Science education in Indian universities: Proposal for a 5-year integrated M Sc course in life science

Sohan P. Modak

The undergraduate and postgraduate science degree courses in India lack a conceptual basis and systems approach for designing syllabi. Existing syllabi are repetitive and wasteful. An integrated 5-year M Sc in life sciences is proposed. Life sciences decipher mechanisms and processes underlying structural and functional organization and the basis of instability of the living state. These should be taught in a synthetic sequence beginning with Physics, Chemistry and with English, Computing, Mathematics and Statistics as languages during the first 3 years. The final two years should cover subject of specialization and advanced streams with a research base and management skills. Summer training and remedial courses should be obligatory.

THOUGH India is the tenth largest world economy with the third largest trained work-force in science and technology, it is still a developing country. The size of our economy primarily reflects the developments in the agriculture and the size of our population, and only secondarily the size of our industry that mostly caters to the local needs. We do not really design, develop and produce modern amenities maintaining high quality standards using our trained work-force. Barring specific cases like rockets, satellites, or a small software industry, our industrial missions involve outdated *ckd* kit assemblage or copying through reverse engineering. Post-war Japan, on the other hand, with practically no natural resources, started out from scratch, but where is it now? Mountain ice is the only natural resource of Switzerland[1] and yet it produces the best of everything from textiles to paper, machine tools to industrial plants, watches to microelectronics, marine engines to solar cars, etc. Its agriculture can hardly feed 60% of its population, yet the food processing giant, *Nestlé*, is Swiss. For a 41,293 sq km landmass and a population of about 6.8 million, Switzerland boasts of one of the largest pharmaceutical industry with CIBA–Geigy–Sandoz combine and Hoffmann–La Roche. In contrast, India has immense natural resources, practically a mosaic of all climates and biodiversities, but do we have any impact on the global trade and economy? Nation building and technological leadership require trained work-force with creative and innovative mind sets, hard work and entrepreneurship. This is what the education system should catalyse. Therefore, it is necessary to assess our educational system and its output.

The NCERT and the State Board of Higher Education devise and regulate the teaching syllabi and methodologies up to the 10+2 level. NCERT has maintained the tempo for a continuous evolution of syllabi to ensure a broad-based training. In contrast, an excessive specialization in college and university, without emphasizing the basic tenets of science education has led to the production of a work-force loaded with information but without integration. This situation is similar to our copying data bases with neither relevant questions to ask nor the tools to find answers. In Maharashtra, mathematics has been de-emphasized *de facto* for +2 level students opting for the biology stream. The 10+2 acts as a screen to select the 91%+ students seeking admission to medicine, engineering and technology courses. Earlier, it was respectable to study sciences and a good proportion of students around $80 \pm 5\%$ entered the science discipline. With the proliferation of private engineering and medical colleges, the screen for open seats has moved down drastically. Similarly, with the advent of professional courses such as MBA attracting better informed and versatile students, only those from the lower percentile are available for traditional M Sc. Ten years ago, admission to physics and electronics courses at the University of Pune ended at 75% marks, while today this is down to 50%. In some subjects moreover, over 60% seats have remained vacant at FY B Sc and the enrolment to M Sc will continue to decrease. Since 10 years there has been a diminishing interest in Sciences world wide and we are just beginning to see the fall-out in India. A major proportion of Indian M Sc degree holders become teachers for lack of better opportunities. Among them, less than 7% students pass the UGC–CSIR NET because of the poor quality of B Sc and M Sc training. In India we have over 200 universities and 10,000 colleges whose job is to produce trained personnel. The present education is neither learner-friendly nor user-friendly, nor has it kept pace with modern trends in sciences. Besides, most bright students joining Medicine

Sohan P. Modak is in the Departments of Zoology and Botany, University of Pune, Pune 411 007, India.

and Engineering, do not go in for research and development. Let us examine all components of our science education.

