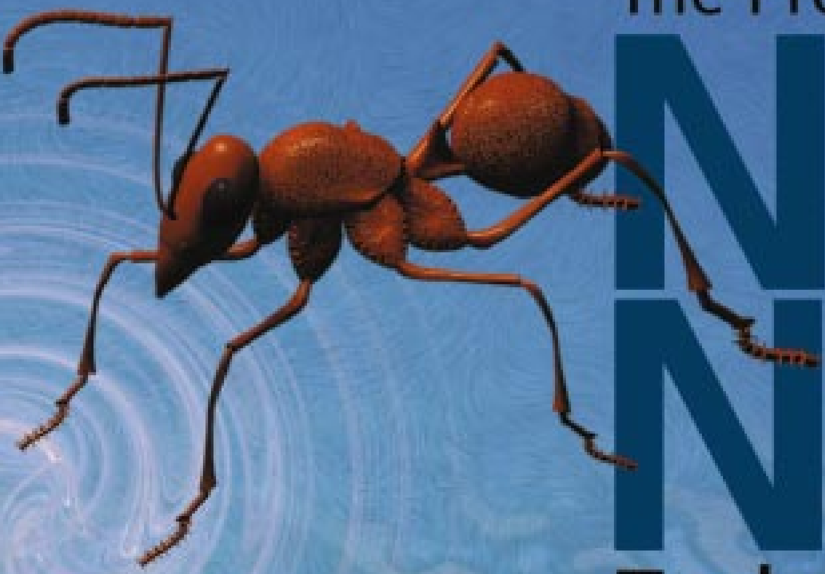
IIT BOMBAY

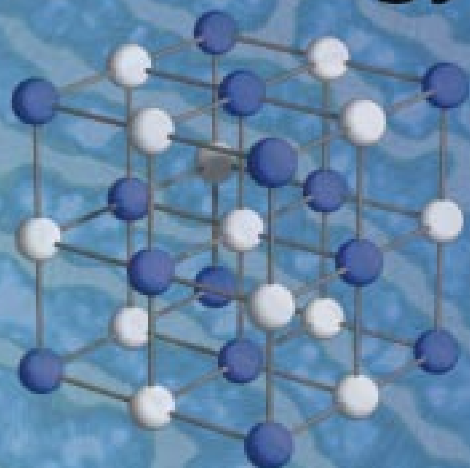
update

A Newsletter of Industrial Research & Consutancy Centre

No. 3, 2003
For Private Circulation Only
ISSN 0972-6632

The Promise of NANO Technology





- Organic Synthesis for Better Pharmaceuticals
- Development of Tools for Managing Railway Operations
- The Academia in Transition
- Globalization and its Implications for Urban Planning in India
- Globalization of R & D: The Indian Experience

Editorial

In the new R&D regime, Nanotechnology has emerged as a veritable *El Dorado*. It is likely to usher in an entire range of novel technologies in almost all areas of human endeavour. In the technology focus of this issue we present both an introduction to the subject and to the gamut of related research now underway at our institute.

In continuation with the last issue of this magazine, we explore the likely impacts of globalization on two more areas: *urban planning* and *corporate R&D*. In both cases our country may stand to gain and lose at the same time, which calls for understanding the subtle implications of the processes unfolding, and evolving effective strategies. Globalization has also entailed a lowered role of government in national economies. Reduced public spending in higher education is one of its many effects. Today, the academia has to increasingly rely on self-generated funds through mechanisms that in some ways mimic business. In *Commentary* we explore the conflicts this is causing within the academia.

The science of *organic synthesis* (i.e. mimesis) of natural molecules is a potent route for manufacture of a host of pharmaceuticals and new materials. Some of the research programmes in this field at IIT Bombay have received much acclaim. A multi-disciplinary team of faculty has been developing software tools for efficient management of railway operations. The work has the potential for securing substantial benefits for the country's railway network, one of the largest of its kind in the world. We review both these R&D activities.

Over the recent years the emphasis on developmental work has been deepening at IITB. We present an array of such successful ventures in this issue.

Sandip Roy
Editor

Initiatives for Research @ IITB

A recent report by a global consulting firm projected that India would be one of the major global superpowers in 2050. To convert this scenario to reality, India would have to attain a leadership position in science and technology. Institutions like the IITs have an important role to play in this.

IIT Bombay has decided to give a greater impetus to Research and Development (R&D). We feel that the main ingredient for successful R & D is enthusiastic young minds. To achieve this, we are launching a National Research Fellowship Scheme to provide challenging opportunities for bright young students to pursue a research career at IIT Bombay. We hope to encourage the best students around the country to pursue a research degree at our institute (M. Tech./ Ph.D) while simultaneously contributing to basic research and technology development. We plan to reach out to science and engineering colleges around the country and enthuse students about the possibilities of research in our Institute (*see back cover for details*).

India has already been recognized as a potential research hub for its competence in software and analytical skills by many global companies. It is important to realise that we can also make an impact in cutting edge research areas like Nanotechnology. Recently we organised an in-house symposium on nanotechnology showcasing the existing projects in nanomaterials, nanobiotechnology, and nanoelectronics. A look at the presentations and posters revealed that researchers at IITB are at the forefront of this rapidly growing field.

Although the Indian industry is beginning to enhance its R & D spending, currently it is only 0.5% of its sales turnover. This accounts for about 20% of the nation's total R & D expenditure. Contrast this with an industrial R & D contribution of 52% in the European Union, 68% in the US and 72% in Japan. If our industry is to be globally competitive, its focus on R & D will have to increase. This will also need enhanced industry-academic linkages.

IIT Bombay has good industrial links as evident from the large number of industrial consultancy and sponsored projects. However, many of these projects have a relatively short term focus since they address the immediate concerns of the industry. At IIT Bombay, we are keen to pursue long-term research partnerships with industry. The aim is to build joint research teams that operate across the academia-industry boundary and leverage on each other's strengths to create future technologies and products. We have initiated discussions with several large industries to build such partnerships and have been encouraged by their response. We realise that in order to build meaningful partnerships, we must enable greater industry-academia interaction. We are in the process of building a web-portal that will help in this process and facilitate innovative problem solving. Interestingly the idea of this portal was seeded by an initiative from the Ministry of Human Resources and Development. Government, Industry and Academia must work together if India is to make its mark in science and technology. IIT Bombay has also established a Society for Innovation in Entrepreneurship to facilitate the incubation of research ideas into commercial products.

As a nation we have all the ingredients required to provide a push to R&D. We must make the transition from technology followers to technology leaders. This is not by any means an easy task. We need help from the bright, ambitious researchers of the country. We need them to opt for a research career in India. We need commitment from the industry and the government to provide challenging opportunities to these researchers. At IIT Bombay we have taken the plunge with our new initiatives and hope they will have the desired effect.

Rangan Banerjee
Associate Dean (R&D)

Patron: Ashok Misra(Director) ❐ Advisory Board: K C Khilar(Dean R&D) ➢ Rangan Banerjee (Associate Dean R&D)
Editor: Sandip Roy ❐ Assistant Editor: Padma Satish ➢ Prema Prakash ❐ Illustrator: Arun Inamdar
Cover Visual : Gaurav Mathur ❐ Production: Archana Upendra

Major New Consultancy Projects

Investigator	Department	Project Title
R Sinha	Civil Engg.	Safety Evaluation of Sewage Treatment Plants Design
G Venkatachalam	Civil Engg.	Ground Improvement for Petroleum Products Storage Tank
A Mehra	Chemical Engg.	Process Intensification for 'Intermediates' Industry
H S Shankar	Chemical Engg.	Soil Biotechnology Plant for Waste Water Purification for Reuse
N L Sarda	Computer Science & Engg.	Wide Area Networking for Core Banking Applications
D Manjunath	Electrical Engg.	Multimedia Transport with VoIP and Network Video Applications
K K Trivedi	Industrial Design Centre	Design of Low Cost Multi-media Product for Community Use
K G Narayankhedkar	Mechanical Engg.	Development of Cryogenic Flow Sheet for Hydrogen Systems
M G Korgaonkar	S J M School of Management	Assessment of Competencies of Executives in Marketing Division

Major New Sponsored Projects

Investigator	Department	Project Title
S Kotha	Chemistry	Design of Novel Nano Construction Tools
A K Lala	Chemistry	National Facility for Protein Sequencing
P Mathur	Chemistry	Identification of New Systems for Metal-Oxo Clusters
M Mukhopadhyay	Chemical Engg.	Micronization of Pharmaceuticals using Supercritical Carbon Dioxide
K Ramamritham	Computer Science & Engg.	Information and Communications Technology for Development (Research and Training Centre)
V Sethi	Centre for Environmental Science and Engg.	Design and Development of Clean-up Systems for Producer Gas from Thermal Gasification of Biomass
G Mohan	Earth Sciences	Broadband Exploration of the Indian Continental Lithosphere for Imprints of Deccan Volcanism
G G Ray	Industrial Design Centre	Development of Product Ergonomics for Consumer Awareness & Product Evaluation
N B Ballal	Met. Engg. & Mat. Science	Texture and Orientation Imaging Microscopy - A National Facility

Select MOUs

Organization	Date Signed	Scope
CMC Vellore, Worth Trust	September 2003	Manufacture of Artificial Hand
Altech Industries	September 2003	Marketing of CFDTutor Version 1
World Health Organisation	September 2003	Screening a Natural Compound Library for Molecules with Antimalarial Activity
SSEDS Industries	September 2003	Marketing of CFDTutor Version 1
IISc Bangalore	October 2003	Collaboration in Science and Engineering for Research and Education Programmes
MTNL	October 2003	Setting up a Centre for Excellence in Telecom Technology and Management

Awards

Prof K Pande, Earth Sciences, awarded the prestigious *Shanti Swarup Bhatnagar Award* for Earth and Atmospheric Sciences for the year 2003, by CSIR, Govt. of India.

