Helping to bring the gold in

THE ROOTS OF THE EUCALYPTUS TREE TRAP VALUABLE DEPOSITS 40 METRES DEEP, SAYS **S ANANTHANARAYAN**

While the demand for gold, as ornaments, an investment and in industry, is rising, known gold mines are getting depleted and new deposits of ore are hard to find. Mining for the metal has been directed mainly by historical record of deposits, or by chance discovery and systematic prospecting is expensive and involves deep drill holes and environmental damage.

A comparatively simpler method of discovering underground deposits could be to detect traces of gold in vegetation above the place where gold is buried. But the method is often misleading and no mechanism by which particles could be harvested by plants has been proposed. Melvyn Lintern, Ravi Anand, Chris Ryan and David Paterson, working in Australia, report in *Nature Communications*, a clear demonstration of gold particles being transported by the eucalyptus tree, which could promote confidence in a new method of prospecting.

Deposits of heavy metals are typically located at great depths. This is because the earth, in its early geological history, was a molten mass and heavier elements sank deepest. Most of the gold in the earth may hence lie in the core and any gold that is discovered on the surface is considered to have arrived via meteorites. But gold from deep underground is also raised nearer the surface by volcanic activity or geological disturbances. The Witwatersrand basin in South Africa, which has the world's richest deposits of gold, is believed to have been created by an asteroid that struck the earth 2,000 million years ago and formed the 300-km Vredefort crater, distorting the rock strata and raising gold deposits.

Nearly 50 per cent of all the gold mined on earth has come from Witwatersrand rocks. All other mines are in the form of wide, open-cast mining or through deep tunneling. Discovery has been historical or by chance, often by casual prospectors finding nuggets in the water with rocky material carried down by streams.

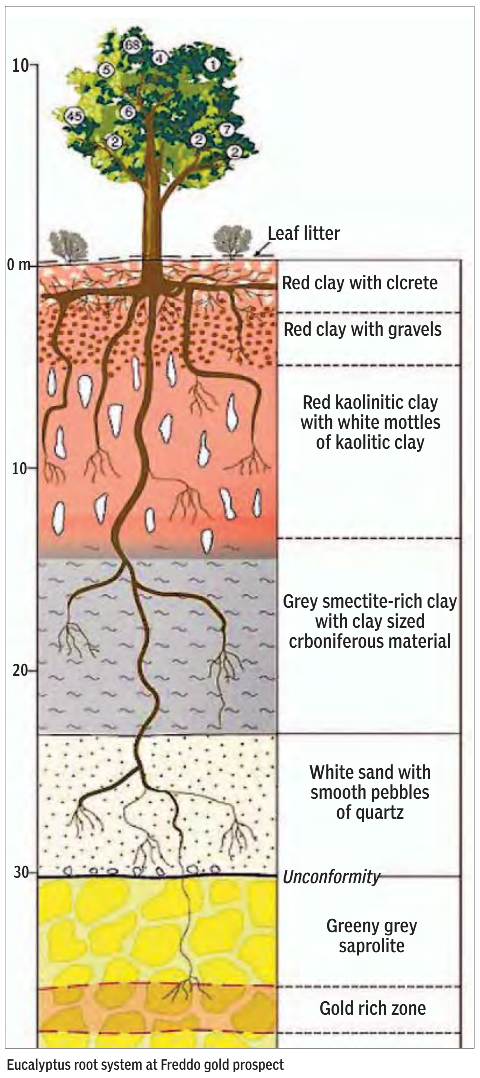
Prospectors "pan" the flowing water and any gold stays back while other rocks are washed away. Once gold is found like this, tracing the stream to its source reveals where the metal came from, for mining.

But except for discovery like this, actually searching for gold deposits is neither practical nor economical.

The methods used are painstaking inspection or laboratory examination of different kinds of rock that are at the earth's surface or within reach, selected according to rock types that are known to have gold content, or by geophysical anomalies. When there are prospects of discovery, drill holes are made and rock samples from deep underground are analysed. But gold deposits are typically just a few hundred metres wide and a great many holes need to be drilled before deposits can be located.

