Relevance of mathematics to other branches of science

I enjoyed going through the special section on Mathematics[1]. For obvious reasons I could especially empathize with the views expressed by Desiraju and Nanjundiah.

What surprised me, however, was that none of the authors has even marginally referred to the view that 'by giving so much emphasis on mathematics, science seems to be losing sight of the wider context of its vision'[2]. Perhaps this only reflects the extent of David Bohm's fall from grace!

1. *Curr. Sci*., 2005, **88**, 360–423.
2. Bohm, D. and Peat, F. D., *Science, Order and Creativity*, Routledge, London, 2000.

S. RAJAPPA

B-1, Melody Apartments,
12, ICS Colony,
Pune 411 007, India
e-mail: p_rajappa@vsnl.com

Upon going through the special section I remembered an incident, which I witnessed few years ago. I was then a member of a committee empowered to select a young chemist for a national level award. About 12 promising scientists presented their work with the proper introduction and background, philosophy of the Institute they work, philosophy of chemistry or science in general, etc. At the end of it all, the Chairman of the committee mentioned that everything was fine but there was no chemistry in any of the talks! Naturally, no award was given that year!

To me, in this special section, there is everything but Mathematics (except one article, p. 405). As a member of the editorial board of *Current Science* I must welcome this effort, however, I wish this special section was named as 'Mathematics and Philosophy' or 'Mathematical Philosophy' or the like.

DIPANKAR CHATTERJI

Molecular Biophysics Unit,
Indian Institute of Science,
Bangalore 560 012, India
e-mail: dipankar@mbu.iisc.ernet.in

The special section on Mathematics is outstanding. The role of mathematics *vis-à-vis* the physical world, and its effectiveness (unreasonable or otherwise!), are deep questions that should certainly exercise not only scientists and technologists but also every thoughtful person. The articles are uniformly excellent, instructive and thought-provoking. Together, they constitute a most valuable collection of essays on almost all facets of this important topic.

I would like to mention a couple of very pertinent additional references in this regard for the benefit of some readers who may perhaps be unaware of them. An incisive discussion is presented in J. D. Barrow's book, *The World Within the World* (Oxford University Press, 1988). Chapters 5 ('Why are the laws of Nature mathematical?') and 6 ('Are there any laws of Nature?') deal with several of the issues involved in a very readable fashion. Evidently, the author thought the subject was quite important, because he returned to it a few years later in a full-length book, *Pi in the sky… Counting, Thinking and Being* (Oxford University Press, 1992). I would recommend these books to anyone with an interest in the basic mystery of whether mathematics is in our minds or whether it is 'really out there'.

It seems to me that each individual who thinks about this question presumably evolves a personal working philosophy. Without getting into metaphysical discussions which are well beyond my purview and competence, my own opinion (for what it is worth) is that the 'truth' probably lies 'in between', and that the question of whether mathematics is subjective or has objective reality is in itself a loaded one that cannot have a completely unambiguous answer. The discussion will presumably go on, much like the discussion of whether; in the ultimate analysis, 'the continuum is more fundamental than the discrete', or the other way around.

V. BALAKRISHNAN

Department of Physics,
Indian Institute of Technology – Madras,
Chennai 600 036, India
e-mail: vbalki@physics.iitm.ac.in

Phytomining of gold

The Kolar Gold Fields (KGF) in Karnataka, locally known as Bangarapet (city of gold), was a premier gold mining area in India and was operated by the Bharath Gold Mines Limited (BGML). The mines have a recorded history of nearly 200 years of operation. Owing to a faulty process of extraction, defective and outdated technology and deep mining, there has been an escalation in the production cost of gold over time rendering it uneconomic. The production[1] during the first decade of the last century was around 45 g/t while during 1999, it was approximately 3 g/t. Hence the union government decided to close the mines. The closure of the mines eventually created a catastrophic impact on the inhabitants of KGF. Before the closure of the mines, the government was thinking about rehabilitation measures and many expert committees visited the place and submitted alternative proposals to continue mining activities. A team headed by C. P. Nair, Chief Technical Advisor, Ministry of Steel and Mines and K. V Krishnamurthy, Deputy Director of Geological Survey of India suggested[2] an unmined parallel reef in 1990. One of the panels had even proposed a scheme to recover gold from larger residual dumps (mounds of tailings) that had accumulated over the years[3]. Studies have shown that there are about 33 million tonnes of dumps accumulated over the years which may be a source of 24 tonnes of gold. The use of phytomining technology may prove to be a novel cost-effective technology to extract gold from these tailings and also from low grade ore (extraction grade less than 3 g/t).

Use of plants to extract metals from ore is called phytomining. The uptake of gold by plants has fascinated scientists for over 100 years but no hyper-accumulator-species for this metal has been reliably reported. This is due to gold's low solubility in a soil environment. Induced hyper-accumulation of gold by plants was first reported[4] in 1998. Preliminary research conducted in our laboratory also proved that some of the terrestrial wild cultivars of local plants are the best candidates for this purpose and accumulate high amounts of gold up to 30–40 mg/kg of plant dry weight (unpublished data) in the presence of a known chelating agent which increases the availability of gold to plant roots.