Prof K V Subbarao, Earth Sciences, selected for International award of the *Third World Academy of Sciences Prize in Earth Sciences for 2003* for his pioneering contributions to the understanding of linkages between oceanic and Deccan volcanism.

Prof D N Singh, Civil Engg, recipient of *Shamsher Prakash Foundation Research Award* for the year 2003 for his contributions in environmental geotechnology, and mechanics of unsaturated soils.

Prof V K Singh, Chemistry, elected *Fellow of Indian National Science Academy*.

Prof M N Kulkarni, Lt. Col. (R), Civil Engg, awarded *Bharat Excellence Award and Gold Medal*, by the Friendship Forum of India.

Prof V S Raja, Corrosion Science Engg, awarded the *Mascot National Award*, by Electrochemical Society of India in recognition of his contribution in Corrosion Research and its Application to Industries.

Prof H C Sheth, Earth Sciences, selected as a *Young Associate* of the Indian Academy of Sciences, from the year 2003 to 2007.

Y Kanoria, Elect Engg, **S Harlalka**, Elect Engg, **S Dwivedi**, Elect Engg, and **A Agrawal**, Comp Sci Engg (undergraduate students), represented India and won two Golds and one Bronze medal at the International Physics Olympiad in Taiwan, held from August 2 - 11, 2003.

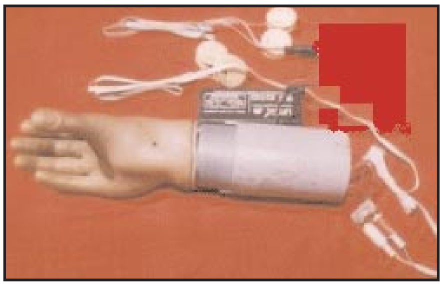
K Viswanath, **R Raj**, **K Kulkarni**, and **N Anand**, students of Prof R Poovaiah, IDC, received the design award for the *Best Product Idea* at Materialica Design Award 2003, conducted by International Forum Design, Hannover, Germany for 'Leaf Plates - Eco-Friendly Foodware', an alternate foodpackage design carried out as part of MDes project.

R Brijesh, **R Raj**, and **A Kamath**, under the guidance of Prof Ravi Poovaiah, IDC, won the *Most Outstanding Design Process* award at the Design Expo 2003 organised by Microsoft Research, USA, for their project 'Jodo - the Touch and Doodle Communicator'.

Technologies & Products

Low-Cost Motorized Artificial Hand

The incidence of limb loss due to road accidents, and unsafe handling of machinery is fairly high in India. Loss of the hand may be below the wrist, the forearm, or in the upper arm; a loss at the shoulder results in the greatest loss of function of the hand. An 'artificial hand' can help restore a measure of normalcy to the injured. One of the options for obtaining a man-made replacement for a lost hand is an internally-powered motorized hand that can perform finger-like pincer movements. The control of such a hand is usually achieved by bioelectric signals picked up from muscles in the residual limb. The costs of such imported motorized hands, however, are prohibitive - it can be more than Rs. 3.00 lakhs.



With funding from the Ministry of Social Justice and Empowerment (1999), a team of three researchers from IITB and the Christian Medical College (CMC), Vellore, have developed the first successful, indigenous, motorized artificial hand that would cost less than Rs 10,000. The motorized hand has several user-friendly features including myoelectric and whistle controllers. A single motor helps the co-ordinated movement of the fingers and thumb, while another motor turns the hand at the forearm. The motors are operated by switches placed in the socket of the artificial hand. The bulging of the muscles and the slight movement in the residual limb of the amputee are used to control these switches. Apart from its lower cost, the advantage that the indigenously developed product has over imported ones is that it works better in humid climates.

Following preliminary tests at the All India Institute for Physical Medicine and Rehabilitation, Mumbai, an initial set of artificial hands fabricated by WORTH (Workshop for Rehabilitation and Training of the Handicapped) Trust, Tamilnadu, was subjected to extended clinical trials at CMC-Vellore. Improvements including miniaturization of the electronics, and placement of control switches inside the socket were made based on further studies and user feedback. Sizes appropriate for both young children and adults are available. Commercial manufacture of the artificial hand is underway, and a project for extended clinical evaluation for further enhancements and improvements is in progress.

Contact: Prof S Devasahayam, surdev@cmcvellore.ac.in, R Lal, rlal@ee.iitb.ac.in P C Pandey, pcpandey@ee.iitb.ac.in

3-in-1 Heat Pump Utility

Air-cooling, and generation of hot and cold water are essential utilities for human comfort and convenience. Generally, these utilities are provided by separate systems, each with its own capital costs and energy requirements. A hybrid **S**ystem for **A**ir-cooling, **C**old- and **H**ot-water generation (SACH), which combines the functions of air-conditioning, water heating, and potable water-cooling has been developed by Prof. Milind Rane of Mechanical Engineering Department. Potentially useful in community and residential places, the 3-in-1 heat pump was successfully demonstrated in a hostel premise on the IITB campus. The system not only provides air-conditioning in the inadequately ventilated computer laboratory, but also heats tap water for use in the kitchen and bathrooms, and cools drinking water in the dining hall. The initial capital cost for this system is lower than the combined cost of conventional methods, with an additional 60 to 70% reduction in the operational cost. These energy-saving, environment-friendly, window and split heat pumps have also been successfully demonstrated in residential and community premises. The table shows a comparison of the power profiles of conventional utilities and the new heat pump developed at IITB. Patent applications have been filed, and the technology is available for licensing for commercial exploitation.

Utilities Produced	**EWH+AC+WC***	**Heat Pump**
Tap Water Heating to 45^{0}C	7 x 2 kW	2 x 6 kW
Air Conditioning	2 x 1.5 TR	2 x 1.5 TR
Water Cooling	0.5 TR	2 x 0.25 TR
Power Consumed	**EWH+AC+WC**	**Heat Pump**
Electric Water Heater (EWH)* @ 10 h/day	7 x 2 kW	
Air Conditioners (AC)* @ 12 h/day	2 x 2.08 kW	2 x 1.8 kW
Water Cooler (WC)* @ 12 h/day	0.75 kW	
Total Power Consumption	**199 kWh/day**	**43 kWh/day**
Reduction in Power Consumption		**78%**

Contact: Prof M V Rane ranemv@me.iitb.ac.in

Technologies & Products

A Learning-based Tool for Automatic Address Segmentation

Large organizations like banks, government departments, universities, and corporations need to handle massive databases of postal addresses. These databases are often poorly structured and frequently accumulate several duplicate entries for the same person. Hence, such organizations periodically engage in a data cleaning or warehousing activity where addresses are stored in a standard format, with duplicates removed. A key step in this process is address segmentation that involves extracting from address strings, individual structured fields like 'Landmarks', 'House number', and 'State'. In the less structured Indian addressing system, existing commercial approaches require extensive manual effort due to various reasons like: non-uniform building numbering schemes, reliance on ad hoc descriptive landmarks, changing city names, non-standard abbreviations of state names and style of writing addresses, spelling mistakes, and optional zip codes.

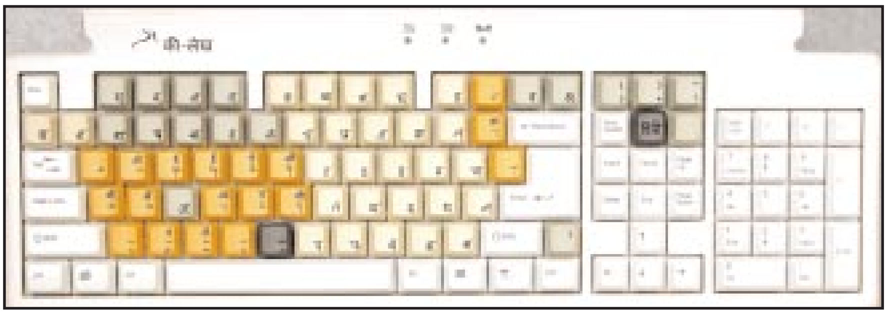
Prof. Sunita Sarawagi and her team at the Kanwal Rekhi School of Information Technology (KReSIT) have developed a software tool that will 'learn' a model for segmenting unseen addresses when ‘trained’ with some examples of segmented addresses. The underlying model is a powerful statistical machine-learning technique that can handle new data robustly, is computationally efficient, and is easy for humans to interpret and tweak in order to rectify the address segmentation problem. Experiments using nationwide, heterogeneous collections of actual addresses showed encouraging results, with high levels of accuracy. The software is now licensed to a data cleaning company in India, and is being deployed commercially.