To implement undergraduate and postgraduate syllabi, institutions and government provide the infrastructure. Let us examine their performance. The Boards of Studies continually dilute syllabi, ignore modern teaching methodologies, and promote obsolete and often-plagiarized teaching texts. Course structure and teaching sequence are haphazard with futile attempts to introduce 'catchy' titles under the garb of vocational courses which the teachers are not competent to teach. The laboratory exercises are obsolete, unimaginative and lack the inductive stimulus. Most postgraduate departments follow this trend. A few try to undo the damage by packaging so much material that it is difficult to digest. Either situation leads to a perpetuation of mediocrity, absence of work culture, suppression of dissent, kills curiosity, and wastes student's time, thereby preventing development of scientific temper. Boards of Studies also promote mediocre and repetitive Ph D theses supervised by guides of questionable competence and assessed by referees of equally questionable integrity. Managements are responsible for this lack of infrastructure and operate the educational institutions as money-spinners through capitation fees and forced donations. Elected Governments are the main culprits in giving higher education the lowest priority. Furthermore, many teachers participate in a parallel 'black' educational network, thriving on private coaching classes and tuitions while disregarding their professional obligations in the classroom and laboratory. Governments engage only in the rhetoric of a mass higher education and not higher education *per se*. The UGC, the body for regulating the quality of higher education, is toothless. Attempts to make passing in NET/SET compulsory for teacher appointments have failed under the pressure of various teachers' unions. All of this has led to a monumental 'academic fraud' perpetrated on the Indian student and the nation.

By mid-80s it became clear that a dramatic fix was necessary to make a quantum improvement in the teaching infrastructure and syllabi in modern biology. The National BioTechnology Board mooted the idea of introducing a training programme in M Sc biotechnology with UGC's support. For this course, science graduates were selected by an entrance test. The programme, originally restricted to 6 universities, quickly became a model for quality training in Life Sciences as it included many innovations, flexibility in its course-design and the openings for creative teaching. The programme attracted good students in the 80 ± 5 percentile. However, the geopolitical considerations led DBT and UGC to extend this programme to over 19 institutions. Consequently, the percentiles dropped below 75%, and the syllabus- and teacher-quality plummeted. Ever-changing policies on reservations for teaching posts and lack of concept-basis have drastically reduced the effectiveness of biotechnology training programmes. For example, in Pune 3 out of 6 teaching posts still remain unfilled. This is also true of other subjects which suits state exchequers who naturally save on already depleted funding for higher education. Almost everywhere in India, a new class of education empire-builders have come to the fore who have done very little to evolve a good educational system. I agree with Sitaramam[2] that the Biotechnology students do well because they are basically talented and not necessarily due to skilled teachers, good syllabi on job-potential. In mid-eighties, UGC and CSIR introduced the National Eligibility Test (NET) for postgraduate research fellowships and evolved advanced syllabi hoping that this would force major revisions in the undergraduate and postgraduate syllabi in the country. I was involved in the establishment and the syllabus-framing of both Biotechnology Training programme and the NET, but, in retrospect, I find that the impact of these syllabi on teaching life sciences in India is at best disappointing. Towards the end of 80s, various surveys revealed that, excepting for a few late-bloomers, most students performing around 80 percentile at +2 level do well in B Sc, M Sc and UGC–CSIR–NET. This has direct bearing on the learning potential of the student, communication skill of teachers, the quality of syllabi and infrastructure at the +3 level. As most students opt for undergraduate science subjects in the absence of other channels, the concern for a good teacher-quality has become important.

The teacher

A teacher is the primary medium of information-transfer who also catalyses the process of learning or integrating the information into knowledge. I examine here the requirements for making a good teacher. A good teacher should be motivated and able to communicate and induce the student. The teacher should be an expert who continually updates her/his knowledge. An ideal teacher should be highly skilled and involved in the process of enquiry and research. Such a teacher would have self-respect and the mind-set with scientific temper without loss of empathy. The teacher should know that the information is not knowledge and that creative teaching involves inductive inputs, not dictations, to promote learning. A good teacher also knows that the science is introvert. It superposes philosophy, and the process of creative learning involves analysis, synthesis, dissent, high-level curiosity, and the search for truth at any cost. These are the conditions for developing the scientific temper. In contrast, the technology is extrovert requiring skills and aptitude for execution, management, innovation and enterprise. On a ten-point assessment scale, I predict that the top 2% undergraduate teachers will score 7 or more points, the next 5% five points and the remaining 3 or less. A horizontal scale-amplification with excellent, very good, good, fair and poor, will hardly change this situation. Using the same scale, postgraduate teachers in universities may perform only marginally better. Yet, student's examination scores are high because of manipulation of the examination system. This is the epitaph to undergraduate and postgraduate teaching in India and is the reason for a low-quality output of scientific work-force. Improving teacher-quality is not a make-shift operation possible through refresher courses and monetary incentives. It has to begin in the schools and colleges. Those who have not learnt, and therefore are not knowledgeable, just should not be in this profession. Learning is solving puzzles where a picture emerges using the memory base, recall, and integration in real-time by recognizing patterns through trial and error, multiple choice selection, common sense, general knowledge, intuition, creativity and enterprise.