The concentration of gold that can be induced into a plant is dependent upon the gold concentration in the soil on which a plant is growing[5]. Experimental results showed that plants will accumulate approximately 20% of the total amount of gold available within a root zone based on any one treatment by different chosen chelating agents[6]. The 20% recovery rule was proved to be true for many tested plant species. Anderson and his coworkers showed that approximately 2 mg of gold per kg of soil is needed by considering a soil profile of 20 cm depth to achieve 100 mg/kg of plant dry biomass. The model also assumes a harvested biomass of 10 tonnes/ha and a gold concentration of 100 mg/kg of plant dry weight. This will yield 1 kg of gold per hectare. It has been proved that the conventional solvent extraction method to recover gold from 1 tonne of ash obtained by incinerating 10 tonnes of dry plant material, is an economically viable option.

A study was conducted at the Fazenda Brasileiro Gold Mines[6], north of Salvador, Brazil during April–July 2003. The extraction grade of ore was approximately 1.5 g/t. The plants *Brassica* sp. and *Zea mays* were used as hyper-accumulator plants and the results proved that the phytomining technology is a cost-effective promising technology. There is an urgent need to conduct some field experiments and optimize this technology in KGF soil using ore tailings and fresh ore sample to develop some economic models. If a proper approach is given to address this problem using phytomining technology, the city of gold will regain its glitter soon.

1. Annual Report 1999–2000, Bharat Gold Mines Limited, chapter VI.
2. http://www.deccanherald.com/deccanherald/jun222004/spt1.asp
3. http://www.deccanherald.com/deccanherald/jun072004/s8.asp
4. Anderson, C. W. N., Brooks, R. R., Stewart, R. B. and Simcock, R., *Nature*, 1998, **395**, 553–554.
5. Mohan, B. S., Ph D thesis, Mangalore University, 1999.
6. Anderson, C., Stewart, B., Wreesmann, C., Smith, G. and Meech, J., Proceedings of the Fourth International Conference on the Intelligent Processing and Manufacturing of Materials (IPMM) (eds Meech, J. A. *et al.*), Sendai, Japan, 18–23 May 2003.

B. S. MOHAN

Centre of Biosciences,
T. John Group of Institutions,
B. G. Road,
Bangalore 560 083, India
e-mail: mohanbettageri@yahoo.com

Systems biology is all noise

Old age is generally characterized by a set of debilitating health conditions. The symptom-free and the disease-free definitions of old age are unpopular. Likewise, a perturbation-free description of gene expression is uncommon, i.e. the gene expression profile is usually defined in relation to changes in environmental conditions, both external and internal.

Michael Elowtiz[1] and his colleagues showed that genes do not *talk* they actually *chatter*, i.e. the gene expression flux varies significantly during transcription. Cells heuristically guide transcriptional machinery towards an optimized output while retaining the noisy expression profile in the background. To understand the gene network dynamics, it may be intuitive to follow the 'conversation', but studies hint that 'chatter' may be equally or even more important[2–5]. Thus a complete understanding of the system would emerge by taking into account the optimal trajectories of gene expression, the range within which genes express themselves and the underlying reason of chosen trajectories. Thus, the key to understanding gene behaviour in a multi-component and hierarchical network lies in the ability to systematically capture, manage and analyse gene expression noise, while following the optimal solution temporally. Here I discuss various aspects of noise dynamics and try to build a case for 'noisome'—a perturbation-free, time-correlated, background gene expression profile under normal physiological conditions. Since the expression data can be temporally sampled in a controlled environment using defined genes, promoters and environment, it is experimentally feasible to build a module-centric, network-centric or cell-centric noisome. Noisome can serve as a reference point for understanding the mechanistic basis of perturbation-induced variations with their corresponding phenotypic outcomes.

What are the raw materials and challenges in building 'noisome'? At the component level, the primary requirement is the availability of a reproducible time-series expression data[6]. At the network level, it is the availability of expression data of at least a pair of interacting genes. Due to experimental limitations and prohibitive lab costs, it is unfeasible to cover all the desirable time points. To overcome this limitation, computational modelling can be used to fill-in the missing data points between any two experimentally derived data points. Of various qualitative and quantitative methods of animating gene expression *in-silico*, stochastic approach gives the most accurate solution. However, both stochastic and spatio-temporal algorithms impose the immense computational burden and are painfully slow. On the other hand, Tau–Leap methods, hybrid algorithms and parallel algorithms are among the fastest simulation algorithms, but are less rigorous. A good compromise is offered by Stochsim and Gibson algorithms, which increase the speed of simulation without sacrificing the accuracy of solutions[7].