Contact: Prof Sunita Sarawagi, sunita@iitb.ac.in

Key Board for Text Input of Indian Languages

For a majority of the Indian population, a vernacular is preferred for informal communication, especially so within families. Even when English is used, it is often liberally sprinkled with words from an Indian language for greater effect. This is quite common in direct and telephonic conversations, and even in written communication, but not on a computer. This is because, typing Indian languages on the computer keyboard is complex, and current schemes for feeding text in Indian languages are not adequately usable. Hitherto, there have been many solutions for

'Text Input in Indian Languages' (TIIL) such as *Inscript, Traditional Typewriter, ITR, Desha, Phonetic, and Transliteration,* which are based on the currently used QWERTY keyboard designed for the Roman script. Further, they have essentially been limited to running a piece of software 'on top of' the existing operating system and applications.



Indic scripts have a different structure from the Roman ones. A typical syllable is formed by placing a vowel symbol above or below a consonant, or by a conjunction of two or more consonants. Moreover, most Indic scripts need more primitives (a minimum of 52 for Devnagari, as compared to 26 for English). Hence, none of the above commercially available keyboards are usable by a majority of Indian people.

As a solution to this problem, Prof. Anirudha Joshi and his team at the Industrial Design Centre (IDC) have worked on designing alternative mechanisms for text input in Devnagari. What began as a student project was later incorporated into a project in the 'Interfaces for All' group of the IIT Bombay hub of Media Lab Asia. Amongst several alternatives, a keyboard called Key-Lekh was developed with a goal to enable persons familiar with Devnagari to use it without instructions. For example, on a ticket vending machine at a railway station, literate passengers should be able to 'walk up and use' this keyboard to type their name, destination and other details to buy train tickets. The underlying concept of the design of Key-Lekh is based on the 'Varnamala'-the well-structured Indian alphabetic system.

Studies on a prototype have proven that the Key-Lekh is an efficient 'walk-up-and-use' keyboard, and can also work as a desktop keyboard. The prototype has been subjected to extensive tests by users in various age-groups through road shows and competitions held on the campus. The initial feedback suggests that Key-Lekh is the easiest-to-learn keyboard yet developed for Indian scripts. Presently its performance is being tested more rigorously. Key-Lekh's design is being further improved to make it sufficiently robust and useful as a commercial product. A patent application and design registration applications have been filed for this invention.

Contact: Prof A Joshi anirudha@iitb.ac.in

Seminars organised by IRCC

◆ A Colloquium and Seminar on '**Issues in the Intellectual Property Policy Implementation with an emphasis on Copyrights**' was organized on July 12 2003. Prof H P Khincha, Chairman, Division of Electrical Sciences, and former Chief Executive, Society for Innovation and Development (SID), IISc Bangalore, offered a comprehensive overview on the 'Experiences in the Function of Innovation and Entrepreneurship at IISc'. Prof S Suryanarayan, Professor in Charge, Society for Innovation and Entrepreneurship (SINE, IITB) reviewed the current IPR policy at IIT Bombay while Prof P Ganguli, Adjunct Professor, SJMSOM, illustrated some nuances of copyright laws using case studies. Prof Sandip Roy, Chemical Engineering and Prof M U Deshpande of KReSIT dwelt on copyright issues in academia. The seminar concluded with a talk by Mr Sanjay Kher, Advocate, on some of the legal aspects of copyrights.

◆ **Dr Raj S Dave**, Attorney, Morrison & Foerster, USA, gave a seminar on 'Intellectual Property (IP) Strategy for Patenting Inventions', on August 11, 2003, highlighting strategies for preparing patent applications and maximizing its benefits.

◆ **Dr R S Baheti**, NSF, USA, gave a Seminar on 'Research and Educational opportunities at the National Science Foundation, USA', which elaborated upon the various schemes and initiatives for funding research in key and emerging areas by NSF.

◆ An **In-house symposium** on ***Nanotechnology @IITB*** was held on 13 September 2003, with wide participation from faculty, scientists and students of the institute. The aim was to showcase ongoing Nanotechnology related research at IITB. The symposium was the first of its kind at the Institute to preview a futuristic technology to which the institute faculty is contributing actively.

Dr G N Mathur, Director DMSRDE, (Chief Guest), elaborated the importance of dedicated research to make an impact in this emerging and extremely vital area. He highlighted the multi-disciplinary nature of nanotechnology, and DRDO's interest in supporting related reserach.

The institute-wide research activities on nanomaterials, nanoelectronics and nanobiomaterials were showcased through presentations by faculty, scientists, and posters on research mostly carried out by research scholars. A concluding panel discussion on 'Synergizing the Nanotechnology Activities at IIT Bombay & Looking Ahead' yielded a number of action points that are expected to provide a thrust and focus to further research at IITB. These include initiating postgraduate programmes and / or electives in the areas of Nanoelectronics and Nanobiotechnology, formation of a centralized research facility, and emphasizing on producing more PhDs in this area. Further, communicating the significance of this area to the Indian industry would be necessary to promote association towards commercial product development.

Organic Synthesis for Better Pharmaceuticals

Sambasivarao Kotha, Department of Chemistry

The word 'synthesis' is derived from the Greek *suntithenai* (meaning putting together). Organic synthesis is the systematic building of organic molecules through chemical reactions involving the making or breaking of bonds. It has enabled the replication of almost any substance found in nature, the design of new chemicals to fulfill specific needs (for example, medicines, fuel, or structural material), and even the prediction of the properties of a target molecule.

Organic synthesis is important because, not only can natural products be expensive, they are often difficult to extract and purify from natural sources. They, therefore, need to be mimicked by synthesis from less-expensive or more available raw material. Examples of such products include aspirin and Vitamin C. Additionally, many synthetic substances like certain drugs, agro products, plastics, and polymers, have novel properties that make them especially useful.

However, synthesizing structurally complex organic molecules is not easy. An organic chemist's task is often limited by the availability of starting materials, and an imperfect knowledge of their possibilities and limitations. Additionally, the synthetic compound should be safe, environmentally acceptable, and cost-effective. Such challenges call for new reagents, new strategies and a new science altogether. This article explores the advantages of incorporating synthetic alpha (α)-amino acids into peptides, for the preparation of therapeutically superior compounds.

The Origins

The first chemical synthesis of a natural product from inorganic compounds was in 1828, when Friedrich Wöhler accidentally created urea in place of the intended ammonium cyanate. However, the first real demonstration of organic synthesis was the production of acetic acid from carbon disulphide by Hermann Kolbe in 1844. Soon follwed by the synthesis of salicylic acid and more organic compounds, the introduction of sulphonamides in 1935 became the point of departure for explosive growth in organic synthesis.

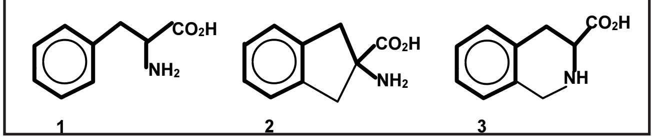
Peptides as life saving drugs

Proteins and peptides play a vital role in cell function. The amino acids, which are the building blocks of peptides, can be arranged in an infinite number of sequences to make a variety of proteins. The unique three-dimensional structure formed by the folding of specific amino acid sequences, determines the protein's function.

Several peptides have been identified as life saving drugs, and the demand for them is growing. However, unfavorable pharmacological properties such as, rapid degradation in body fluids have limited their applications. Hence, it is necessary to identify the structural modifications that may give stability to the native peptide, and improve its pharmacological profile.

The Natural and The Unusual: Protein-forming α-amino acids are a group of 20 naturally occurring amino acids encoded by DNA, and obtained by the hydrolysis of proteins. In addition to these, a large number of amino acids, variously known as *unusual, unnatural, synthetic, non-standard* or *non-coded* α-amino acids have been synthesized. They are used to prepare several therapeutically useful compounds. For example, D-phenylglycine and its derivatives are used as building blocks in the synthesis of popular antibiotics such as, ampicillin, cefalexin, and amoxycillin. Combined with carbidopa, L-Dopa, an analogue of the amino acid phenylalanine, is widely used in the treatment of Parkinson's disease. Incorporation of unusual α-amino acids into peptides has led to unique analogues, which are biologically active and relatively stable. Hence, the preparation of unusual α-amino acids extends the availability of building blocks for the synthesis of natural products and drugs. Moreover, some of them are themselves biologically active.

Constrained α-amino acids: In constrained α-amino acids, the side-chain flexibility of proteinogenic α-amino acids is restricted. The figure shows the phenylalanine molecule (1), along with its constrained analogues (2 and 3). When phenylalanine is replaced with a constrained analogue such as 2, in peptide modifications, the resulting peptidomimetics (compounds that mimic peptides) show enhanced pharmacological properties.



Constrained Phenylalanine (Phe) analogues - 2 and 3 (the thick line indicates Phe moiety).

