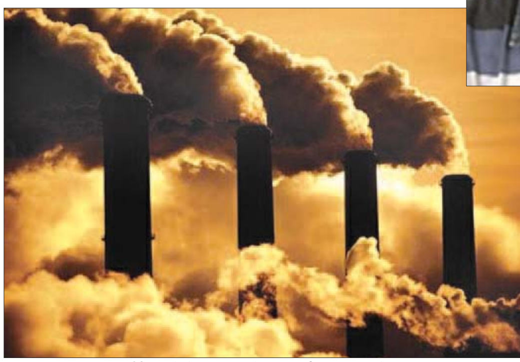
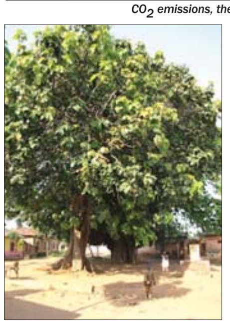
Bugs and the carbon budget

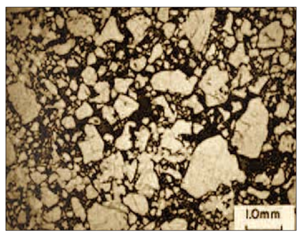
Microbes have a large role in taking carbon out of the atmosphere, says s ananthanarayanan

Bryne Ngwenya



CO_2 emissions, the main cause of global warming.





Calcite-cemented pure-quartz sandstone generated by Iroko trees (left).

PHOTOSYNTHESIS has been the great carbon fixer and is, in fact, the reason for our oxygen-rich atmosphere. In earth's very early history, the oxygen generated in this way did not accumulate because it got used up, mainly in oxidising free iron, which was abundant. But when this drain of oxygen was depleted, its levels began to rise and oxygen-dependant life forms became dominant. Till this change took place, which was 2.4 billion years ago, most living things used no oxygen and depended on fermentation, (which is an *anerobic*, that is, works in the absence of oxygen) for energy, and this resulted in the emission of methane and carbon dioxide. With the decline of free iron and build-up of oxygen, fermentation slowed down and these earlier life forms now flourish only in remote or confined spaces. The other oxygen-dependant vegetation, and photosynthesis, increased apace and there is no visible reversal of the oxygen-dominated earth we have now.

But competition has come from man-made emissions, mainly carbon dioxide, whose increase is proving more than photosynthesis and other natural carbon fixing mechanisms can handle. The rising level of carbon dioxide in the air is leading to global warming, which affects climate, vegetation, sea levels, causes population migration, deprivation and what have you. While the world fights a barely effective battle to contain emissions or promote environment-friendly power generation, there is huge investment in finding ways to trap and contain rising CO_2 levels.

Photosynthesis and a healthy green cover may still be the most effective way, and the green cover may increase with warming but the role of other mechanisms — of algae in the sea and of microbes, both in the sea and in the soil — have been recognised as the larger force, both in containing carbon and in the carbon cycle.

An international group of scientists sponsored by the European Commission's seventh Framework Programme (FP7) project initiated by the Brussels-based business enterprise, Biomim-Greenloop, has studied the processes of microbes acting to remove carbon from the atmosphere and tie it down as carbonate, in the form of limestone. An important function identified is of microbes that become effective in collaboration with the *Iroko*, a large hardwood tree from the west coast of tropical Africa that is known to promote the formation of carbonates in soils that are acidic and not likely to support this formation. The carbonate forming influence of the Iroko is thus seen as a vector, to be used worldwide to multiply the rate of fixing atmospheric carbon in mineral carbonates and then as limestone by the action of microbes.

The ideal condition for soils is that they have a low level of acidity, which is measured by an index called *pH*. This index is seven for a neutral solution like water, is more than seven for alkalis and is less than seven for acids. The level for soil should be not less than 5.5 as lower levels are too acidic. The level of acidity of soil is usually kept down by the presence of basic (ie, opposite of acidic) elements, which include calcium, magnesium and potassium. Intensive harvesting of crops can take up these minerals and deplete the soil, which grows acidic through the effect of rainfall and organic decay. Hence, apart from the effect of higher acidity to slow down the formation of calcium carbonate, higher acidity of soil also indicates lesser levels of calcium itself. It is in these soils that the Iroko, with the help of micro-organisms, is found to neutralise at least the effect of acidity on available calcium.

The action of the Iroko is linked to the tree being *oxalogenic*, or a creator of calcium oxalate, which is expressed as $Ca(COO)_2$, or the constituents of two molecules of CO_2 combined with every atom of calcium. We can see that this is itself a form of carbon fixing which takes place by using the energy of sunlight. Oxalates, in fact, are found in many plants, spinach leaves being one, which persons with a tendency to suffer from kidney stones are advised to avoid. But oxalate is produced in quantity by the Iroko — as it grows, there is a flow of organic matter to the soil and an "oxalate pool" is formed. This is worked on by 40 different bacteria to break it down to carbonate ions, or groups of atoms, CO_3^-, the minus sign showing that the ion is negatively charged. This readily combines with the calcium released from the oxalate or other calcium to form calcium carbonate, or $Ca(CO_3)_2$, which is limestone, the hardy mineral storehouse of carbon.