The student

Then, what about a potentially good student? A good student should be able to read, write, speak and listen in the languages of science and able to observe, recognize shapes, patterns and relationships between these through recall and retrieval from the memory base. A good student should have acquired skills to analyse and synthesize, and be logical in thinking to question beliefs, falsities as well as truths. The student should be on constant lookout for what is happening around with fearlessness and hard work, should have manual skills to match the information base, appreciation of quality and quantity and the desire to overcome. Unfazed curiosity is the hallmark of a good student and the cumulative experience hones the sense of intuition and leads to creativity.

The goal of education is to facilitate an individual's passage to become an ideal student. He/she should be induced to develop a correct mind-set and personality conducive to the conduct of a scientific enquiry. 10+2 syllabi do not promote language skills, the mind–hand connection, fearlessness, general knowledge, appreciation of diversity and quantity, or thinking. At this point, the student is in a formative period, with the left side of the brain still untapped. Only serious attempts to promote each ideal trait will elicit a variable but positive response of the heterozygous *Homo sapiens* that cannot be achieved through a 'mutant' selection or despotic social engineering.

University of Pune – A case study

The University of Pune administers undergraduate and postgraduate education including professional degrees in engineering and medicine in three districts in Maharashtra, namely, Pune, Ahmednagar and Nasik covering over 200 colleges. The Boards of Studies (BOS) in each subject frame the undergraduate and postgraduate syllabi. Each BOS contains 6 members elected from among Heads of College Departments teaching TY B Sc, the Head of the University department, two teachers co-opted from among teachers who are not department-heads, and two outside experts. Thus the BOS primarily represents the constituency of undergraduate teachers and frames even postgraduate syllabi. Only after syllabus-ratification by the Academic Council, heavily representative of college teachers and managements, can the course be taught.

During 1980–1984, the University placed greater trust in teachers by allowing them to allot 40% marks by internal assessment for each course, and the entire examination of the so-called C component (vocational courses) and departmental courses. Unfortunately, this led to an excessive marking (never below 90%) in internal assessment and C component-courses very much due to peer-pressure and teacher's goofing-off, as compared to an average of 50% in centralized external examinations. The syllabus framing also included preparing question banks from which at least 50% of questions were included in the external examination. In most subjects the question banks were so small the teachers restricted their lectures to these, thereby diluting the syllabus and destroying the work-culture among students. Under the pretext of syllabus modernization, some of the important topics, taught in B Sc in 60s and 70s, were not covered till later in M Sc. The responsibility for this failed experiment lies squarely on the shoulders of the 'untrustworthy' teachers. This forced the University to eliminate question banks and the C component, and to change the marking ratio for external:internal from 60:40 to 80:20. The departmental courses still serve as fodder for teachers involved in excessive marking to cover-up their own deficiencies which is hardly different elsewhere.

In mid-80s, as the admissions to University PG courses, based on merit list at the +3 level did not reflect in the student performance in MA and M Sc, two solutions were used in science departments by preparing merit lists from marks secured in the external examinations and giving academic autonomy to University departments recipient of UGC–DSA, CAS and COSIST. Such departments framed their own syllabi and conducted entrance examinations independent of college postgraduate centres. In 1985–1986, NBTB (DST)–UGC awarded M Sc Biotechnology Training Programme to the Zoology department. Earlier, TIFR had initiated a collaborative teaching programme with the Physics department, while NCL did the same with the Chemistry department. UGC recommended that all departments with DSA, CAS or COSIST should have academic autonomy and admission through a nationally advertized entrance test. While admissions to Biotechnology and