The Building Block Approach: The 'building block approach' generates a large number of compounds starting from a common precursor, by processes that are flexible enough to generate various unusual α-amino acid derivatives. These building blocks can be incorporated into small peptides, and similar transformations can be performed at the peptide level, thereby providing a large number of *modified peptides* in lesser time. These compounds can be used for *in vivo* and *in vitro* optimization studies on therapeutic targets. Since unnatural peptides are prepared in a step-wise fashion, development of methods based on chemical modification of the intact oligopeptides, will deliver them without having to repeat the entire sequence of peptide synthesis.

Research at IIT Bombay

Our group has been working in this area since 1994. We have demonstrated that various types of reactions can be useful tools for the preparation of a library of unusual α-amino acid derivatives. In addition, it is feasible to modify peptides using these unusual α-amino acids in a *post-translational* manner. Such methodologies have direct applications in drug design.

We have developed several new methods for the synthesis of cyclic amino acids, beyond the few being used since 1930. Around 250 unusual α-amino acid derivatives have been prepared, most of which are not accessible in a direct manner by known methods. Additionally, various synthetic methods developed in our laboratory have been used in materials science applications and in crystal engineering studies. Details of the work are reported in 'Recent applications of the Suzuki-Miyura cross-coupling reaction in organic synthesis', (*Tetrahedron* 2002, 58, 9633-9685, S. Kotha, K. Lahiri, and D. Kasinath; *http://www.tetrahedron.info/tet*)*

With its seemingly inexhaustible inventory including fabrics, fuels, dyes, perfumes, pharmaceuticals and polymers, the products of organic synthesis will continue to provide many benefits for humanity.

** The paper was rated as the third most requested paper during the 2nd and 3rd quarter of 2003, by the Chemical Abstract Services (CAS) in Columbus, Ohio. Prof Kotha has been recently awarded the CRSI Bronze medal by the Chemical Research Society of India.* **- Editor**

Development of Tools for Managing Railway Operations

Narayan Rangaraj, Industrial Engineering and Operations Research

The suburban railway system on which Mumbai is heavily dependent, has been rightly called 'the lifeline of the city'. Railway operations present a huge range of problems to work on. For over six years, our group* at IIT Bombay has been working on various aspects of suburban railway operations management. The areas of study include Capacity Studies and Planning, Timetable Construction, and Rake Management.

Line Capacity Simulator

To represent the operational features of trains in selected sections, we have developed a *simulator* for the Indian Railways Institute of Signal Engineering and Telecommunications. The simulator can help estimate the capacity of long-distance track segments on the railway network under complex traffic conditions. It is also useful in changing time-tables, analyzing the effect of adding scheduled trains in a section, evaluating investment at a local level (such as additional loop lines and platforms), and studying the effects of signal failures and train delays. Essentially the programme uses priority-based scheduling of trains along with the operating constraints of track occupancies and platform availability.

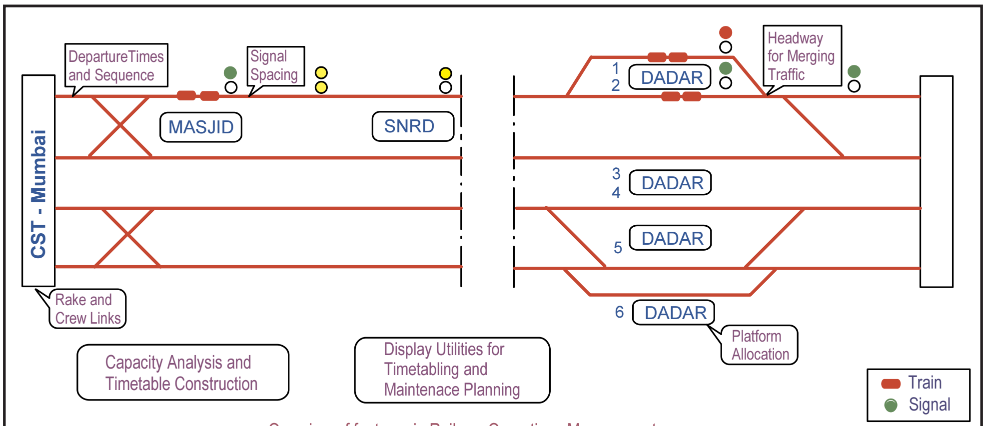
The simulator allows realistic analyses by reproduction of the operational logic of railway movement, and related engineering details. It also records train speeds that depend on track signal conditions, which in turn depend on the status of several trains ahead of the signal. The simulator can display train movements on a distance vs. time graph with details of individual trains.

Presently, experiments are being carried out in the suburban section of the Mumbai division of Central Railways, and in the mixed traffic conditions on the Virar-Dahanu Road section of the Mumbai division of Western Railways. The former study is aimed at spacing signals for achieving a desired frequency of train service, while the latter study allows preparation of temporary timetables in the event of major maintenance work, which usually imposes restrictions on train movement and speed.

Timetabling for Suburban Railway Operations

Preparing suburban railway timetables is a highly skilled and complex task entailing months of data collection and analysis before finalization. Inputs from numerous quarters such as: commercial, operations, safety, signalling, track, civil and electrical departments are essential pre-requisites.

We have designed a *semi-automated support* for a variety of planning decisions involved in the preparation of such timetables. Already implemented in the Western Railway division of Mumbai, the simplest one is for visualization and monitoring of current timetables and platform occupancies with facilities for enabling gradual changes as needed. Currently, we are developing a tool that will allow a high degree of automation in timetable generation.



Overview of features in Railway Operations Management

Rake Management System (RMS)

The Rake Management System (RMS) is a set of *utilities* and *tools* designed for analysis and decision-making on the overall use of rakes vis-a-vis their deployment, operation, and maintenance cycles for suburban train services. Additionally, it provides occupancy profiles of trains at terminals, platforms, and sidings. Thus, it is also useful in operations planning, time-tabling, maintenance plans and crew scheduling. The RMS consists of the Rake Linker and Post-Processor.

Rake Linker: The Rake Linker allocates rakes to services so that the number of rakes used to run all services, and the total distance run by all the rakes is optimal. In technical terms, the approach involves a *minimum-cost flow network flow optimization*. Further, it models the various linkage possibilities (including empty rake movements, and movements to and from car-sheds and terminals), assigns costs to them, and picks the 'best' overall set of linkages.

Post-Processor: The Post-Processor summarizes information about 'stabling line' and car-shed movements in accordance with the availability of stabling lines, and optimizes the total distance run by the rake in these activities. For example, if there is more than one car-shed, and if the rake can be moved to any of them, then these movements are optimized. It also generates the occupancies of the rakes at every station and track. The RMS also provides for extensions in the areas of *rostering*, i.e. the assignment of actual rakes to a starting service each day, so that the overall balance of rakes at various car sheds is satisfied. Finally, a higher level analysis which examines the possibilities of savings by small changes in operating parameters, can also be done. The RMS therefore provides a comprehensive set of tools for optimal rake operation and maintenance.

The techniques used in our work on railway operations planning are applicable to several other areas such as: fleet management, vehicle scheduling, personnel scheduling, distribution management and so on. Obviously, each of these problems need customized approaches. IITB currently has research programs in these areas as well.

*Faculty members involved in this effort are Narayan Rangaraj (Industrial Engg. and Operations Research, narayan@me.iitb.ac.in), Milind Sohoni (Computer Science and Engg., sohoni@cse.iitb.ac.in), Abhiram Ranade (Computer Science and Engg., ranade@cse.iitb.ac.in), K M Moudgalya(Chemical Engg., kannan@che.iitb.ac.in)

The Academia in Transition

Sandip Roy, Chemical Engineering

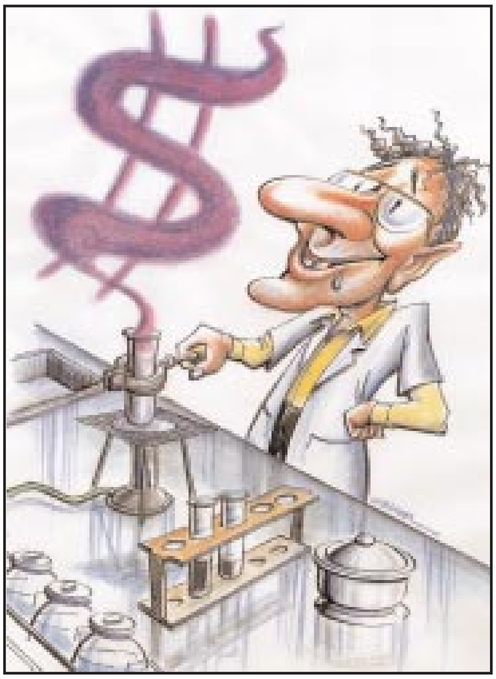
In the year 2001, *Nature* (Volume 409) featured an article that might have appeared almost alarmist: "Is the university-industrial complex out of control?" But the article had only voiced what had been troubling many academics, especially in the western world, for several years: that the academia was starting to look more and more like business, and was in danger of loosing what was its hallmark, its openness and freedom. If anything, the reality which lay behind such concerns has only become more pervasive across the world today. The academia is increasingly embroiled within the forces that are shaping today's so-called global economy: declining government role and funding, and the dominance of the market forces. These issues are likely to haunt the academia for sometime and shape its future.

