In this issue

String theory

The special section on String Theory in this issue is intended to introduce readers to a field of research which has caused tremendous excitement over the last 15 years. String theory is an area of fundamental physics which attempts to consolidate the tremendous advances made in elementary particle physics over the last few decades and to push them further. Its goal is the unification of all fundamental forces including gravity, into a mathematically consistent and predictive framework.

As the reader will quickly learn, the theory has not yet attained its goal and therefore must be judged as a speculative proposal, or class of proposals, about the real world. Qualitatively, the theory describes a class of hypothetical worlds which resemble the real world in many ways: worlds with light elementary particles, some of which are bosons and others fermions, some of which carry charges and experience gauge interactions and all of which interact with the gravitational field. Along with the 'semi-realistic' nature of these worlds, the structure of the theory exhibits an unparalleled degree of beauty and internal consistency, and it incorporates a consistent quantum theory of gravitation.

Time will tell whether string theory is the correct description of our world, but the time is already ripe for a non-technical description, addressed to a general scientific audience, of the novel concepts involved and the many theoretical successes that it has already had.

In the first article, 'The theory of strings: An introduction' (**page 1624**) the basic notions, successes and limitations of the Standard Model of elementary particle physics are introduced. This is followed by a discussion of several speculative ideas which over the years attempted to remedy these limitations. Finally, the basic concepts of string theory are described in the light of this discussion. In the second article, 'Duality symmetries in string theory' (**page 1635**), emphasis is given to the striking developments of the last five years where various 'dualities' played a key role. Dualities are symmetries of string theory that map different regions of its parameter space onto each other. They provide a window into the most important and hitherto most mysterious aspects of string theory – namely, those aspects that cannot be studied in a perturbation series order by order in the coupling strength.

The third article, 'String theory and Hawking radiation' (**page 1646**) focuses on an aspect of string theory where it has scored some striking successes. String theory gives the most complete description of quantum gravity presently known, so it is not surprising that it provides an impressive microscopic explanation of the famous puzzles associated with black holes: black-hole entropy and Hawking radiation. The final article, 'The gravity–gauge theory correspondence' (**page 1659**) attempts to describe developments in the last year or two, according to which the distinction between field theory and string theory, or between gauge theory and gravity, appears to be less fundamental than previously thought. Gauge theories, similar to those which describe the nuclear forces, are 'dual' to string theory under some conditions, with a one-to-one correspondence between the physical objects on the two sides. This discovery provides an unexpected relationship according to which we can learn more about gauge theories using gravity and vice-versa. It also lends support to the presence of a fascinating physical property of gravitation, called 'holography'.

A significant omission from the present collection is any detailed discussion of specific phenomenological string-based models to describe the real world, though some general features are discussed in the various articles here. The subject of 'string phenomenology' as it is today, offers many distinct – some mutually contradictory – approaches to extracting observable particle physics from strings. Hence at present it might be premature to present a survey of this field. If string theory lives up to its promise, in due course string phenomenology would merit a special section of its own.

Sunil Mukhi

Nuclear explosion: Yield estimates

One of the important applications of modern seismology is the monitoring of global underground nuclear testing. The seismic waves generated by such explosions reveal the occurrence of the explosion and provide an estimate of its yield, in equivalent kilotons of TNT. How precisely the yield can be estimated depends on a variety of factors, including the quality of the calibration event.

The Pokhran test of 11 May 1998 was conducted at a time when the US Government was getting ready to seriously discuss the Comprehensive Test Ban Treaty (CTBT) with India. With that as a backdrop, the Indian explosion together with that of Pakistan a fortnight later, attracted tremendous international attention. The administrative as well as the scientific communities have been quite articulate about the magnitude and yield of the Pokhran blast.

