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EDITORIAL

Gold: Macroeconomics and Nanoscience

Early March is always dominated by the Finance Minister's presentation of the Annual Budget in Parliament, made invariably on the last day of February; a ritual that appears to have few parallels elsewhere in the world. Budget watchers, many of whom should know better, wait with bated breath for the policy announcements that may revive the flagging spirits of the economy. Would there be new proposals that might inject even a limited dose of Keynsian 'animal spirits', alluded to by the Prime Minister not too long ago? As a curious, but completely ignorant bystander, I have always been struck by the fact that even a generally excitable group of parliamentarians appears to subside into thoughtful silence, as Finance Ministers over the years have quoted dry statistics and flowery poetry in long speeches, while experts wade through the voluminous budget proposals seeking evidence for fresh initiatives. This year was no exception. The poets may have been less evident and the deficits more prominent, but there was one sentence that caught my eye: 'The household sector must be incentivised to save in financial instruments rather than buy gold.' The Finance Minister seemed weighed down by the growing imbalance between the import and export of the total of goods, services and transfers that contributes to the country's rising debt. He was candid: 'My greatest worry is the current account deficit (CAD). The CAD continues to be high because of our excessive dependence on oil imports, the high volume of coal imports, our passion for gold and the slowdown in exports.' Why had the Finance Minister turned his guns on gold?

Trained as a chemist and having drifted away to the fringes of biology decades ago, I have never had even a passing interest in the precious metals. For me, elemental gold and its relatives have always been tucked safely out of sight, in the recesses of Mendeleev's Periodic Table. My interest in gold was sparked, momentarily, a few months ago by an announcement that a university would reward its stellar students with gold medals, each containing 5 grams of 'pure gold'. The unstated implication was that the medals of yesteryear were contaminated or probably largely composed of baser metals. Shortly thereafter, I was reminded that I too was the recipient of a gold medal, undoubtedly conferred by an error of judgement, which had remained uncollected for several years. The organization was kind enough to suggest that it might be sensible to collect the medal as it was fashioned from an unspecified quantity of gold, presumably of a desirable purity. I remained disinterested until the Finance Minister and the March issue of the journal *Nature* aroused my interest in gold. Indeed, in his post-budget interactions with the press and the public, the Minister seemed almost wistful: '…if we do not import gold for one year, half of our current account deficit will disappear.' The Minister's aversion for gold appears, to an uninformed observer like me, to stem from the fact that gold imports in India lead to an excessive outflow of foreign exchange. The imported gold disappears into private hands in widely dispersed hoardings, which contribute negligibly to economic growth. Vanity and a well honed hoarding instinct contribute to India's insatiable and unsustainable desire for gold. The journal *Nature* in its special supplement on 'Gold' provides a very broad overview of the international scenario on production and consumption, even while drawing attention to state-of-the-art applications in science and technology of a metal that has always occupied centre stage in human affairs.

The prefatory editorial note, introducing the special section in *Nature* (2013, **495**, S1), reminds us of the 'celebrated place' that gold (element 79 in the periodic table) occupies in 'the history of science and technology'. Michael Faraday experimented with colloidal gold in experiments that today would have qualified as nanoscience (and even possibly, nanotechnology). Ernest Rutherford ushered in the age of atomic physics and chemistry, by bombarding a slice of gold foil with alpha particles and interpreting his results in terms of a nuclear model, that forever altered our view of atoms. More recently, the electronics revolution has been driven by the elements. While silicon occupies the pride of place, gold has played a critical but unobtrusive role. The supplement's editor, Herb Brody, reminds us of gold's place in language: 'Its contribution to metaphor alone is legion – who would want a therapy that is, let us say, the silver standard.' Gold's electronic structure, rarely discussed in chemistry courses, is responsible for its characteristic colour, the golden hue which has captivated humanity for millennia. Most remarkably, gold can play tricks with light; a property that lies at the heart of the ongoing photonics revolution. Neil Savage draws attention to a chalice, the Lycurgus Cup displayed in the British museum, which has a jade colour in ambient light, but glows bright red when light shines through it. The artisans who crafted the goblet embedded 'tiny beads of gold and silver, about 70 nanometres in diameter' into the glass, creating an artefact, which clearly must find a place in the pre-history of nanotechnology. The properties of gold, as the metal is shrunk to nano-dimensions, are truly spectacular. Light striking surfaces with nanometer dimensions orchestrates a symphony of gold's electrons, resulting in the phenomenon of surface plasmon resonance which drives much of modern research in photonics (Savage, N., *Nature*, 2013, **495**, S8). Gold nanoparticles appear to be a 'goldmine' for research in the areas of solar energy conversion and nanoelectronics and in building metamaterials 'that seem to defy common sense'. Gold, more precisely 'nanogold', has been tantalisingly promising in the area of catalysis. The ability to produce truly nanoscale gold particles often containing a well defined number of atoms (clusters) fuels much of the excitement in the applications of gold in nanotechnology. Mark Peplow traces the history of gold particle mediated catalysis to the late 1980s, when Japanese chemists discovered the catalytic conversion of noxious carbon monoxide, produced in automobile exhausts, to the more benign (although I suspect some may disagree) carbon dioxide (*Nature*, 2013, **495**, S10). Since then, gold catalysts periodically surface in the literature, although there are few major successes. For the mechanistically inclined, the idea that gold atoms at the 'corners' of nanoparticles are catalytically competent has triggered the hunt for smaller and smaller, viable gold clusters.

