having ignored him till then. Chandrasekhar's election as a fellow in 1944 ended his professional isolation in British India which had begun in 1935 with Sir Arthur Eddington's imperious dismissal of his now-celebrated white dwarf work. Interestingly, Eddington strongly supported Chandrasekhar's nomination.

Not surprisingly, (what is now) the Indian National Science Academy (INSA), set up in 1935, was modelled after the Royal Society. Curiously, of the Society fellows since elected, B. P. Pal is the only one who was not a fellow of INSA.

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Genetically modified organisms – A brave new world??

Recent researches have enabled manipulation of the existing genetic configurations of organisms, thereby giving rise to what in scientific parlance are called genetically modified organisms (GMOs). These can be microbes, plants or even mammals. Are we not then eventually playing God to ourselves? Even creation can now be challenged, modified and manipulated. Alterations are possible to what was even a few years back considered inevitable and providential; for example, dwarfism, if detected early, can be genetically modified to help escape from such a disorder.

Genetically modified bacteria are routinely used in the production of human therapeutics and offer impressive proof of clinical efficacy and safety to human beings. For instance, human insulin gene has been expressed in *E. coli* and has been approved for clinical use in humans for the treatment of diabetic patients. In another example, the recombinant bacterial product is human tissue plasminogen activator used in the treatment of patients with acute myocardial infarction. Besides, interleukins, interferons, serum albumin and superoxide dismutase, are also produced from recombinant bacteria for different clinical uses. Another thrust of GMOs is in the agricultural sector. Leguminous plants such as soybean form symbiotic associations with *Rhizobium*, *Bradirhizibium* and *Frankia* bacteria, which fix atmospheric nitrogen to the soil by *nif* gene. Now-a-days genetically modified *Rhizobia* have been added to the soil as legume inoculum, to reduce need of the nitrogenous fertilizer.

Like bacteria, GM crops are also coming up very fast; these crops are endowed with higher yield, nutritional quality and resistance to insects and pests. This could be done by modifying genomes of crop plants through biotechnological methods. Several genes are available for designer crops; for example; *glufosinate* (herbicide resistance), *Bacillus thurigiensis* toxins (insect resistance), *barnase* (male sterile), *virus coat protein* (virus resistance). Many commercial organizations utilize technical development, both for commercial and developmental purposes. Different crops have been modified and are in commercial use; for example, herbicide-resistant canola and sugarbeet, insect-resistant cotton and tomato, virus coat progein-resistant papaya, squash, soybean and potato and male sterile corn for hybrid seed production. The next generation rice with more vitamin A and transgenic tomato, with an anti-freeze gene, which will increase its shelf life, are on the way to more widespread commercial use.

In animal husbandry too, GM animals are on their way. For example, designer eggs and genetically engineered salmon fish with human growth hormone are just waiting to appear on our dining tables, subject to regulatory approval. And, waiting in the pipeline are fast-growing trout and catfish, oysters which can withstand virus, as well as an 'enviropig', whose faeces is supposed to contain less phosphorus and therefore will be less harmful to the environment.

Lay people are concerned about the safety of genetically engineered organisms and GM food, as one is not yet aware of the long-term effects on human health and on the ecological environment. Genes that make crops herbicide-resistant could spread by pollination to weedy relatives, creating super weeds. Or fish with growth hormones which make them grow faster, might out-compete others for food or mate.

Genetic food alert (GFA) was founded by the UK wholefood trade in 1998 to compaign for a GM free trade, and ask for a ban on the production, import and sale of GM food. Companies should provide a summary of products, their safety and nutritional assessments, and discuss their result prior to commercial distribution. Talks on these topics broke down at the WTO in December 1999 at Seattle, USA. The Third World united to stop WTO, multinationals and biotech industries from release of GM foods and crops, arguing that the GMOs are 'anti-environmental', promote an 'exploitative economic system' and are 'anti-union'. They also asked for an immediate five-year freeze on these products. There is fear among the general public because of the perceived threat to health and environment, as seen in the after-effects of the occurrence of mad cow disease in Britain and dioxin-tainted chicken in Belgium.

The examples cited above show that alterations in the smallest unit of organic life form can have far reaching changes. There is another side that is beyond the merely biological/scientific issue, namely legal and ethical. The pressing question is to what extent should we lead our lives according to the directions of a handful of scientists, whose promotion of the new technologies can have unforeseen consequences.