The possibility of natural probes that go deep underground have been proposed and one agent proposed by Australian scientists was termites. Termites burrow beneath the earth that may hide a vein of gold and ingest nanoparticles of the metal. The excreta of the termites would then have traces of gold and examining their may be a non-invasive and, hopefully, economical way of detecting underground deposits. The other natural probe is of the root structure of trees. Some traces of gold have been found, for some time now, in the leaves of the eucalyptus tree, which is common in Australia, but these traces are so minute that it has not been possible to say for sure that these are not due to surface level contamination. This *biogeochemical* method of prospecting has, thus, not been seriously pursued.

The main features of the eucalyptus tree is that it has roots that go deep and that the root structure rapidly raises underground water to the surface. Planting eucalyptus has, thus, been a method of draining swampy land or for lowering the water table, which may be needed for construction. As eucalyptus can extract water from deep underground, the tree can survive arid conditions and has been planted in dry places to "promote greening", only to find that the water table recedes and conditions become more arid than before.



Eucalyptus root system at Freddo gold prospect

But eucalyptus abound in Australia and the authors of the paper in *Nature Communcations* were able to study the trees that grew above two known deposits of gold, and also in the laboratory, to analyse the real source of traces of the precious metal in their leaves. The two locations were the Freddo Gold Prospect in western Australia and the Barns Gold Prospect in southern Australia.

The deposits at Freddo are about 35 metres underground and were discovered by exploratory drilling. But the deposits are not worth mining and the area is undisturbed and covered by large eucalyptus trees in an open, woodland setting. The picture shows the kind of strata and the depth of the root structure. At Barns, which lies over a sub-economic gold deposit, previous studies have shown that the fluids extracted from the trees that grow there, as well as the calcium-rich mineral content of the soil, have an unusually high gold content.

Freddo and Barns, thus, provided undisturbed samples of eucalyptus trees in a natural setting, for laboratory testing. That plants take up gold nanoparticles has been established, but earlier studies have used gold concentration that is higher than what is found in real locations. And the studies have not always used the plants that actually grow in the areas of interest. The present study hence used greenhouse plants of the same species found in Freddo and Barns and studied where and how much the gold accumulation was, for different concentrations in the soil.

The results showed that the foliage of trees at Freddo, over deeply buried gold deposits, and in the case of Barns, the fluid extracted, had gold particles in the same way as in the laboratory. The detailed study also shows the role of other elements, particularly calcium, which participates in the uptake of gold and apparent sequestering of the metal to the periphery of the plant, for the protection of the plant. And also the collection of gold in the soil as a result of leaves that fall from the tree. The study, in any case, shows that biogeochimistry is a viable and reliable prospecting tool. "Collectively," the authors say, "these results are important for mineral explorers to consider as they access more difficult terrain with deeper sediments and assess more subtle surficial geochemical anomalies."

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CELLULAR STRUCTURE

TAPAN KUMAR MAITRA DWELLS ON THE CYTOLOGICAL STRAND CONNECT

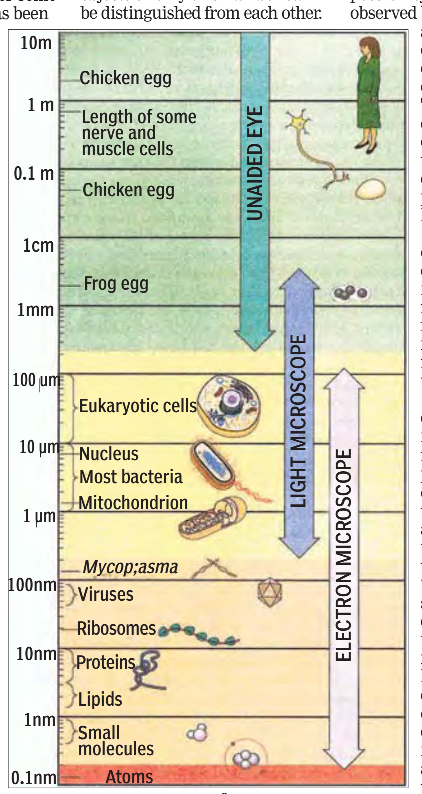
Strictly speaking, cytology is the study of cells — the literal meaning of the Greek word *cytos* is "hollow vessel", which fits well with Robert Hooke's initial impression of cells. Historically, however, cytology has dealt primarily with cellular structure, mainly through the use of optical techniques. Let us consider some of the microscopy that has been important in cell biology.