From even before the onset of economic liberalization, the Indian academia has had to contend with declining (per capita) public expenditure for higher education; this in the face of increased demand for, and cost of such education.

Added to this is the ongoing WTO-mediated talks on *General Agreement on Trade of Services*, which, *inter alia*, aims to liberalize market access to the education sector of all participating nations. Any such deregulation may entail increased competition from foreign academic providers. These new circumstances may compel the nation's educational institutions to increasingly raise more of its resources from private sources, both for sustenance and better performance.

The Academia's IPR Drive

In 1980 the US *Bayh-Dole Patent and Trademark Law Amendments Act* empowered US university researchers to share the proceeds of their patents with their schools. The premise was that more work would migrate from the universities to the marketplace if the schools and researchers had an economic stake. Although slow to respond initially, today a large number of US universities have opened "technology-management" offices which deal with the intellectual property arising out of academic research and enable their transfer to private corporations. In the process, the academia is able to partially compensate for reduced public funding. The website of the Association of University Technology Managers (www.autm.net) is replete with impressive facts and figures on licensing activity nationwide.



Nevertheless, such successes have not been embraced wholeheartedly by the entire academia, which now is caught in a fractious debate. Supporters claim that in linking more strongly with markets, the academia will become more relevant in strengthening a country's competitive position in a global innovation economy and more efficient or accountable in the process. Opponents, on the other hand, point to increasing conflicts of interest, profit-driven decision-making (including those relating to for-profit ventures growing out from academic institutions), and corporate influence in curricula content and design. These presumably will weaken academia's ability to encourage critical thinking, new ideas, spontaneous innovation and free scientific discovery. A section of students and faculty-both in the US and Europe-has dissented against the "new academic style." In a wider sense, such protests are part of a larger phenomenon that has divided the proponents and critics of globalization: that global corporations now exert an inordinate influence on public institutions, including universities.

Academic institutions in several other nations, including India (the IITs and IISc, in particular) have also created internal mechanisms to protect and license IPR to the industry, to promote entrepreneurship and for-profit ventures — both in an effort to enhance their innovation systems and to generate revenues. The experience of US and European universities, therefore, may be of relevance in establishing the right direction for future academia-industry interactions.

Academia and the Markets

On the face of it, the marketplace realities of competition and profit-motive run counter to the values of academia. Historically, the university has been a place for learning, research, and service to society through the application of knowledge; the spirit of free enquiry and exchange of ideas its *raison d'etre*. The academia was accorded a significant degree of protection from the pressures of society — academic freedom — precisely because it was serving the broader good of society. However, it is true as well that a significant portion of academic research — which has largely been publicly funded till today — often appears unrelated to the needs of the society at large. This perhaps is more pertinent to a country like India, because of larger government contribution to academic research funding.

With the rise of a global market economy, higher education is beginning to be seen as a 'private good' benefiting those who study or do research. As this view has it, the users should pay for this service as for any other. In short, the provision of knowledge is just another commercial transaction. In the marketplace, capital has no loyalty. Can or should the same rule apply to *academic capital* as well? This is the key question that the modern-day academia faces and needs to resolve.

The question of industry-academia linkages, however, resists clear demarcation of boundaries. No doubt, the academic process of peer review and open publication of research papers is critical to the progress of knowledge. Still, a simultaneous link with the market can provide the academia with valuable inputs: Does the concept work? Will a device sell? The idea born in the academia is almost always only an *incipient* one and needs the support of a whole range of business systems — that are beyond the academia — for realizing its economic value. Genuine industrial innovation needs both science and the logic of marketplace. In short, the need between the industry and the academia is mutual.

The general decline in the role of the government in most economies may leave the academia with little choice in the future but to increasingly seek private research funds as well as trade its IPR. To many, this may seem a pragmatic response to the emerging realities. Yet, what place would the arts and humanities (and perhaps even some of the social sciences) have in a regime overwhelmingly governed by *economic utilitarianism?* How much damage will this cause to the credo of liberal education that, historically speaking, the arts, humanities and science together help found? The answers to these questions are not easy. The modern academia perhaps needs to re-define its role and create structures that may help retain what has been its essential ideal: fostering a larger social good.

(sr@che.iitb.ac.in)

Globalization and its Implications for Urban Planning in India

Kushal Deb, Humanities and Social Sciences

Globalization is a word that has several connotations today. But broadly speaking, it is a process which began around the late 1970s, by the shift in world economy from an *international* to a more *global* one. In the international economy, individuals and firms from different countries traded goods and services across national boundaries, and the trade was closely regulated by nation-states. In the global economy, goods and services are produced and marketed by an *oligopolistic* web of global corporate networks whose operations, although spanning several national boundaries, are only loosely regulated by nation-states.

The Paradigm Shift

The paradigmatic shift to a global economy has been possible because of the 'Information Technology' revolution ushered in by synergistic developments in the fields of microelectronics, opto-electronics, computing, and telecommunications. The *global economy* is therefore also an *informational economy*, in which the method of production has shifted from mass production of goods at a centralized location (Fordism) to a flexible system of production (post-Fordism).

Advanced combinations of telecommunications and computing technologies (telematics) have underpinned a new and variable dimension of international economic activity, and also a new social division of labor. Other contributory factors have been the globalization of finance — evident in the emergence of transnational banks and investment companies — and the advent of twenty-four hour global trading in capital and security markets. The growth of the Euro-dollar and the increased interest shown by national governments in attracting foreign investments have also expedited the process, duly encouraged (or, often coerced) by the World Bank, the IMF and the OECD.

The Cultural Dimensions of Globalization

The process of globalization has also its cultural dimension, which has been conceptualized in terms of *cultural flows* that both reflect and reproduce global metropolitanism. Arjun Appadurai, (Professor of International Studies and Director of the Initiative on 'Cities and Globalization' at Yale University), suggests that there are five dimensions to these flows:

- *ethnoscape*: produced by flows of business personnel, guestworkers, tourists, immigrants and refugees
- *technoscape*: by flows of machinery, technology and soft ware produced by trans-national corporations and government agencies
- *finanscape*: by flows of capital, currencies, and securities
- *mediascape*: by flows of images and information through print media, television and films
- *ideoscape*: by flows of ideological western worldviews like democracy, sovereignty and welfare rights

To these, Paul Knox (Professor and Dean, College of Architecture and Urban Studies, Virginia Polytechnic Institute) adds a sixth category, *commodityscape* — produced by flows of high-end consumer products and services that are signifiers of taste and distinction, and are propagated by the trans-national producer service.

A Tale of World Cities

Cities like New York, London, Paris and Tokyo, at the top of the hierarchy, and others like Chicago, Dusseldorf, Los Angles, Madrid, Montreal, Munich, Rome, Toronto, Washington, Zurich and a few others have been labeled as world cities. This is because they are the nodal points that function as control centers for the interdependent skein of material, financial and cultural flows, which together, support and sustain the globalization process. Some of the cities of developing nations like Sao Paulo, Mexico City, Singapore, Shanghai and Seoul are already occupying important positions in this global hierarchy of cities.

About World Cities

According to Paul Knox (referred earlier), world cities are sites of:

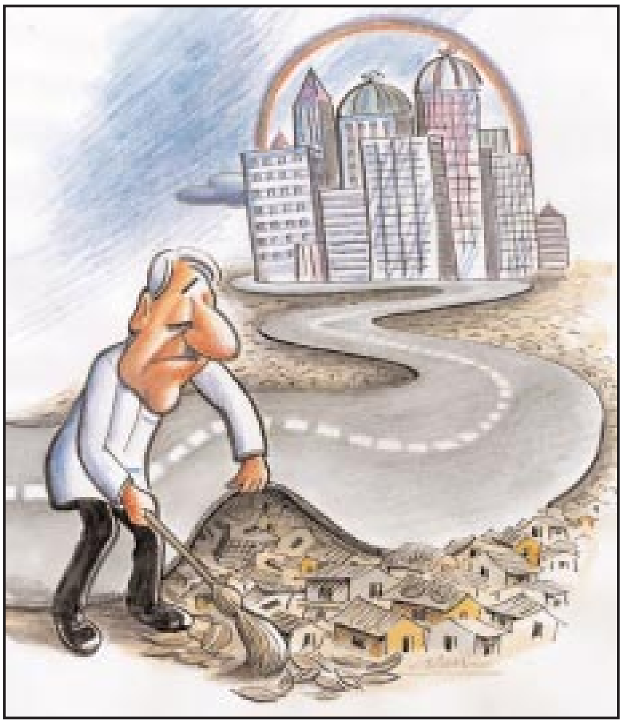
- most of the leading global markets for commodities, investment capital, foreign exchange, equities, and bonds with high-order business services attached to finance, advertising, property development and law.
- corporate headquarters of transnational corporations, major national firms and large foreign firms.
- national and international headquarters of trade and professional associations
- internationally influential media organizations and cultural industries.