Advances in seismic monitoring have broken the barriers of secrecy in nuclear testing and the treaties like CTBT are fallouts of that transparency. Today, most underground explosions are detected by global seismic stations. The detection threshold under the CTBT is reported to be 1 kt, but how precise the yield estimates are, remains debatable. It should be remembered that as in any geophysical interpretation, these estimates are also guided by model parameters. This may be one reason why the estimates of yield for the Pokhran blast by different workers vary between 15 kt to 58 kt. Using the amplitudes of regional Lg and Rayleigh waves and the 1974 Pokhran event for calibration, Roy *et al.* (**page 1669**) reiterate their earlier estimates of yield of about 58 kt, which is higher than most estimates by workers abroad. How can this disparity be explained? The authors suggest that the use of teleseismic P-wave data and constraints on other input parameters may have led to lower estimates obtained by some workers.

Kusala Rajendran

Opium-less poppy?

Any visitor to the United States is likely to be taken aback by some of the advertisements for food stuffs which I can only describe as that bordering on insanity. Would you not if you were to come across billboards proclaiming 'nicotine-less tobacco', 'sodium-less salt', and 'alcohol-less beer'? Quite obviously, these billboards are an attempt to rally the clientele from deserting the use of tobacco, salt and beer after these have been bashed about to be notorious for the maintenance of good health. The success of these harmless or should we say inert stuff such as nicotine-less tobacco, alcohol-less beer or sodium-less salt, however, depend upon how well they can deceive the consumer in believing that they are consuming what they are actually not consuming. As our knowledge about the adverse effects of many of our 'till recently safe foods' are becoming known, more and more foodstuffs and addictions are getting to be made to have a placebo. Thus we might have in the near future cocoa-less chocolates and fat-less oil, to keep the ghosts of blood pressures and related problems away. While these are frightening day-to-day concerns of the Americans, we are fortunate that we have no such problem yet or even if we do we are blissfully oblivious of the potential dangers.

But as I write this, I have before me a paper from Sharma and his co-workers (**page 1584**) on their efforts in successfully developing a opium-less poppy variety, strangely called *Sujata*. The power of addiction of opium is well known all over the world and is believed to have almost started the decline of a number of countries in the early 1960s when it took siege over a large proportion of the youth. It probably led to the most number of drug-abuse deaths leaving behind scores of morbid and physically and mentally debilitated youths all over the world. In this context, the effort by Sharma and his team to develop opium-less poppy attains profound significance. The variety is the first of its kind in the world and has been awarded a United States patent.

Opium poppy, as it is popularly referred to, contains three alkaloids, morphine, codeine and papaverine. Of these, morphine is the largest component and is well known as a potent painkiller. However, overuse of this, as by the addicts, induces severe depression and stimulation of the central nervous system in the gut leading simultaneously to sedation and euphoria and a feeling of 'heavenly bliss'. Opium is usually collected as latex by lancing the flower or fruit; the variety *Sujata* does not exude latex on lancing and of course does not synthesize these alkaloids. The authors believe that such a variety could help reduce the problems of addiction to opium poppy. However, I am not too sure. *Sujata* would discourage a potential addict as it does not exude latex, the source of opium, and is likely to turn his attention to other conventional and land races of opium varieties to reach his lofty goals!

However, as the authors point out, the variety could be used as a valuable source material to develop other opium varieties with important pharmaceutical properties. Besides, because the variety contains a high amount of oil and protein comparable and even higher than conventional crops such as rapeseed and mustard, they believe that the non-narcotic variety could contribute to enriching the edible oilseed production in the country. Thus after all, it appears that the efforts of the authors may not go in vain entirely – 'nothing less nothings do produce something'!