Normal plants also trap carbon but use water and create more of carbohydrates, which can burn or otherwise send carbon back to the atmosphere. Creating oxalates, on the other hand, allows micro-organisms to lock carbon down in the form of hard rock — the objective of most carbon sequestering programmes.

The breakdown of oxalates has another effect on soil quality — it reduces soil acidity, or raises the pH. Raising the pH is again effective in promoting the precipitation of carbonates and also improves the quality of soil for agriculture.

The Universities of Lausanne and Neuchatel in Switzerland have charted the symbiosis between the Iroko and the bacteria and fungi and the effect on soil fertility. "By taking advantage of this natural limestone-producing process, we have a low-tech, safe, readily employed and easily maintained way to lock carbon out of the atmosphere, while enriching farming conditions in tropical countries," says Dr Bryne Ngwenya of the University of Edinburgh's School of GeoSciences, who led the European Union project. "… this carbon sink, driven by the oxalate carbonate pathway around an Iroko tree, constitutes a true carbon trapping ecosystem as define by the ecological theory," says an article in the journal, *Biological Discussions*.

The EU group has pressed in expertise from the Universities of Edinburgh, Grenada, Lausanne and Delft to address the many challenges to make this microbal process industrially acceptable. A main challenge is to find cheap and plentiful sources of calcium to fix as carbonates without tapping existing carbonate formations. And then to fine-tune the strains of bacteria and conditions of growth for maximum carbon fixing. Some African trees and their bacteria store up to five kiolgrammes of CO_2 equivalent in a year. But strains of bacteria in laboratory conditions have clocked 40 kg of CO_2 in five hours!

The group is now identifying the processes that would be applied in two industrial projects to be set up this year. The generation of calcium or carbonate could then be included in an organisation's carbon balance and uncarbonated calcium in the waste stream could become a saleable byproduct. Apart from the use of such commercial and industrial carbon trapping, there could be an industry of "bio-cement", where microbes could help seal cracks in masonry!

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You have to hand it to the Neanderthals

Cave paintings dated as 15 millennia older than originally thought make theirs Europe's earliest known paintings, writes david keys

A detail from the "Panel of Hands" in El Castillo Cave, northern Spain, showing red disks and hand stencils made by blowing or spitting paint onto the wall. A date from a calcium carbonate layer covering one of the red disks has revealed that the painting is more than 41,000 years old, making it the oldest known definitively-dated cave art in Europe.

NEANDERTHAL Man, normally typecast as brutish, unsophisticated and primitive, may well have had a distinctly artistic streak, according to new archaeological research. A series of Stone Age cave paintings in northern Spain, long thought to be less than 25,000 years old, have just had their dates pushed back more than 15 millennia making them Europe's oldest known definitively-dated paintings.

The new date for the art works means that, on balance of probabilities, they were potentially painted by Neanderthals rather than members of our own species of humanity, Homo sapiens. The dating test shows they were painted at some stage prior to 41,000 years ago – and potentially up to several thousand years earlier. The reason for the imprecision is that scientists got their date from a layer of calcium carbonate (stalagmite material) which had formed immediately over the surface of the painting at some stage after the art work had been painted.

If the art works — images of hands and red discs — were painted during the 500 or so years prior to the formation of the calcium carbonate layer, then they could be the work of either Neanderthal or Homo sapiens, because the first Homo sapiens arrived in the area 41,500 years ago. But if the paintings were created before that date, they would therefore have had to have been the work of Neanderthal Man.

The discovery is particularly important because of its implication for understanding Neanderthals and/or the complex interaction between them and Homo sapiens. Significantly, cave art was not a Homo sapiens tradition prior to their arrival in Europe. There are no equivalent really early art works in Homo sapiens' original homeland, Africa. This may suggest that either early European cave art emerged as a result of some sort of social behaviour developed by Homo sapiens in Europe (perhaps due to competition with Neanderthals), or, alternatively, and much more controversially, that Neanderthals "invented" cave painting and somehow passed the tradition on to Homo sapiens. The idea that the artistic member of the human evolutionary family was originally Neanderthal Man rather than us, and that the Neanderthals "taught" our species a love of art would certainly turn popular perceptions of Neanderthal/Homo sapiens interaction on its head.

