

and neural development. In the nervous system, *emc* functions as a negative regulator of adult sensory organ development. Loss of function of these genes causes most or all cells in the ectoderm to develop as neuronal precursors, resulting in hypertrophy of the nervous system at the expense of epidermal development. *emc* participates in sensory organ development by antagonizing the neurogenic activity of genes in the AS-C. Extra doses of AS-C linearly enhance the *h* and *emc* phenotypes, and extra doses of *h*⁺ and *emc*⁺ suppress the excess sensory organs induced by overexpression of *ac* and *sc*. It appears that *h* and *emc* products repress *ac* and *sc* leading to local depletion of these products. This causes spatially restricted activation of *ac* and *sc* genes and the development of sensory organs²⁰⁻²². *dpn* is expressed transiently in most or all neuroblasts²³. The pattern of expression of *da*, *sis-b*, *runt* and *dpn* is spatially restricted during neurogenesis, but appears to be temporally restricted and spatially uniform for activation of *Sxl*.

HLH transcription factors are also candidate regulators of development in the mammalian nervous system. Homologues of the *Drosophila* AS-C genes have been isolated in several vertebrate species including the rat²⁴, and mouse²⁵. Two such genes, Mammalian *achaete-scute* homologues 1 and 2 (*Mash-1* and *Mash-2*), have been studied in some detail. *Mash-1* expression is restricted to the developing central and peripheral nervous systems, whereas *Mash-2* transcripts are formed exclusively in trophoblast cells. *Mash-1* expression is initially spatially restricted to specific domains of embryonic neuroepithelium. Later, *Mash-1* is more broadly expressed within the ventricular cells. In postnatal animals, expression of *Mash-1*

is detected only in regions undergoing neurogenesis, such as the cerebellum and hippocampus. The expression of *Mash-1* generally precedes the appearance of markers of neuronal differentiation such as tyrosine hydroxylase and neurofilaments and, like the expression of *achaete-scute*, appears to be extinguished shortly prior to terminal neuronal differentiation. In mice homozygous for *Mash-1* the olfactory epithelium and the sympathetic, parasympathetic and enteric ganglia are severely affected²⁴⁻²⁷.

The occurrence of similar HLH regulatory proteins in organisms as diverse as flies and mammals and their involvement in developmental pathways as different as sex determination and neuronal development suggests both conservation and multifunctionality of these proteins. One might expect to see genetic redundancy²⁸ among those genes that code for proteins which dimerize with a common target molecule to perform a common function. Partial substitution of the function of one gene by another is in fact observed among *sis-a*, *sis-b* and *runt*⁴, the *Drosophila* sex determination genes which act as numerators for X:A ratio measurement (reviewed in ref. 29).

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Challenges of user-driven R&D: BARC model*

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It is an honour and privilege to deliver the first P. R. Roy Memorial Lecture. Pradip Ranjan Roy did pioneering work

in plutonium technology, beryllium technology and nuclear fuels—fields in which there was hardly any published work to serve as a guide for a newcomer. Starting from scratch and learning everything the hard way, Roy became an international authority in these fields and made India self-reliant in established as well as novel nuclear fuels. He accomplished these in

a short span of 23 years with self-effacing modesty. His cheerful and helpful personality enabled him to build a dedicated team to carry on his work.

Roy personifies the philosophy and achievements of Bhabha Atomic Research Centre (BARC), Trombay, Bombay, which is an outstanding example of user-driven research and development in the Indian

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context. The perceptions of an outsider about BARC are discussed here as a case study of user-driven R&D in India.

Major contributions

One of the most important achievements of BARC is to train young persons, with a first degree from Indian institutions, into full-fledged competent professionals. Some obtained advanced degrees based on work done at BARC. Many, such as Roy, acquired international recognition. Typically, a BARC scientist is characterized by self-confidence, pride in his work, strong motivation and deep dedication. This culture became ingrained and carefully nurtured from the early days of BARC under the leadership of Homi Bhabha.

Another major accomplishment of BARC is to come up with usable solutions to user-originated problems. While the problems may be mundane, practical and complex, the approach to solve them is as thorough, rigorous and scientific as in basic research, instead of an ad hoc, empirical or superficial methods.

BARC has demonstrated repeatedly that excellence in science and technology and finding implementable solutions to practical problems can be achieved simultaneously and need not be looked upon as alternative paths as is often believed.

Another requirement of user-driven problem-solving is that an integrated, systems approach spanning research, development, design, fabrication, erection, testing, commissioning and operations has to be adopted. The reason for the success of BARC solutions is in no small measure due to the adoption of such an integrated, systems philosophy.

