spawns mangrove deforestation, poaching and overfishing, even though mangroves are the hatcheries for the fish which locals catch and provide vital building materials.

FAO estimates that 50% of the total mangrove forest has been lost along the Kenyan coast. Some has been cleared for agriculture and housing, some destroyed to produce salt factories and some polluted by oil spills. The Mida Creek Conservation Community Group and others have been working in the biosphere reserve to replant some of the mangrove areas. The population is being encouraged to take an active part. The fact that tourists are flocking to the area to see migratory birds like flamingos is an added incentive, as it opens up opportunities for eco-tourism.

The situation is not without conflict, with passionate local community groups trying to stem the tide of uncontrolled coastal development and stop destructive illegal fishing and mangrove-cutting. The Malindi Watamu community seems to be far more in touch, though, than its North Devon counterpart with the value of its ecosystems and the services these provide and therefore more willing to work with them. Perhaps this is what Kenya has to offer the UK.

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Local people replanting mangroves under the watchful eye of the TVE camera

©Andrew Bell

Fishermen with their nets in shallow water at Malindi

Narrowing the technology gap

The Malindi Watamu committee would like to obtain more information and data on climate change in the biosphere reserve but does not yet have the resources to model the impact of sea-level rise. The teams from both biosphere reserves hope to raise at least US$150,000 to enable them to obtain LiDAR and bathymetry data for the area and establish both more robust monitoring systems and participative management. In the meantime, the biosphere reserve team in Malindi Watamu has set up simple monitoring regimes which will help in modelling this stretch of coast once funding can be found.

The large-scale climate models and IPCC reports give some indication of what to expect but we also need a more local understanding of the impact of climate change, in order to adapt before it is too late. This is even more urgent for developing countries, given that they are likely to bear the brunt of climate change. There is no time to lose in strengthening collaboration between countries which have the technology and those which do not. The UK Met Office has provided sub-Saharan states with training on how to use Precis, a downscaling tool for the large climate models. The application of Precis models, LiDAR and other tools will help countries start planning their future.

If we may conclude with a metaphor, just as a surfer sees a wave approaching, anticipates its behaviour then rides it to make sure it does not kill him or her, biosphere reserves can help society learn to ride the unfurling wave of climate change.

Andrew Bell[15] and Paul Makenzi[16]

For a map of Braunton Burrows–North Devon's Biosphere Reserve, see page 6. See also: www.northdevonbiosphere.org.uk

The work in the twinned reserves has been captured by TV Trust for the Environment (TVE) and broadcast this year on BBC World, a production financed by UNESCO and the European Union. The full 22-minute DVD of Rising Tides *is available in English and French from UNESCO: a.candau@unesco.org. It may also be viewed here: www.unesco.org/mab (click on Multimedia).*

The UK–Kenyan biosphere reserve twinning project was made possible by the support of the UK Department for International Development.

14. The Big Climate Thing: www.bideford.devon.sch.uk/climatelab/page4/index.html

15. Coastal scientist. Braunton Burrows-North Devon's Biosphere Reserve: Andrew.bell@devon.gov.uk

16. Rural Resource Management Specialist. Kenya Man and Biosphere Programme: pmakenzi@yahoo.com

Diary

1–3 October
Water, cultural diversity and global environmental change
Emerging Trends, Sustainable Futures? Intl symposium by UNESCO-IHP, Research Institute on Humanity & Nature and UNU. Kyoto (Japan): *l.hiwasaki@unesco.org; www.waterandculturaldiversity.org*

25–28 October
Young Earth scientists
First world congress, under UNESCO patronage. Interdisciplinary roundtables. Beijing (China): *www.yescongress2009.org/index.php*

26–29 October
Managed aquifer recharge in SADC countries
Training workshop with UNESCO Chair in Hydrogeology at University of Western Cape (South Africa). UNESCO Harare (Zimbabwe): *m.tchaou@unesco.org; s.taongai@unesco.org*

28–29 October
Earth science education in Africa
2nd of four regional scoping workshops for UNESCO's new initiative within Intl Year of Planet Earth. (The 1st held in Luanda, Angola, on 18–19 September) With Geological Society of Africa, University of Assiut. (Egypt): *www.unesco.org/science/earth; s.gaines@unesco.org*

4-7 November
Regional Coordination Mechanism
for UN activities in Africa meeting to report on progress in activities of UN S&T Cluster in Africa. UNESCO coordinates cluster. Addis Ababa (Ethiopia): *www.unesco.org/science/psd/cluster.shtml; s.nair-bedouelle@unesco.org*

5–7 November
World science forum
4th forum, proposes 10-year review of follow-up to World Conference on Science (1999). Hungarian Academy of Science with UNESCO's Division of Science Policy, European Commission. Budapest (Hungary): *www.sciforum.hu; www.unesco.org/science/psd*

6–9 November
Mondialogo
Engineering award symposium and prize-giving. Istanbul (Turkey): *t.marjoram@unesco.org*

10 November
World Science Day
for Peace and Development. Includes award of UNESCO's Kalinga and Sultan Qaboos Prizes. Budapest (Hungary): (Kalinga) *y.nur@unesco.org*; (Sultan Qaboos) *p.dogse@unesco.org*

17–18 November
Implementation of Global Earth Observation System of Systems
6th Plenary Session of Group on Earth Observation (GEO). Washington (USA): *http://earthobservations.org/*

19 November
The need for Earth observation yesterday, today and tomorrow
Symposium of GEO and Integrated Global Observing Strategy Partnership. Washington (USA): *http://earthobservations.org/*