Zoology continued through entrance tests, the latter with 25% seats to students with B Sc in other science subjects, the entrance tests in Chemistry and Physics were restricted to the collaborative programmes. As the number of PG centres in Zoology increased, the total number of seats for M Sc Zoology quadrupled. Admission to University department being in part on scores in the entrance tests, good but poor students in the rural areas became attracted towards the University department that does not charge capitation fee. Only in 1996 was the botany syllabus revised to match the standards of UGC–CSIR–NET, and an entrance test introduced. However, even this trend is not prevalent in most other universities. Unfortunately, the academic autonomy is now under fire from the University legislative bodies presumably due to the loss of control over University departments. Concomitantly, admissions to life science subjects at undergraduate level have dropped as the State Board of Higher Secondary Education separated biology and physical–mathematical science streams at +2. This drastically reduced the number of postgraduate centres with spurious teaching and examination record. Other than CAS-Sanskrit, UGC also identified statistics, sociology, and mathematics departments for special assistance. But these did not opt for an entrance test as the available seats remain unfilled using B Sc merit lists. In conclusion, the faculty performance in teaching and research should allow identification of expertise in the thrust areas in different subjects. Such an exercise in botany restricted the teaching to 5 specializations out of a plethora of eight.

Teaching life sciences in India

Life science subjects are taught at the undergraduate level in a macro to micro sequence beginning with, say, the animal kingdom, then the taxonomy, speciation, study of types, morphology, anatomy and histology. Cell biology, genetics and physiological chemistry are taught in the second and third years and the same of the first year is repeated, presumably at a higher level, without paying adequate attention to chemistry, physics, biochemistry and molecular biology. The pattern is repeated in M Sc, with minimal inputs in modern biology. This sequence inculcates an analytical frame of mind, destroys the ability to synthesize, to formulate concepts, designs, structures and to understand the structure–function relationships. The lack of a synthetic sequence also suppresses innovativeness, creativity and enterprise. This is true of all undergraduate and postgraduate courses in life sciences in India taught using substandard teaching methods which condemn students to the dungeon of boredom. Life science teaching has, thus, become sterile. An occasional flash of brilliance is a fluke due either to the inherent capacity of the student, or a rare teacher, or both acting in harmony. Life sciences, though, offer a fertile field for research in chemistry, mathematics and physics, but in India, there is no dialogue among the teachers in these subjects. Thus, we will remain as customers for information from the West.

The correct approach

Life sciences decipher the mechanisms and processes underlying structural and functional organization of the living, and the basis of instability of components and systems, entities or beings, and their associations at molecular, cellular, and organismic levels. The principle of instability is evident in atomic nuclei and particles, atoms and their isotopes. At the molecular level, weak and strong interactions affect the stability of bonds. In contrast, most macromolecular aggregates hold together through weak interactions. These aggregates combine to form cell organelles and perform structure- and composition-specific functions segregated in space (position) and time. Cell organelles perform specific function and, in desired formulations, give rise to cells. Cell communities either share all functions, or exhibit complementarity through acquisition of specialized functions, and form organs like root, stem, leaves, flowers, fruit brain, heart, gut, bones, skin, etc. A perfect blend of structurally segregated but functionally linked cell communities give rise to multicellular beings that grow or reproduce, adapt to changes in the environment, defend against toxins and parasitic attack, and exhibit societal interactions. Only this sequence ensures assimilation of the paradigm relevant to the functionality and the division of labour. Thus, a student must begin learning in this 'synthetic' sequence for generating complexity out of simplicity which will have a dramatically different effect on the mind-set and temper as it follows an architect's and builder's 'psyche' based on constituents, composition and management. It favours inventiveness, allows trial–error and the ability to retrace the path, and completely changes the attitude of students towards life processes. We have attempted this approach in M Sc Zoology at Pune but it is often too late because college students already have hardened the opposite mind-set and lost the work-culture due to easy marks, weak and repetitive courses, poor teachers, absence of an argumentative atmosphere, and absence of modernity. Therefore, attempts to resurrect a correct teaching sequence at M Sc can be only fractionally successful. In India, more than a quarter million students lose three precious and intellectually formative undergraduate years. Earlier, a matriculate could become a clerk, section officer or a school teacher which the present-day graduate cannot. The present educational system is not only chaotic but dumps the students in the rut of postponing entry in to professional life.

What can we do?