In India, cities like Mumbai, Delhi, Bangalore and Hyderabad are trying to outdo one another in order to claim positions in the global network. Mumbai is supposedly the financial capital of India, with Nariman Point, Cuffe Parade, Worli and Fort areas acting as the hub, where most of the financial and producer services are located. Newspapers are regularly replete with controversies about a plethora of proposed commercial and developmental projects. Similarly, India's 'Silicon Valley', Bangalore, is poised for take-off with projects for modernization, promotion of four satellite cities, and the plan for an expressway. In Hyderabad, the present chief minister has changed the trajectory of growth of the city by building what is known as the 'Hi-tech city' or 'Cyberabad'. It offers various infrastructural facilities to the info-tech industry.

What implications do all these developments have for the planning of the metropolitan cities of India? One group of scholars and urban planners opine that globalization has changed radically, the concept of planned growth of cities. They feel that the power of national governments has been considerably eroded by the global nature of economic activities. Governments are obliged to entrust decisive influence over the employment, incomes and welfare of the population, to external forces and global markets — the outcome of which can neither be predicted nor determined. As Nigel Harris (Professor Emeritus of Economics, University College, London) states, globalization has led to the liberation of cities, and has restored the local at the cost of the national. Cities, he feels, ought to be characterized by a constant activity of reinventing itself, expelling some activities that no longer need the incubator atmosphere, and drawing in others that do. However, the dominance exerted by the national state contravenes the essence of a city. Thus, a 20-year Master Plan assuming the predetermination of the future is an attempt to thwart *the essence* of a city's contribution to the world — that of continual self-transformation.

Of Metropolitan Spaces

Manuel Castell (Professor of Sociology, University of California) has theoretically differentiated between *the space of flows* and *the space of places* in the metropolitan environment. The former — created by the information technology revolution — is of several layers, comprising the circuit of electronic impulses, its nodes and hubs, and the spatial organization of the dominant managerial elites. These elites live as segregated communities on 'spaces', with easy access to cosmopolitan complexes of arts, culture and entertainment. Important elements of *the space of flows* are the creation of a lifestyle and spatial design aimed at *unifying* the symbolic environment of the elite around the world. Such elements *supersede* the historical peculiarities of each locale. Thus, offices of MNCs, international hotel rooms, airport VIP lounges, express highways and the like seem similar across the world, and create a sense of familiarity with the inner world of the *space of flows.*



In contrast, the *space of places* is historically bound and specific, and is also culturally plural — its dwellers having constructed a meaningful, interacting space with a diversity of uses, and a wide range of functions and expressions.

Viewing the scenario in metropolitan India, one finds that several State Governments seem to have realized the role which information technology is going to play in the present globalized world. But instead of relinquishing their stranglehold on the urban growth process, these governments seem obsessed with building up their own info-tech cities by either decongesting city centers, or taking up 'mega city' projects on the periphery of congested metropolitan centers. They are availing huge loans either from international funding agencies, or from the Central Government, to build expressways, flyovers, modernized airports, or dedicated water and electricity supply for corporate info-tech parks and housing, all in creation of the so-called *space of flows.*

As part of a 'Mission Mumbai,' an all party delegation led by the Chief Minister of Maharashtra recently met the Prime Minister to seek annual aid of Rs. 2,000 crores for the next ten years for the 'make over' of Mumbai in the lines of Shanghai! Close on its heels came a 'Vision Mumbai' report compiled by global consultancy firm McKinsey, promoting a Rs. 200,000 crores re-development plan for transforming Mumbai into a world-class city.

Flows vs. Places

What seems illogical is not so much the government interventions (that are still essential in developing countries like India), but the lop-sided priorities that seem to guide them. An obsession with creation of *spaces of flows* is being undertaken at a willful neglect of *spaces of places*, especially when 40 to 50 percent of inhabitants of metropolitan cities live in slums lacking basic facilities like water, electricity, roads, sewerage and schools.

Further, as Solomon Benjamin (Bangalore-based Research Consultant and Economic Advisor to International Agencies) points out, attempts at decongestion of city cores by shifting wholesale trade to the peripheral areas, is often done at the cost of *local economies* which run on ethnic and kinship networks, and also provide a niche for survival to the poor. Interestingly, these local economies provide the basis for a more democratic municipal politics because their constituent populace is a vote bank for the municipal councilors. In comparison, the development authorities — constituted by bureaucrats and state government appointees — have practically no local level representation, and are often insensitive to the needs of the majority. Similarly, the beneficiaries of mega projects--members of 'enclaved' high-income neighborhoods — who constitute a miniscule of any city's population, often view the surrounding slums as festers that need to be eradicated.

In Conclusion...

No doubt, the niches of the *space of flows* created in metropolitan Indian cities do indeed help in connecting them to the global network of world cities. However, the *space of flows* can neither disconnect itself from the *space of places* that constitutes the major chunk of these metropolitan cities, nor can it get disconnected from the surrounding poverty-stricken hinterland. Cities like Mumbai stand out as islands of prosperity and opportunities amidst the sea of deprivation and poverty which constitutes rest of India. They will therefore continue to attract streams of migrants notwithstanding the 'sons of the soil' campaigns of regional political outfits. Similarly, the Chief Minister of Andhra Pradesh may build a Cyberabad to attract foreign investors and IT firms, which in turn may connect Hyderabad intimately to the Silicon Valley, U.S.A via the cyber superhighways. However, he will also have to contend with simmering communal tensions in the stagnating southern parts of Hyderabad, and with the recently revived movement for a separate Telangana!

(kd@hss.iitb.ac.in)

Globalization

Globalization of R & D: The Indian Experience

Karuna Jain, Shailesh J Mehta School of Management

Corporate Research and Development (R&D) activities have hitherto, been mostly confined to in-house R & D centers of companies in their home countries. But in recent years, the necessity of multi-sourcing of innovations has gained importance due to a variety of reasons, such as:

- Intensified and globalized basis of international competition
- Increasing pressure to shorten international market penetration times for new products, and ensuring the simultaneity of their introduction on a global scale
- Increasing pressure to shorten R&D time-period and decreasing market-life times for new products
- Increasing R&D intensity and costs

In addition, R&D in high-technology industries such as: biotechnology, microelectronics, pharmaceuticals, information technology and new materials has become more science based and consequently, research intensive.

The need to enhance competitiveness through R&D is leading multinational corporations (MNCs) to direct their investments to those geographical regions of the world which can best meet their research and manpower needs. As a result, there is today an enhanced R&D networking between major laboratories spread across the globe not only within large multinational firms, but also between the universities, research institutes, customers and industry consortia.

Today, companies from the United States, Japan and Europe conduct almost the world's entire industrial R&D, and have dispersed their efforts across the globe, especially over the last decade. With the world's third-largest scientific and technical manpower, and well-established R&D infrastructure in the form of national laboratories and universities, India has been a beneficiary of this emerging phenomenon of R&D globalization. We at the Shailesh J Mehta School of Management (SJMSOM), IIT Bombay, have studied this phenomenon within the wider context of globalization and competitiveness of skill-based services.

Following the stronger integration of R&D with business, and the consequent weakening of the strategic position of corporate central laboratories within large firms, there has been a growing tendency for the networking of research between major laboratories within large MNCs. Many of these firms have set up technical support laboratories in various countries, so as to adapt existing products or production processes to the local markets or production environment. In such an integrated network arrangement, subsidiary overseas units are no longer viewed only as the end of delivery pipelines for company products. Rather, the management considers each of the worldwide units as a source of ideas, skills, capabilities and knowledge that can be harnessed for the benefit of the whole organization. Today, overseas laboratories are expected to play an important role in the global program of innovation by conceptualizing new products, which are then produced locally either for the host-country, or for wider markets.

Research findings at the SJMSOM indicate that while both market and technology oriented activities are important for MNC subsidiaries, the spotlight is presently on the former. With the *mantra* now being 'customize products for the Indian market and work with manufacturing facility in India,' the local industry is also assuming a technology-oriented stance. For this it is imperative to source high-calibre scientists, engineers, and designers in India, and to develop new product ideas.

Generally, the R&D centers of MNC's conduct contract research for corporate laboratories or sister R&D laboratories outside India. Consequently, such in-house R&D units are now keen on establishing links with Indian scientists and technologists, and sometimes *sub-contract* a part of the contracted research to Indian universities or laboratories. However, technology-oriented activities like obtaining information on India's scientific and technical R&D, and developing new science and technology rank somewhat lower in their order of priorities. This suggests that although the companies are keen on employing Indian skills, they do not consider Indian scientists to be at the cutting edge of research where breakthroughs are made. Also, such sample units are involved in technology *development* but not in technology *monitoring*. Furthermore, technology development activities appear to revolve more around commercial technology rather than contribute to scientific and technical knowledge.

The ongoing transition of the Indian economy is reflected in the changing nature of R&D in some of the companies. For example, several companies have completely restructured their R&D centres in India. They have shifted focus from developing products for Indian markets, to designating a local R&D unit as a 'Global Centre of Excellence' in some areas. This means that, regardless of the end-use or end-market of a product under development, the R&D in that particular area will be done in India. In other instances, although their original objective in setting-up R&D units was to support Indian operations, some companies have had to re-work their plans, owing to foreign companies acquiring a majority control.