20–21 November
Planet Earth: the present for the future
Global event to review results of Intl Year of Planet Earth. Lisbon (Portugal): *http://yearofplanetearth.org/index.html*

24 November
On the Origin of Species
Scientific, educational and cultural legacies. For UNESCO Permanent delegations. Celebrates 150th anniversary of publication. With guest speakers and projection of film on *Galapagos – a tribute to Charles Darwin*. UNESCO Paris (Room II): *s.gaines@unesco.org*

17–27 November
Khmer science film festival
1st in Cambodia. Screening of films at schools, universities, public parks, cultural centres on science in daily life, climate change, ecology, life sciences, etc: *t.diez@unesco.org*

26–27 November
Earth science education in Africa
3rd of four regional scoping workshops. With African Earth Observatory Network. Cape Town (South Africa): *www.unesco.org/science/earth; s.gaines@unesco.org*

1–3 December
Implementing Madrid Action Plan in Pacific biosphere reserves
Pacific MAB Network. Honolulu, Hawaii (USA): *burnett@bishopmuseum.org; j.steffen@unesco.org; m.clusener-godt@unesco.org*

7–18 December
Climate change
UN Conference to adopt successor to *Kyoto Protocol*. Copenhagen (Denmark): *http://en.cop15.dk/*

9–10 December
Earth science education in Africa
4th regional scoping workshop. With University of Dakar (Senegal): *www.unesco.org/science/earth; s.gaines@unesco.org*

5–12 December
4th African Ministerial Council for S&T (AMCOST)
UNESCO participating in capacity as sole UN body nominated to AMCOST. Cairo (Egypt): *www.unesco.org/science/psd/cluster.shtml; s.nair-bedouelle@unesco.org*

New **Releases**

Aportes para la Enseñanza de las Ciencias Naturales
Julia Leymonié Sáenz. Produced by UNESCO Regional Bureau for Education (Santiago, Chili). In Spanish, 142 pp.
Provides tips for better science teaching. Download : *http://unesdoc.unesco.org/images/0018/001802/180275s.pdf*

Acting on Climate Change
The UN delivering as One
Prepared by UN System Chief Executives Board for Coordination, English only, 35 pp.
Overview of ongoing actions by UN bodies in: climate knowledge: science, assessment, monitoring and early warning; adaptation; capacity-building; financing mitigation and adaptation; reduction of emissions from deforestation and degradation; technology transfer; supporting national and global efforts; and public awareness raising.
Download: *www.un.org/climatechange/pdfs/Acting%20on%20Climate%20Change.pdf*

Education for Sustainable Development
Second collection of good practices
Produced by UNESCO's Associated Schools Project, Exists in English and French, 72 pp.
Innovative ideas for teaching pupils about local biodiversity, solar and wind energy, ways of designing energy-efficient homes, recycling, green tourism, beach monitoring, etc. These projects and many others have been developed and implemented by schools belonging to UNESCO's Associated Schools network. For details: *a.hamshari@unesco.org*
Download: *http://unesdoc.unesco.org/images/0018/001812/181270e.pdf*;

Geoheritage of East and Southeast Asia
M. S. Leman, A. Reedman and Chen S. P. (eds).Produced by member countries of the Coordinating Committee for Geoscience Programmes with Universiti Kebangsan Malaysia. English only, 308 pp.
A contribution to the International Year of Planet Earth, presents geoheritage in China, Indonesia, Japan, Republic of Korea, Malaysia, Philippines, Thailand and Vietnam. Also describes the approach of UNESCO's Global Network of Geoparks to geoheritage conservation and sustainable use. Encourages regional cooperation in geoheritage conservation. Request a copy from: *ccopt@ccop.or.th* or go to: *www.ccop.or.th*

Towards a Science, Technology and Innovation Policy for the Republic of Armenia
Produced by UNESCO Division of Science Policy and Sustainable Development, Paris, English only, 88 pp.
Examines the main features of science, technology and economic development in the Republic of Armenia and underlines the need for decision makers to take steps to ensure that S&T plays a leading role in the national development strategies of the Armenian government.
Download: *www.unesco.org/science/psd/publications/s-p_series.shtml*

Bref état des lieux du système national de recherche scientifique et technique de la République du Burundi
By Hocine Khelfaoui. Produced by UNESCO Division of Science Policy and Sustainable Development, Paris, French only, 84 pp.
Describes the current state of R&D in Burundi and proposes recommendations in the form of discussion points for the commissions which will be working on the country's *Strategic Plan for Science, Technology and Research for Sustainable Development*. Download: *www.unesco.org/science/psd/publications/s-p_series.shtml*

Trends in Global Higher Education
Tracking an Academic Revolution
Philip Altbach, Liz Reisberg and Laura Rumbley. Prepared for the World Conference on Higher Education (see page 11), with support from SIDA/SAREC. The Executive Summary exists in English, French and Spanish, 20 pp.
Download: *http://unesdoc.unesco.org/images/0018/001831/183168e.pdf*

Integrated Urban Water Management
Arid and Semi-arid Regions
Larry W. Mays (ed.) Product of UNESCO-IHP project. UNESCO Publishing / Taylor & Francis, ISBN 978-92-3-104061-0, English only, €34.00, 228 pp.
Considers the various dimensions of water, such as surface and groundwater resources, quality and quantity issues; the fact that water is a system and component which interacts with other systems; and the interrelationships between water and socio-economic development.

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Cover photo: Iguana from the Galapagos Archipelago.