We have to implement drastic changes in the system and process of higher education. The correct format includes (i) a synthetic teaching sequence and multidirectional inputs in foundation courses, (ii) correct information, its verifiability and revision, (iii) continuous teacher training with a research base, (iv) efforts to develop manual, cognitive and combinatorial skills, (v) promotion of climate to learn to make mistakes and to correct these, (vi) cultivation of ability to learn to speak, read, write and listen, (vii) promoting contest, dissent expression and nurture of curiosity, and (viii) promoting ability to compare, verify and correct.

I propose a five-year integrated M Sc which would utilize the entire span to deliver life science graduates who can think, perceive, conceive, and copulate information and ideas into knowledge on a sustainable and constructive basis. The proposal eliminates the existing lacunae. Another such proposal suggested earlier[3] lacked the conceptual framework, a systematic analysis of the reality, or tenable solutions. The 10+2 syllabi are far better than present the FY B Sc. In my proposal, students can take a B Sc after +3 and leave. A 5-year graduate will have comprehensive subject knowledge, a research base, creative inputs and innovative spirit with a hands-on experience in a research laboratory or field. They will communicate well in modern languages in life sciences, develop self-respect, confidence and fearlessness and maintain high level of curiosity. The system will also promote remedial education to students from rural and socially-deprived backgrounds. Only fully-trained graduates should be licensed to practice life sciences. With a 'micro to macro' synthetic attitude inculcated, it does not matter which specific subject and specialization the student pursues.

The five-year integrated M Sc programme in life sciences

After 10+2, all science subjects should teach similar +3 syllabi with emphasis on the development of communication skills, manual skills, interactive teaching, strong bias for field- and laboratory-training to teach the logic of science and concepts. The present analytical teaching cascade needs to be inverted as a natural mimetic to build a synthetic mind-set with readiness to contest through dissent, combativity for the satisfication of the curiosity. The consequences of the synthetic approach would be dramatically different on the mind-set and temper. The exposure to management, accounting practices and patent laws will induce students to go into an operational mode for immediate employment in industry. They will become far better teachers and workforce in science and technology, something that M Sc Biotechnology programme has achieved only marginally.

Summing up

I have evolved a streamlined structure (Table 1) for Life Science education with an exit point, but not entry, after the third year when the student is well trained in basic biology and skills required to promote their access to other professional outlets. The format differs significantly from the classical 3+2 pattern. Similar formats can be developed for other sciences by mini-packaging molecular biology and genetics, cell-developmental biology and immunology, biochemistry and bioenergetics, classical animal, microbial and plant studies, and environmental biology, but not by eliminating these[4] so that students from other science streams can cross over to life sciences after +3. Students and teachers for such a course should have passed appropriate aptitude tests. Naturally, the present makers of the educational policy need dramatic reorientation, and perpetuation of the practice of 'mandarinage' has to be avoided. Here I refer to the proposal[4] that ignores the reality of science teaching in India[5]. The process of education should not be under the control of those who are responsible for destroying our educational system as science education requires a level playing field. Otherwise, this model too will end up as the symbol of a failed trial which, at this point, is tantamount to accepting a pawn-status on the scene of rapid globalization. It will also fail if implemented primarily with part-time teachers, howsoever expert and good research scientists they may be, because a student needs continuity in the teacher-contact and a sense of belonging. The implementation will require an aggressive policy to recruit good teachers from within and outside India, to provide a congenial habitat, well-thought procedures for screening students and teachers, equal opportunity, a thoughtful marriage between private and public resources, updatable infrastructure, and methods to promote better performance in students from deprived and rural populace to match the constitutional guarantees without downgrading the educational standards. A good set-up for higher education cannot do away with the research component and must avoid inbreeding. If state governments do not have the will, then the higher education should be entrusted solely in the hands of the central government[5]. Finally, the confidence in the 80+ percentile group at 10+2 needs reassessment because most such students are also products of the so-called parallel education system which the poor students from the lower percentile groups cannot access. This is why a small but measurable proportion of late bloomers appears.