■ The light microscope was the earliest tool of cytologists and continues to play an important role in the elucidation of cellular structure. Light microscopy allowed cytologists to identify membrane-bound structures such as nuclei, mitochondria and chloroplasts within a variety of cell types. Such structures are called organelles ("little organs") and are prominent features of most plant and animal (but not bacterial) cells.

■ Other significant developments include the invention of the microtome in 1870 and the availability of various dyes and stains at around the same time. A microtome is an instrument for slicing thin sections of biological samples, usually after these have been dehydrated and embedded in paraffin or plastic. The technique enables rapid and efficient preparation of thin tissue slices of uniform thickness. The dyes that came to play so important a role in staining and identifying subcellular structures were developed primarily in the latter half of the 19th century by German industrial chemists working with coal tar derivatives.

Together with improved optics and more sophisticated lenses, these and related developments extended light microscopy as far as it could go — to the physical limits of resolution imposed by the wavelengths of visible light.

As used in microscopy, the limit of resolution refers to how far apart adjacent objects must be in order to be distinguished as separate entities. For example, to say that the limit of resolution of a microscope is 400 nanometres (nm) means that objects need to be at least 400 nm apart to be recognisable as separate entities, whereas a resolution of 200 nm means that objects of only this number can be distinguished from each other.



(A nanometre is 10^{-9} or one-billionth of a metre; 1 nm= 0.001 mm.)

The smaller the limit of resolution, the greater the resolving power of the microscope.

Expressed in terms of l, the wavelength of the light used to illuminate the sample, the theoretical limit of resolution for the light microscope is l/2. For visible light in the wavelength range of 400-700 nm, the limit of resolution is about 200-350 nm.

■ The type of microscopy thus far is called *brightfield* microscopy because white light is passed directly through a specimen that is either stained or unstained, depending on the structural features to be examined. A significant limitation of this approach is that specimens must be fixed (preserved), dehydrated and embedded in paraffin or plastic.

The specimen is therefore no longer alive, which raises the possibility that features observed by this method could be artifacts or distortions due to the fixation, dehydration and embedding processes. To overcome this disadvantage, a variety of special optical techniques have been developed that make it possible to observe living cells directly.

These include phase-contrast microscopy, differential interference contrast microscopy, fluorescence microscopy, confocal microscopy and digital video microscopy.

Phase-contrast and differential interference contrast microscopy make it possible to see living cells clearly. Both these techniques enhance and amplify changes in the phase of transmitted light as it "sees" through a structure that has a different refractive than the surrounding medium. Most modern light microscopes are equipped for phase-contrast and differential interference contrast in addition to the simple transmission of light, with conversion from one use to another accomplished by interchanging optical components.

Fluorescence microscopy enables researchers to detect specific proteins or other molecules that are made fluorescent by coupling them to a fluorescent dye. With the simultaneous use of two or more such dyes, each coupled to a different kind of molecule, the distributions of different kinds of molecules can be followed in the same cell.

An inherent limitation of fluorescence microscopy is that the viewer can focus on only a single plane of the specimen at a given time, yet fluorescent light is emitted throughout the specimen. As a result, the visible image is blurred by light emitted from regions of the specimen above and below the focal plane, which historically limited the technique to flattened cells with minimal depth. This problem is largely overcome by confocal scanning, in which a laser beam is used to illuminate a single plane of the specimen at a time. This approach gives much better resolution than traditional fluorescence microscopy when used with thick specimens such as whole cells. Further, the laser beam can be directed to successive focal planes sequentially, thereby generating a series of images that can be combined to provide a three-dimensional picture of the cell.