Biotechnological advancement involves a lot of money. And more than that the power to control, alter and

modify the most precious thing on earth – human life. Power and money can take greed to unbelievably high levels of satiation. Worldwide protests are on the rise regarding the penetration of GMOs through multinational corporations (MNCs). In Europe, there is an increasing fear that these 'Frunkenfood', a term coined by critics for GM food are nothing but MNC strategies; after all they control most hi-tech labs. Their concern is more with increase of their own revenues and greater market control than with the damage they may be doing to public health and the environment. Hence there are legal and ethical battles regarding MNC food products all over the world.

Are we heading towards a bioengineered disaster? Or are we heading towards a bolder, brave new world where hunger, disease and physical deformities will be a thing of the past? Evolution, as they say 'is a forced random process' and risk is imperative to evolution. But from the days of cave painting to the creation of 'Dolly', without risk man would not have achieved anything. GMOs are speeding the evolution process.

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Sequencing of the human genome: Then what?

France hosted *Biovision*, the World Life Sciences Forum (7–10 February 2001) in its beautiful World Heritage City, Lyon. The timing could not have been better, just preceding the announcement of the sequencing of the Human Genome by rival research groups in journals *Nature* and *Science*. Almost every discussion in that International Conference had something to do with the consequences of sequencing, or the controversy surrounding the project.

It is surprising to me how quickly history is forgotten. Not long ago, people believed that Newtonian Physics was all that was left to be discovered. Einstein opened a new chapter in our understanding of the physical world and reduced Newton's framework as a special case of quantum mechanics. Post-Einstein, scientists are zeroing in on Unified Field Theory and String Theory. Each time a greater level of understanding was achieved, there was a sense of complacency and self-congratulation following it. The same might hold true for biology – after all, people believed for many centuries that women had fewer teeth than men because Aristotle said so! Today we may wonder why no one checked his baseless theory by asking Mrs Aristotle to open her mouth, but the chances are that scientific discussions are often steered by 'big names' and it is easy to be carried away. The high point of Biovision Forum was the dinner debate 'Sequencing of the Human Genome: Then What?', which had Craig Venter of Celera Genomics as one of the panellists. The Panel interpreted 'Then What?' in a rather mundane way, and discussed the real meaning of patents, accessibility of information, contribution of Celera, bioethics, discrimination of people with defective genes, what other organisms will be sequenced, etc. No wonder the Nobel Laureate Jean-Marie Lehn was unimpressed and asked the panel to move beyond 'Shopkeepers' discussion'.

Our improved understanding of life sciences, initially at the cellular level and now at the genomic level, is analogous to milestones such as Newton's Law and Quantum Physics, or Dalton's Atomic Theory and Sub-atomic Chemistry. Interestingly, well before Dalton came up with his concept of indivisible atom, the 9th century Tamil poet Kambar wrote: 'If an atom is split into a hundred [sub-atomic] particles, called Kones, God is in each of them' [*Or aNuvai(ch) chatha(k)kooRitta kOnilum uLan*]. It may be premature to assume that biology has answered all the questions by sequencing the Genome. Genetics may one day become a special case of a much more fundamental and detailed understanding of biology, and we need look no further than Venter's remarks to the BBC to guess this: 'Most of us thought that there were somewhere between 50,000 to 100,000 genes, but we were stunned that we only have between 26,000 and 30,000'. That human beings perhaps have only a few hundred more genes than a mouse has renewed the 'Nature vs Nature' debate, but there could be more to Nature itself.

In my opinion, Celera claims too high rewards for its efforts. For one, they started eight years after their rivals, the publicly-funded Human Genome Project (HGP), when computers were much faster and more powerful. Secondly, there are arguments that Celera could not have put its sequence together without the public HGP's data, and that the quality of information is not as superior as vaunted by the company. For example, HGP repeated the squencing four to five times instead of Celera's three. But even HGP's 99.9% accuracy is not enough, because the error is comparable to the 0.1% difference in DNA between human beings. However, a more worrying aspect of allowing industry-sponsored research into basic science lies in Venter's decision not to deposit his data in the public computer archive, *Genbank*. Although Celera has promised full access to its own database, it has set restrictions on distribution of its data. Public sector scientists say this could hinder the free flow of information, and lead to slow progress to developing cures for diseases. Some argue that it is akin to charging people to look at the periodic table! After the Panel Discussion, I asked Venter to give an order of magnitude estimate of the total cost of Human Genome Project, and Celera's expenses on sequencing. He said the total cost is about 2–3 billion USD, of which Celera spent about 60 million! With less than