Table 1. Structure of a 5-year integrated M Sc course in life sciences

Year 1. Nuts, bolts and instability

Semester I

English for Scientists	Computing, MS Word, Excel, Access, Power point
Measurement theory	Principles of Instability – atoms and molecules
Chemistry–synthesis and catalysis	
Catch-up courses	

Semester II

Basic electronics	Philosophy of Science – Logic
Statistics and applied mathematics	Biochemistry
Catch-up courses	

Year 2. The cascade of complexity: transmission and the drive

Semester III

Molecular Biology	Materials and polymers
Cell Structure and Physiology	Bioenergetics
Catch-up courses	

Semester IV

Microbial structure, function and taxonomy	Principles of genetics
Developmental biology	Immunology
Carpentry/machine shop/drafting/photography	
Catch-up courses/Year-end summer project	

Year 3. The body

Semester V

Structure and function relationships in plants	Structure and function relationships in animals
Animal and plant taxonomy and informatics	Science instrumentation
Biochemical techniques	
Catch-up courses	

Semester VI

Evolution	Data bases and information retrieval
Ecology	Biophysical techniques
Microtechnique, morphometry and image processing	
Catch-up courses/Year-end summer project	

Year 4. The road and destination

Semester VII

Any one among specialized streams, theory and lab rotation	Chronobiology
Optional courses (any two)	Research project and seminars
Catch-up courses/Year-end summer project	

Semester VIII

Specialized stream theory and lab rotation	Genetic engineering and gene transfer
Optional courses (any two)	Research project and seminars
Catch-up courses/Year-end summer project	

Year 5. Occupational skills

Semester IX

Specialized stream theory and lab rotation	Optional courses (any two)
Management	Research project and seminars
Catch-up courses	

Semester X

Specialized stream (lab rotation)	Optional courses (any two)
Structure of human society, interactions, eugenics	Research project and seminars
Catch-up courses/Year-end summer project	

Contd...

contd...

Specialized streams	
Animal tissue culture, vaccines and diagnostics	Physiology and metabolism
Molecular biophysics	Plant tissue culture, plant propagation
Plant genetics and breeding	Molecular biology and genetics
Cell and developmental biology	Nutrition, eugenics and anthropology
Computer interactive and audio-visual methods in research and education	Microbial systematics, community structure pathology and management
Ecology and environmental management	Membrane biology
Mycology and plant pathology	Entomology
Comparative plant anatomy, systematics, community structure and management of the flora	Animal comparative anatomy, systematics, community-structure, behaviour and management of the fauna
Industrial microbiology.	Neurobiology
Optional courses [excepting those included in a special stream]	
Genetic toxicology	Phage and viral genetics
Developmental genetics	Genetic engineering
Physical anthropology	Behavioural genetics
Physiology of reproduction	Endocrinology
Neurobiology	Clinical microbiology
Electron microscopy	Toxicology
Pest control	Epizootology
Animal–plant interactions	Insect biochemistry and physiology
Applied entomology	Bioelectronics
Mushrooms and mushroom culture	Horticulture
Medicinal plants	Phytochemistry and plant products
Biopesticides and biofertilizers	Plant propagation
Wild life management and conservation	Land management
Palaeobotany	Palaeontology
Animal behaviour	Remote sensing
Biochemical processes	Enzyme engineering
Cell engineering	Biomes culture
Fermentation technology	Cryobiology
Museum management	Copyright and patent law
Finance and marketing	Computer graphics and modelling science
communication in Indian languages	Foreign language proficiency: Japanese or German or French or Spanish or Russian or Arabic
Virtual reality.	

Teaching methodologies. OHP, 35 mm slides, video, CD-ROMs, interactive computer-based teaching (CBT), laboratory and field work, electrical–electronics–mechanical workshop, seminars, tutorials, visits, summer and autumn training programmes, remedial courses.
Examinations. Objective, short and long answer, seminar, open-book, CBT
Funding. Central and state government, private
Infrastructure. Water, electricity, space, equipment and waste disposal
Faculty and students. Aptitude-tested.

Post-script

Unfortunately, our funding agencies lack the correct attitude for critically assessing mission-oriented projects, guts to make mid-course corrections and 'candour' to terminate open-ended and failed projects, be these in universities or national institutes. Most funding reaches a handful few without emphasizing either cost–benefit ratio or the productivity, and that it is almost never terminated despite failures. The applicants often present unattainable objectives using a rhetoric heard sympathetically by the so-called peers who play the musical chairs in a dual role as peers and applicants, and subvert the entire process by breeding rampant nepotism. We really do not have a critical mass of peers for a meaningful peer-review in most hi-tech areas, or low-tech but multifaceted disciplines. Most members of the so-called expert panels do not even read most project proposals. Who, in India will assess proposals, say, from IISc? Who will stop the February gold-rush to Delhi? How can one eliminate the parochialism in research committees? In the West, peer review committees change through rotation at intervals. We should recruit expert-help from outside, an idea vehemently opposed by the 'mandarins' of Indian science. At present, there is no independent audit of individual or mission-oriented research projects. Like in finance and accounts, the 'spender' cannot be the 'auditor'.