Another recent development in light microscopy is digital video microscopy, which makes use of video cameras and computer storage, and allows computerised image processing to enhance and analyse images. Attaching a highly light-sensitive video camera to a light microscope makes it possible to observe cells for extended periods of time using very low levels of light. This image intensification is particularly useful for visualising fluorescent molecules in living cells with a fluorescence microscope.

A major breakthrough in resolving power came with the development of the electron microscope, which was invented in Germany in 1932 and came into widespread-biological use in the early 1950s. In place of visible light and optical lenses, the electron microscope uses a beam of electrons that is deflected and focused by an electromagnetic field. Because the wavelength of electrons is so much shorter than that of photons of visible light, the limit of resolution of the electron microscope is much better than that of the light microscope: about 0.1-0.2 nm for the electron microscope compared with about 200-350 nm for the light microscope. Indeed, the electron microscope has about 100 times more resolving power than the light microscope. As a result, the useful magnification is also greater: up to 100,000-fold for the electron microscope, compared with about 1,000-1,500-fold for the light microscope.

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A resurrection of sorts

KASHMIRA GANDER REPORTS ON AN AMPHIBIAN CONSIDERED IMPORTANT IN SCIENTIFIC RESEARCH BEACAUSE OF ITS ABILITY TO REGENERATE SEVERED LIMBS

A rare salamander-like amphibian has been spotted in its only known natural habitat, and this after researchers feared the creature had disappeared from the wild. Mexican biologists have seen, but not caught, two axolotls during a second attempt to find them in the Xochimilco network of lakes and canals of Mexico City. They took to the muddy waters of Lake Xochimilco in small boats last year and searched for weeks for the amphibian, but to no avail. But biologist Armando Tovar Garza, of Mexico's National Autonomous University, said members of the team carrying out the search had seen two axolotls during the first three weeks of a second survey expected to conclude in April. "We weren't able to capture them... because the behaviour of the axolotl makes them very difficult to capture," he said. "But we have had two sightings. That's important, because it tells us we still have a chance."

The axolotl has a slimy tail, plumage-like gills and a mouth that curls into an odd smile, and is known as the "water monster" or the "Mexican walking fish". Growing up to a foot long, axolotls use four stubby legs to drag themselves along the bottom or thick tails to swim in Xochimilco's murky channels while feeding on aquatic insects, small fish and crustaceans. It is regarded as important in scientific research because of its ability to regenerate severed limbs.

Some axolotls still survive in aquariums, water tanks and research labs, but experts said those conditions were not the best, because of interbreeding and other risks. Releasing captive-bred axolotls into the wild is not an option as it could spread a fatal fungus and reduce their genetic diversity.

The "floating gardens" of earth piled on reed mats that the Aztecs built to grow crops where axolotols live in the wild, are now suffering from pollution, urban sprawl and invasive species. Tovar Garza said some small mutations, possibly the result of interbreeding, had already been seen.

An axolotl in a tank at the Chapultepec Zoo in Mexico City.

Alarmed by the creature's falling numbers in recent years, researchers built axolotl "shelters" in Xochimilco to help them breed in the cleanest part of their remaining habitat. Sacks of rocks and reedy plants act as filters around a selected area, and cleaner water is pumped in to create better conditions.

The Mexican Academy of Sciences said a 1998 survey found an average of 6,000 axolotls per square kilometre, a figure that dropped to 1,000 in a 2003 study and 100 in 2008.

THE INDEPENDENT

PLUS POINTS

Genome decoded

The genome of a species of hot pepper or chilli, *Capsicum annuum*, has been sequenced and can now help improve a vegetable used for adding a pungent flavour to food as also a means to more effectively select and develop varieties with different flavours, textures, nutrition and colour. This will involve a procedure towards a higher, more disease-resistance yield.