The key factor driving the investments and activities of foreign R&D laboratories is the importance of *human capital*. As pointed out above, overseas laboratories of MNCs increasingly utilize high-quality local scientific ability in internationally integrated programs of basic research. One of the benefits of R & D globalization is the enhanced technical learning of local scientific talent. Additionally, the local industry is also likely gain from technology spillover effects such as custom or toll manufacturing. (kjain@som.iitb.ac.in)

Technology

The Promise of Nanotechnology

Prema Prakash

An invasion of armies can be resisted, but not an idea whose time has come. — Victor Hugo

Although the idea that materials and devices could be manipulated at an extraordinarily small scale was envisaged in the 1950s, it began to be seriously pursued only in the eighties. Today, Nanotechnology — the word used to describe such an approach — already has significant applications and commercial impacts, with a projected worldwide market size of over $1 trillion annually, in the next 10 to 15 years!

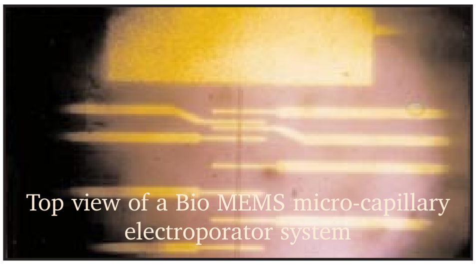
Originally coined by K. Eric Drexler, Founder-Chairman of the Foresight Institute (US), in his book 'Engines of Creation', the term *Nanotechnology* is used to describe an interdisciplinary field wherein the critical dimensions of materials, devices and systems are in the *nanometer* (10^{-9} m) scale. At the nanoscale, all streams of science converge towards the same principles and tools. Consequently, progress in nanoscience is expected to have far-reaching impacts and revolutionize the creation of materials in unprecedented ways.

The present article outlines the relevance of Nanotechnology and provides a glimpse of the multi-faceted research that is underway at IIT Bombay in this field.

Impact of Nanotechnology

Encompassing almost every sphere of human life, the impact of advances in Nanotechnology will be felt in a host of areas including: industrial manufacturing, electronics and communication, healthcare services, transportation and space exploration, energy and environment, agriculture, and defence.

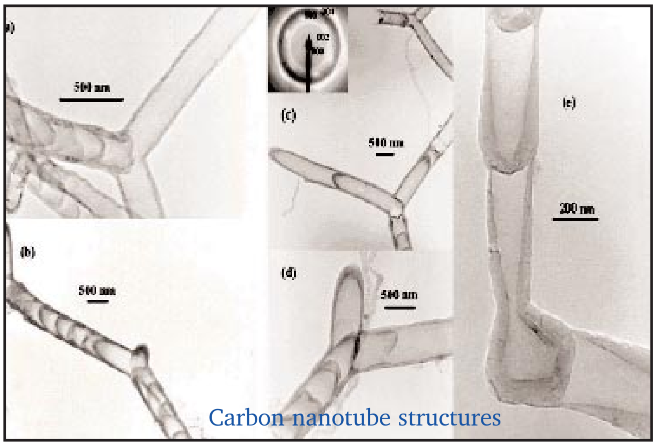
Far beyond being just another step towards miniaturization, the nanoscale represents a whole new dimension wherein substances begin to exhibit novel properties, as compared to their bulk counterparts — a fact that is exploited for the manufacture of novel devices, for a host of applications ranging from information storage to biomedical engineering. Such nanoproducts are lighter, stronger and more precise in functionality, and allow for reduced life-cycle costs through lower failure rates.


Top view of a Bio MEMS micro-capillary electroporator system

The exponential growth in microelectronics and VLSI — enshrined in Moore's Law — has revolutionized the computer and communications industry. In the realm of electronics, the radical scaling down of microelectronic, magnetic, and optical devices has enhanced our capacity to store, process, and transmit information. Silicon based nano-fabrication has been extended from integrated circuits to micro-mechanical mirror arrays, assay chips for gene expression and even the realization of entire systems-on-a-chip!

The realization of yet another 'wild idea' is the 'injection of the surgeon into the blood vessel', envisioned by Nobel Laureate physicist Richard Feynman in 1959. The use of nano-fabricated devices will transform medicine and healthcare. Apart from facilitating drug usage, nanotechnology can provide new routes for drug delivery, and novel formulations that are high-performance and biocompatible in nature.

Nanocomposites and nanoelectronics will yield lighter, safer, and more fuel-efficient vehicles. Simultaneously, they will result in reliable and cost-effective roads, runways, and pipelines. Nano-devices and sensors will help in the condition monitoring of bridges, rail systems, and other infrastructure. The current cost of transporting payloads into space is over $20,000 per kilogram. Nanotechnology will help in creating lighter, stronger and thermally stable materials for aircrafts, rockets and exploratory platforms.



Carbon nanotube structures

From high-efficiency fuel cells including hydrogen storage in carbon nanotubes to removal of ultra-fine fuel contaminants using mesoporous molecular sieves, nanotechnology will enable more efficient storage and utilization of energy. Nanoscale semiconductors used in the preparation of light emitting diodes (LEDs) and solar cells, can reduce worldwide consumption of energy and thereby, carbon emission.

Nanotechnology based devices will also enable the desalination process of seawater at a fraction of the energy required by reverse osmosis or distillation methods. A cleaner environment may be achieved through control of emissions, removal of air and water contaminants, and new technologies that minimize the generation of undesirable by-products.

Radical improvement of agricultural yields through biodegradable nanomaterials for plant growth and pest inhibition will also be feasible. Additionally, genetically improved strains of plants resistant to environmental stresses of salinity or drought may be developed through nano-array based DNA testing for determination of gene expression.

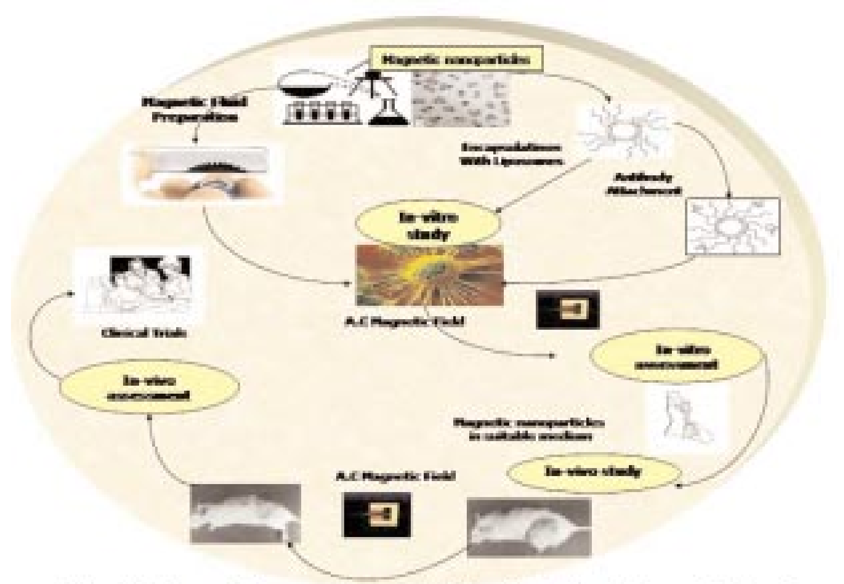
From empowering a soldier with gear having 'smart capabilities' to using nano-sensors in aircrafts for myriad uses — such as vibration damping, noise reduction, and life-monitoring of missiles — nanotechnology has tremendous potential in defence applications, where the considerations for precision and performance override those of economics. The increased use of nano-robotics and automation will help reduce risks to military personnel, while nano-sensors would be invaluable in monitoring chemical, biological and nuclear warfare agents.

Nanotechnology Initiatives at IIT Bombay

The current research at IIT Bombay covers a gamut of areas including: Nanomaterials, Nanoelectronics, NanoElectro-Mechanical Systems (NEMS), Nanomagnetics, and Nano-biotechnology. Research is being carried out with support from both Indian and international agencies. IITB is equipped with sophisticated infrastructure — including a Class1000 Clean Room — and several requisite characterization facilities. The ongoing research activities are described briefly in the subsequent sections.

Nano-materials: The basis of this domain of research is the controlled synthesis of multilayers, ultra thin films, nanoparticles, and nanoclusters of materials like: metals, metal oxides, ceramics, polymers and nanocomposites. Currently, nanomaterials find use in the areas of catalysis, paints and pigments, drug delivery, photonic crystals, electronics, magnetic recording materials, fuel-additives, and non-linear optics among many others.

At IITB, nanomaterials are synthesized using a variety of methods, such as Pulsed Laser Deposition, Hot Wire Chemical Vapour Deposition, DC Magnetron Sputtering, and glass ceramic methods. Nanoparticles for various uses are also produced at room temperature and pressure, by methods using surfactants and interfacial techniques (such as sol-gel technique and micro-emulsion methods), or bio-mimetic methods of self-assembly. Additionally, studies at IITB have identified the suitability of using Supercritical Anti-Solvent methods for preparing pharmaceutical nanoparticles of controlled sizes and shapes, in a single step operation.