Western medicine has always been wary of heavy metals, advocating a cautious approach towards therapeutic mixtures used in some forms of traditional medicine which contain apparently significant amounts of toxic elements. Gold nanoparticles have entered modern biomedical research through the exploding field of diagnostics; gold's ability to change colour has been widely exploited for detecting molecules and organisms. An area that currently appears to be attracting increasing interest is the ability of gold nanoparticles to act as transporters for drugs. Disguising the gold particle surface with nucleic acids is a stratagem that is being explored for transporting them 'into the cytoplasm without eliciting an immune response'. Cancer therapy, where distinctions between malignant and normal cells are essential, is an area where gold nanoparticles are being touted as the vehicle for the next advance on a very difficult front. Toxicity issues rear their head with predictable frequency, but growing evidence suggests that gold nanoparticles may be safer than the critics think (Weintraub, K., *Nature*, 2013, **495**, S14). In many technological applications of gold, cost issues invariably arise. The very factors which make gold the central element of the world economy may mitigate against its widespread use in the devices of the future.

The trouble with the metals is that they must be mined and the ore processed by procedures which are far from being environmentally benign. The extraction of gold using procedures that employ cyanide can leave the mining countryside devastated. Worldwide, the annual production of gold is miniscule compared to some of the other elements. 2011 figures, cited in the *Nature* Supplement, reveal that 2700 tonnes of gold were produced as compared to 8 million tonnes of silicon, 44.1 million tonnes of aluminium and 16.1 million tonnes of copper. Clearly, gold production is controlled and reserves carefully protected. The top ten producing countries are China, Australia, USA, Russia, South Africa, Peru, Indonesia, Canada, Uzbekistan and Ghana. The unrestrained passion for gold in India makes this country one of the largest importers of gold, much of it finding its way into private hoards. India comes in at the 11th position as far as 'official gold holdings' are concerned, a position that may not entirely please those who manage the country's finances. In times of economic crisis and in the face of global economic competition, 'physical gold holdings constitute a crucial geopolitical variable' (Chossudovksy, M., 2013; http://www.globalresearch.ca). It may be of some interest to ask how physical gold holdings held by central banks are audited. India's vast unaudited and hidden hoards of private gold may contribute negligibly to national wealth. With the increasing use of gold in electronics and the dramatic growth in the use of the many devices of the information age, it has become relevant to address issues of recycling. Encouragingly, the *Nature* overview suggests that for the period 2007–11 mining contributed 61.4% of gold produced while 37% came from recycling procedures. Only a small amount, 1.6%, was attributed to releases from governmental reserves. A fact that might surprise some, as it did me, was that 'the "urban mine" of electronic waste – old computers, mobile phones and the like is far richer than natural deposits; a typical open-pit mine will yield between 1 and 5 grams of gold per tonne, but mobile phone handsets can contain up to 350 grams per tonne gold and computer circuit boards up to 250 grams'. Recycling procedures appear to be becoming sophisticated and efficient and most importantly, environmentally friendly (Owens, B., *Nature*, 2013, **495**, S4). Inevitably, there is the hope that biology will trump chemistry. Microorganisms provide promising leads for leaching gold and for producing nanoparticles via a biological route (Gwynne, P., *Nature*, 2013, **495**, S12).

Gold prices have been rising exponentially over the last few years; undoubtedly an outcome of global economic turbulence. While importing oil may be an essential necessity, paying exorbitantly for gold to satisfy private vanity appears to be a path that is unlikely to help an ailing economy. Can vanity be moderated? Shakespeare may have provided wise counsel in the *Merchant of Venice*. Portia's suitor, the Prince of Morocco, chose a gold casket in which he hoped to find her portrait. Instead he found the picture of Death, with a message:

'*All that glisters is not gold,*
Often have you heard that told,
Many a man his life hath sold,
But my outside to behold,
Gilded tombs do worms enfold.'

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