The research was led by Doil Choi, professor of plant science and director of the Plant Genomics and Breeding Institute at Seoul National University, South Korea. The variety sequenced is a domesticated strain of *Capsicum annuum* found in Morelos, a state in Mexico. This local variety, known as *Criolo de Morelos* 334, has high resistance to a range of plant pathogens and is widely used in research and breeding programmes. The research team also provided sequences for two more cultivated varieties, *Perennial* and *Dempsey*, and a related *habanero* pepper species called *Capsicum chinense*.

The team looked for genetic influences that could underlie the hot pepper's pungency, ripening process and disease resistance, and found different molecular patterns of ripening in hot pepper and tomato (a related genus). The results show that the pungency of the hot pepper originated from the the evolution of new genes by duplication of the existing ones and changes in gene expression.

"Like most genome sequencing projects, the pepper genome, especially when compared to genome sequences of relatives (such as tomato and potato) provides some insight into how evolution (either through natural selection or domestication where selection has been guided by humans) has shaped the modern genome of the organism," said James J Giovannoni, professor at the Boyce Thompson Institute for Plant Research, an independent non-profit affiliated with Cornell University, New York.

"The hot pepper genome sets the stage for further studies using comparative genomics, metabolic engineering and transgenic approaches to unveil the complete pathway of capsaicinoid biosynthesis in capsicum species," said the researchers in the paper published in *Nature Genetics* on 19 January. Capsaicinoids are responsible for the pungency in hot pepper and more than 22 of these compounds are already known. These also have health benefits in that they inhibit tumour growth, relieve arthritis-related pain and help towards suppressing appetite during weight loss programmes.

CSE/DOWN TO EARTH FEATURES SERVICE

Double trouble

Black carbon, a pollutant emitted due to incomplete combustion of fossil fuels, biofuel and biomass, is blanketing the atmosphere above the Brahmaputra Valley in two layers. Usually there is just one layer of the pollutant and the valley has been experiencing change in local climate, ostensibly because of the double layers of black carbon. Surface temperature increased at the rate of 0.03 kelvin per year (one kelvin equals -272° Celsius) from 1980 to 2005, and precipitation has been increasing at the rate of four millimetres per year.

Black carbon is an aerosol pollutant that does two very different things in the earth's atmosphere. It reduces the amount of sunlight that reaches earth's surface by absorbing and scattering light, but also absorbs heat and radiates it back to earth, causing atmospheric warming.

During an experiment headed by the Indian Institute of Tropical Meteorology, black carbon levels were measured above Guwahati (the largest city in the Brahmaputra Valley) from an aircraft for three days in August and September 2009. The data showed something anomalous and interesting. Usually, black carbon levels are found to increase in the layer of air closest to earth's surface (called the boundary layer). The extent of this layer differs as per local conditions. Above the boundary layer, black carbon levels are usually steady, or drop until a height of 3.5 km. But above Guwahati, a second layer was found, five to six kilometres from the surface. "Due to this second layer, an additional heating of around 2 K/day is reported to occur at five-six kilometres in the atmosphere over (the) Brahmaputra Valley resulting in a doubling of the radiative heating in 2009," says lead author of the study Rahul PRC, a scientist with the Indian Institute of Tropical Meteorology. "The second layer is forming probably because of the largescale monsoon circulation winds that transport black carbon up to five-six kilometres," he adds.

Arindam Chakraborty from the Centre for Atmospheric and Oceanic Sciences at the Indian Institute of Science, Bengaluru, says that formation of a second layer is plausible. "However, there will probably be seasonal variations in the levels of black carbon," he adds. "Some studies show that black carbon is washed away during the rain. One can expect lower black carbon levels after the monsoons. You do need more measurements, spread out through the year, to arrive at more conclusive data."

The study was published in Scientific Reports on 14 January.