A schematic diagram showing magnetic nanoparticle-based hyperthermia for cancer treatment

Another area of interest is the synthesis by self-assembly, and the characterization of nanostructured photonic crystals. These find applications in fiber optic communication, optical ICs and in zero-threshold lasers.

In the area of organic multilayers, faculty at IITB have focused on the development and characterization of a variety of Langmuir-Blodgett multilayers, semiconducting nanoclusters, nanocrystalline films and nanocomposites. Some of these nanomaterials find uses in LEDs and biosensors.

The confinement of nanoparticles within the pores of mesoporous materials is useful in a number of applications such as separation technology, heterogenous catalysis and sensors. At IITB, metal oxide nanoparticles of titanium, zinc, lead and iron have been prepared within the pores of mesoporous MCM-41 and MCM-48 molecular sieves.

Nanoelectronics, NEMS and Nanomagnetics: A host of nanotechnologies will influence the electronics industry in the span of a decade. Accordingly, several groups at IITB are currently engaged in developing various nanodevices. Additionally, studies are focused on nano-crystalline silicon with grain size less than 10 nm. These could be applied as window layers in solar cells, and in nano-devices such as micro cantilevers and micromotors

Nano CMOS devices: Today's manufacturing methods have enabled the lithographic fabrication of transistors with a size of 100nm. However, in the sub-100nm regime, critical dimensions on the chip will have to be defined by novel processes. Accordingly, an important area of endeavor at IITB is the fabrication of CMOS FETs with ultra-short channel length of 50nm.

NEMS devices: Nano-transistor technology is being adapted for building silicon-polymer hybrid nanosystems or NEMS with the aim of developing a low-cost, field-portable biomedical system and a total assay system. The former is designed to track diseases ranging from AIDS to breast cancer, while the latter helps in localized monitoring of the environment - for example, arsenic level variation in groundwater.

Research in NEMS Bio-sensors involves the fabrication of integrated cantilever arrays to detect *markers* for Acute Myocardial Infarction (cardiac muscle damage accompanying a heart attack). The advantage of such a protein chip is that it detects multiple markers in a single reaction. Faculty at IITB are also exploring the possibility of making 3D NEMS devices through structuring glasses, using a combination of UV light and annealing.

Carbon Nanotubes (CNT): An important activity at IITB has been the synthesis of Carbon Nanotubes — a sequence of C60 atoms arranged in a thin cylindrical structure (picture on page 13). CNTs find uses in ultra-capacitors, solar cells, diodes and transistors. Such CNTs can be produced at low cost, and localized on silicon and other planar substrates using the Chemical Vapour Deposition method.

Nanomagnetics: A significant application of magnetic technology is information storage and retrieval. Magnetoresistive sensors made up of nanostructured multilayers find uses in reading heads of computer hardware products, in medicine, in surveillance and manufacturing control, and also in the automobile and aerospace industries. At IITB, the current focus is on the preparation and characterization of a series of multilayered products. Systems under investigation are iron, nickel, cobalt, rare earths, and their alloys. Nanocomposites of these with non-magnetic and non-conducting materials such as oxides of silicon, aluminium and zirconium, are being examined for enhanced magneto-resistance.

Nano-biotechnology: The nano-biotechnology research at IITB involves an interdisciplinary approach. It encompasses development of biocompatible nanoparticles for therapeutic use, nanoparticles as drug delivery agents, and biomaterials and devices for biological applications.

Nanoparticles for treatment of cancer: A promising therapy for treatment of cancer involves the selective destruction of cancer cells by raising their temperatures to 42-56^{o}C. The magnetic properties of nanoparticles in the presence of an external alternating magnetic field is used to bring about such localized *hyperthermia*. Certain nanoparticles need to be encapsulated with suitable biocompatible material (such as liposomes) before being administered intravenously to a patient. A schematic representation of the treatment is shown in the last figure.

Nanoparticles as drug delivery agents: A research group at IITB is developing nanoparticles for inhalation in Neonatal and Adult Respiratory Distress Syndromes. The idea is to mimic the role played by naturally occurring pulmonary surfactants, which may be inadequate or dysfunctional in certain respiratory diseases. Yet another study in progress is the evaluation of the therapeutic efficacy of *Bhasma* preparations as nanoparticles in drug delivery. Bhasmas are extremely fine powders coated with herbal extracts, used in the Ayurvedic and Siddha systems of medicine.

Biomaterials and devices: Bone defects due to gum diseases or injuries require bone replacement. Nanocomposites of hydroxyapatite and bioglass ceramics are being studied as suitable bone substitutes for dental and maxillo-facial use. Researchers at IITB are also developing micro-engineered devices to be used in trans-catheter and endoscopic surgeries.

The Road Ahead

The fundamental knowledge gained through nanoscience will expand over the coming decades. Accordingly, governments and major corporations around the world have been committing several billion dollars annually for the advancement of nanotechnology. The ever-increasing additions to the repertoire of nanotechnology-based applications is an indicator of the promise of nanotechnology as a dominant force in our society.

Faced with the challenge of developing new characterization techniques, novel systems and devices in the nanoregime, an institute-wide initiative has been launched to make IITB the nation's hub for nanotechnology research in the near future.

Acknowledgement: *I thank Prof D Bahadur (Deptt. of Met Engg. and Mat. Science) and Prof S Duttagupta (Deptt. of Electrical Engg.) whose help and guidance have been invaluable in the composition of this article. The graphics used in this article have been obtained from various research groups of IITB.*

Research Areas in Nanotechnology at IIT Bombay

Research Area	Teams
Magnetic and magnetoresistive properties of spin valve multilayers	M Senthil Kumar senthil@phy.iitb.ac.in
Infrastructure development for measurement of MicroElectro-Mechanical Systems (MEMS)	P S Gandhi, G Vishnoi, R Rao gandhi@iitb.ac.in
Ultra thin films and multilayers for X-ray optics; Photostructurable glass ceramics; Magnetic nano- crystalline materials from metallic glass precursors	Satish Vitta svitta@met.iitb.ac.in
Nanoscale CMOS devices ; Nanoscale Electro-Mechanical Systems (NEMS);	S P Duttagupta, V R Rao, A N Chandorkar, R Lal, J Vasi, P R Apte, R Pinto, S Mahapatra, D K Sharma, M B Patil, P S Gandhi, S Mukherjee microe@ee.iitb.ac.in
Carbon nanotubes for energy applications	M Sharon, R Banerjee sharon@chem.iitb.ac.in
Nano-optics, photonic crystals and photonic bandgap materials	R Vijaya rvijaya@phy.iitb.ac.in
Confinement of nanomaterials in mesoporous molecular sieves	P Selvam pselvam@chem.iitb.ac.in
Nanocrystalline silicon thin films by hot wire chemical vapour deposition.	Rajiv O Dusane rod@met.iitb.ac.in
Influence of structural and micro structural tuning on the physical properties of manganates	D Bahadur dhiren@met.iitb.ac.in
Magnetic nanoparticle-based intracellular hyperthermia — A promising therapy for cancer	D Bahadur, D Datta, J Bellare, R Banerjee, G Vishnoi, dhiren@met.iitb.ac.in
Synthesis of nanostructured magnetic materials for different applications	D Bahadur, S Vitta, Om Prakash, C V Tomy, K Suresh, dhiren@met.iitb.ac.in
Structure-properties relationship in nanocrystalline ferrite thin films	N Venkataramani ramani@acre.iitb.ac.in
Production of nanoparticles using supercritical carbon dioxide	M Mukhopadhyay, Sandip Roy, Swapneshu Baser mm@che.iitb.ac.in
Organic multilayers and related nanostructures	S S Major syed@phy.iitb.ac.in
Measurement of aerosolized nanoparticles	G Habib, Chandra Venkataraman chandra@cc.iitb.ac.in
Nanoparticles for ophthalmic drug delivery	S Das, J Bellare, Rinti Banerjee jb@iitb.ac.in

National Research Fellowship Scheme

IIT Bombay announces a new fellowship scheme to encourage bright students to opt for research at the institute.

- Eligibility: Final / Pre-final year students
- Fellowship Amount: Between Rs.8000-10000 p.m. (B.E./B.Tech./M.Sc.), or between Rs.12000 - 15000 p.m. (M.E./M. Tech. + experience)
- Opportunity to work on challenging research projects
- Simultaneous registration for academic degrees (Subject to meeting admission criteria)
- Mentorship: Faculty-guided vacation projects for pre-final year students (stipend @ Rs. 3000 p.m. during mentorship)
- Admission process to start from 1st January 2004.

Further details: http://www.ircc.iitb.ac.in/~fellowship

Address for Correspondence:
Dean R&D, Industrial Research & Consultancy Centre (IRCC)
IIT Bombay, Powai, Mumbai 400076
Tel : +91 22 2576 7039 Fax: 2572 3702 / 3480
E-mail: update@ircc.iitb.ac.in

The Web Edition of this Newsletter, available at: http://www.ircc.iitb.ac.in/update
IIT Bombay's Homepage: www.iitb.ac.in

Designed by IDC, IIT Bombay
Printed by PRINTECH - 5699 6454