R. Uma Shaanker

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EDITORIAL

Biology at millennium's end

Biology is a vast continent, with a great deal of virgin territory that remains to be explored. Biology's borders with the neighbouring areas of chemistry, physics, medicine, technology and even mathematics, are extended and diffuse. Specific sub-disciplines of biology comfortably straddle the 'no-man's' land between the 'hard' and 'soft' sciences. Indeed, biology provides a somewhat tenuous link between the traditional sciences and the 'social sciences'. Extrapolation from studies of animal populations and their behaviour to the human condition can often be seductive. The promise of 'applicable' biological research, to enhance the quality of life, has been dramatically realized over the course of this century. The explosive growth of molecular biology and biotechnology and their myriad applications in agriculture and medicine have propelled biology to the forefront of the sciences. It is now a cliche to say that we live in an age of biology. Unlike its sister sciences, biology is an all-encompassing field, a forgiving religion, which welcomes all comers. It is almost impossible to enter physics, chemistry, mathematics or engineering after the first flush of youth has passed. Formal degrees and a well-defined pedigree are a necessary passport to work in these fields. In contrast, defections to biology are easy to effect (and often profitable); remarkably, in many areas formal training in other disciplines is a great advantage. Mathematical and analytical skills, familiarity with chemical language and appreciation for quantitative thinking are best acquired when young. Biology's nuances can be appreciated at a more mature age.

Many of modern biology's major triumphs have been heralded by the 'converts'. Max Delbruck deserted physics at the height of the quantum revolution to found the area of bacteriophage genetics, an historic move in the context of the development of molecular biology. Linus Pauling, the quintessential chemist, displayed remarkable prescience, when he recognized the molecular basis of disease. The story of sickle cell haemoglobin is now commonplace; the connection between point mutations in genes and pathology has been repeatedly established. The molecular analysis of genes has been profoundly helped by physicists in search of greener pastures; most notably Francis Crick, whose discovery of the double helical structure of DNA, with James Watson, is now assured immortality and Walter Gilbert, a convert from particle physics, who ironically pioneered the chemical method for sequencing DNA. In India too, the major advances in biology have come from outside the traditional departments of botany and zoology. G. N. Ramachandran's path-breaking analysis of the structure of collagen and his profoundly important insights into polypeptide chain folding were born in Madras University's physics department, eventually legitimising a new subdiscipline of 'molecular biophysics'. Structural biology, now an area devoted to analysing the enormously complex molecular structures, that are a hallmark of cellular chemistry, is a creation of crystallographers and spectroscopists, who have traditionally been physicists or chemists. Biological research has indeed been enriched greatly by the immigrants; the New World drawing its strength from the pilgrims.

At the turn of the century, biology had its inheritance; Linnaeus, Mendel, Darwin and Pasteur ranked among the immortals. In the dying years of the 19th century, Eduard Buchner (somewhat surprisingly more famous for his funnel) demonstrated cell-free fermentation by the 'juices of yeast', establishing that life processes undoubtedly follow the laws of chemistry (and physics). Biochemistry was born and quickly divorced from traditional chemistry; a clear separation of the animate from the inanimate. But, in the caste system of the sciences, biology ranked low. Almost half a century was to pass before the ugly duckling began to turn into a swan. The transformation was complete by the 1970s as biological research moved from triumph to triumph on an extremely broad front. The results of research appeared to quickly relate to practical advances in diverse fields, medicine and agriculture among them; areas of direct societal impact. These developments have been largely fuelled by the ability to isolate, clone, amplify, sequence and manipulate DNA; a package of techniques that form the heart of recombinant DNA technology. Even as the 20th century neared its end, biology's first mega project began to take shape. The 1980s saw the beginning of the discussion on the scientific utility of sequencing whole genomes of organisms. Deciphering the order in which the letters (bases) are strung together in a genome, provides a comprehensive view of the genetic instructions encoded by nature; somewhat picturesquely called the 'Book of Life'. Few would have anticipated, even in the early 1990s, that these 'mega projects' in biology would be completed so quickly. In the last few years, several genomes of microorganisms have fallen to the onslaught of large-scale sequencing. These include, pathogens like *Helicobacter pylori*, the bacterium associated with gastric ulcers and most importantly, *Mycobacterium tuberculosis*, the causative organism in TB (S. T. Cole *et al.*, *Nature*, 1998, **393**, 537). Knowledge of their genomes provides a high resolution map of the enemies' territory, presumably providing insights that may be used for eventual conquest. The results of major international efforts