UGC and all Government agencies and NGOs involved in science and technology development in India should support this 'experiment' because it is revolutionary and original. It is a direct attempt to replant the cured soil of higher education in science with an epigenetically modified and better-yielding variety. Only after success in such efforts would we deserve the status of the third largest work-force in science and technology. Indeed, it is worth rerouting this work-force and even decreasing it because the quality, rather than quantity, is relevant to the process of nation building at this point. Even if the part dealing with the +3 level is implemented, the scenario for life sciences will change dramatically in India. A 5-year M Sc programme is not another band-wagon to attract 'good' students. It must transcend geo-political considerations. Indian teachers are parochial and hate mobility. Then, let students move, as they do, to the training site. The psychological 'fix' by a 5-year M Sc[6] will automatically curtail the use of students as the 'manual labour' for the peers practising science by 'proxy'.

1. Modak, S. P., in *Switzerland, as seen by others* (ed. Commission de coordination pour la présence de la Suisse a l'étrangèr), Der Altag/Scalo Verlag AG, Zurich, Switzerland, 1992, pp. 121–133.
2. Sitaramam, V., *Curr. Sci.*, 1991, **60**, 537–540.
3. Sitaramam, V. and Sauna, Z. E., *Curr. Sci.*, 1996, **70**, 335–340.
4. Indian Academy of Sciences, 1994, Acad. Papers no. 1, pp. 1–32.
5. Sitaramam, V., *Curr. Sci.*, 1995, **69**, 89–94.
6. Estimated cost: Rs. 4.5 crores for capital expenditure, Rs. 50 lakhs/year recurring, an intake of 40–50 students/year, and an endowment of Rs. 4 crores to cover salaries (1995–96 scales). Methods for aptitude tests are being studied.

ACKNOWLEDGEMENTS. I thank Dr V. Gowariker, Prof. M. N. Palsane, and Mr. Zuben Sauna of the University of Pune for critical discussions.

REVIEW ARTICLE

Progress towards malaria vaccine

V. S. Chauhan

International Centre for Genetic Engineering and Biotechnology, Aruna Asaf Ali Marg, New Delhi 110 067, India

Resurgence of malaria has reached alarming proportions. The situation has become worse because of the widespread resistance to anti-malarials. Thus malaria vaccine research has become an area of intense activity even though host–parasite interactions are not well understood. Several antigens from different stages of the life cycle of malaria parasite have been identified. It is now clear that both antibodies and cellular immune responses are involved in malaria immunity. At the same time it is becoming clear that plasmodium has developed exquisite mechanism to evade the immune responses mounted by the host. All kinds of vaccine constructs, based on recombinant antigens, synthetic peptides, and direct use of DNA are being attempted and several of these are undergoing human trials. Results of these trials and other research works clearly indicate that malaria vaccine development is hugely complex and success may not come easily.

MALARIA continues to be a major cause of morbidity and mortality in the tropical and subtropical areas of the world where approximately 350 million malaria cases occur each year. More than two million children die of the disease annually. The overwhelming success of chloroquine as a drug and DDT as an insecticidal, introduced in 1960s resulted in an impression that malaria could be controlled to a large extent if not eradicated. Unfortunately, resistance of the human malaria parasite *Plasmodium falciparum* to anti-malarial drugs and to its mosquito vector to insecticides has led to an alarming situation and drugs-resistant strains of *P. falciparum* have spread throughout the tropics. Given the fact that no new anti-malarial drugs or new insecticides superior to DDT are likely to be available in the near future, the disease situation is becoming hopeless.

Vaccine should be a useful addition to chemotherapy and the vector control program in malaria control. However, until recently there was no way to obtain sufficiently large amounts of antigenic material from the parasite. With the availability of *P. falciparum* in culture form, it has become possible to study the molecular basis of the parasite function. Identification and production of antigens involved in protective immunity by applying tools of modern biology has changed the direction of malaria research, particularly the vaccine development.