But there is other evidence suggesting that Neanderthals were keen on artistic self-expression. Although the Spanish "painted hands" and red discs are the first potentially Neanderthal paintings ever identified and accurately dated, objects decorated with mineral pigments (similar to those used for the paintings) have been found on a Neanderthal site 430 miles south of the newly-dated cave art. Elsewhere in Europe there is possible Neanderthal use of pigments in central France — and a very early use by Neanderthals of red ochre pigment in the Netherlands.

The "painted hands" and red discs were made by artists using their mouths as spray cans. Ground ochre was first mixed with liquid – presumably water. Then the Stone Age artist filled his/her mouth with the resultant red mixture and blew it out onto the wall or roof of the cave, usually using his/her left hand as a stencil. In the cave where the paintings have been dated, around 25 such "negative" stencil images were created in which the shape of the artists' left hand are seen against a red ochre background.

The joint Spanish/Portuguese/British project to date the art was led by Dr Alistair Pike of the University of Bristol and funded by the UK's Natural Environment Research Council. The findings are published in the current issue of *Science*. The paintings are located in El Castillo cave near Santander in northern Spain.

The Independent, London

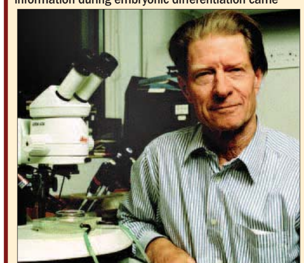
No information loss

tapan kumar maitra **explains the constancy of the genome during cell differentiation**

AT which level cell differentiation is controlled has been analysed, providing experimental evidence indicating that the genome remains contant throughout cell differentiation. Specialised cells from different tissues contain the same kind and number of genes and, therefore, the differences between specialised cells need to be explained in terms of variable rates of gene expression.

Nineteenth century embryologists devoted much attention to the possibility that cell differentiation could be due to the loss of those genes that are expressed. However, the massive loss of chromosomal material cannot be the cause of cell differentiation, since we know that the DNA content of diploid cells is constant in all tissues of an organism.

Rigorous proof that there is no loss of genetic information during embryonic differentiation came

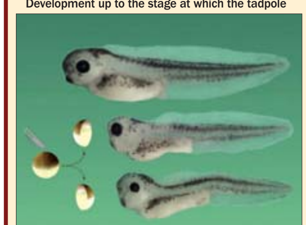


JB Gurdon.

from the classic nuclear transplantation experiments performed by JB Gurdon. *Xenopus laevis* unfertilised eggs can be irradiated with ultraviolet to destroy the endogenous nucleus and can then be injected with a single *Xenopus diploid* nucleus. Nuclei obtained from *Xenopus* tadpole intestinal cells (which are clearly differentiated cells, since they have a "brush border" of microvilli) are able to sustain the development of normal, fertile adult frogs. This demonstrates that the intestinal cells have retained all the genes required for the complete life cycle of a frog.

In addition, since many frogs can be obtained from the intestine of the same tadpole, nuclear transplantation makes it possible for a clone of genetically identical siblings to be created.

Development up to the stage at which the tadpole



In Xenopus*, the blastula constitutes a self-differentiating morphogenetic field, in which cells are able to communicate over long distances. When the blastula is bisected with a scalpel blade, identical twins can be obtained, provided both fragments retain Spemann's organiser tissue. Thus a half-embryo can regenerate the missing half. In humans, identical twins are found in three out of 1,000 live births, and usually arise from the spontaneous separation of the inner cell mass of the blastocyst into two. A normal tadpole is shown on top, and two identical twins derived from the same blastula below, all at the same magnification.*

swims has been obtained using a variety of adult tissues (such as keratinising skin cells and lymphocytes), thus demonstrating that the genes required to make nerve, blood, muscle, cartilage and other tadpole tissues were not irreversibly inactivated in the donor nuclei.

Similar conclusions have been obtained using plant cells. It is common knowledge that whole plants can be grown from cuttings. In come cases, such as in carrots, a complete plant can be grown from a single cultured cell.

One possible way of obtaining differential gene activity would be to increase the number of copies of a given gene. Since some differentiated cells produce large amounts of certain gene products (for example, 90 per cent of the protein synthesised in a *reticulocyte* is *globin*), it seemed conceivable that this could be the case. However, nucleic acid hybridisation studies have shown that there is only one copy per haploid genome of globin genes in all tissues, regardless of whether the gene is preferentially expressed. In other words, a single globin gene, when fully activated, can give rise to all the globin required by a red blood cell.

We have seen that differential gene expression does not result from changes in the kind or number of genes. Another possibility is that it could arise from changes in the location of genes in the chromosomes. Gene rearrangements and translocations do occur in the case of antibody-producing cells; however, the DNA sequences adjacent to the *globin ovalbumin* genes have been analysed by cleaving cell DNA with restriction enzymes and these were found to be the same regardless of the tissues from which the DNA was extracted. Similarly, no differences were found in the restriction enzyme fragments of *Drosophila* DNA extracted from embryonic and adult tissues.

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