The successful BARC approach to user-driven R&D has been duplicated by spawning a number of other DAE R&D centres, such as the Indira Gandhi Centre for Atomic Research in Kalpakkam, the Variable Energy Cyclotron (VEC) Centre in Calcutta, and more recently, the Centre for Advanced Technology (CAT) in Indore. Their success serves to confirm the soundness of BARC philosophy and approach to user-driven R&D in the Indian context.

BARC has contributed to industrial development in India in the field of high technology products and processes in two significant ways. (i) The first is by spinning off BARC R&D into dedicated industrial establishments under the Depart-

ment of Atomic Energy, such as the Electronics Corporation of India (ECIL), Uranium Corporation of India (UCIL), Indian Rare Earths (IRE), Nuclear Fuel Complex (NFC), and more recently, Nuclear Power Corporation (NPC). All of them have been set up based on technology from BARC, continue to depend on BARC substantially for technological nourishment and upgradation. (ii) The second contribution is by sourcing sophisticated equipment for the atomic energy programme from Indian engineering industries, such as Larsen and Toubro, Walchandnagar Industries and Tata Consulting Engineers, thereby enhancing the capabilities and skills of Indian industries. In recent times, BARC has attempted to transfer technologies developed by them to other private and public sector companies in India. So far such technology transfer is quite limited, compared to the rich pool of technological competence available in BARC.

Unique advantages enjoyed

Compared to other R&D institutions in the country, BARC started off with some unique advantages, many of which BARC continues to enjoy in good measure. The single most crucial advantage was the visionary leadership of Homi Bhabha and Vikram Sarabhai in laying solid foundations and nurturing a culture of self-confidence, pride, dedication and self-motivation. The saplings they planted and the soil they provided led to robust growth till the philosophy became a way of life in BARC, because of the continuity of leadership provided by others such as H. N. Sethna, Raja Ramanna, P. K. Iyengar and R. Chidambaram. By contrast, many other institutions suffered due to frequent changes in leadership causing major changes in direction including dismantling earlier approaches resulting in unsettling, even chaotic, conditions. Changes of leadership, not done carefully, can precipitate problems in an otherwise healthy organization. Examples of this abound in our country. BARC, by and large, operates in areas where no information or technology is available from open literature, bilateral or multilateral agreements or from commercial sources. This necessity has been beautifully turned into a virtue by forcing themselves to become totally self-reliant. The non-availability of soft options made men out of boys and athletes

out of men.

The fact that the person with the problem and the problem-solver, or technology generator and the technology user, are in the same organization facilitates close and continuous interaction for coming up with solutions which can be implemented within the boundary conditions and constraints obtaining in the user's environment. This minimizes, but does not totally eliminate, the not-discovered-here syndrome which creates major barriers in technology transfer.

Equally important blessings that BARC always enjoyed is that it is shielded from budget cuts even in periods of extreme financial stringency unlike other R&D organizations, academia and institutions dependent on governmental grants or largesse. One can rationalize the situation by saying that their performance provides BARC with the necessary shield.

Because of the nature of some of its activities, BARC did not have to subject itself to the scrutiny of external review committees unlike CSIR (Abid Hussain Committee), IITs (Nayudamma Committee), universities (Radhakrishnan and Kothari Commissions), etc. By the same token, many of the selections and promotions are by and large through internal assessments and committees. Fortunately BARC is not subjected to political interference, much to the envy of other scientific and academic institutions. Finally, there was very little governmental bureaucracy, at least in the early years, at BARC than most government-aided, so-called autonomous, institutions.

It is thus not surprising that questions of the following kind are raised in some quarters: Will not any other organization also perform as well if it is given the advantages that BARC enjoyed? Is the output and contribution commensurate with the privileges that BARC enjoys and the investments made in BARC? What fraction of their expenses does BARC earn from sources other than grants from DAE? Such questions and others can be debated interminably and inconclusively.

Some constraints

The interaction of a premier institution such as BARC with academia is not as extensive as one might wish, except for small research grants through the Board for Research in Nuclear Science or for some BARC scientists getting advanced

degrees from selected institutions as external candidates. A major national science and technology resource that BARC has had only marginal impact on the educational system in the country. The incredibly powerful assemblage of human and equipment resources in BARC generates more awe and envy than intellectual nourishment and scientific upgradation in our educational institutions.

Since the problem identification and its solution are done within the same organization, there is no scope for competition in problem-solving, which on occasion leads to cost and time over-runs on projects. The public can wonder about this, considering that BARC is a high-powered, well-endowed organization.

The nature of activities connected with the nuclear field demands a great deal of secrecy, making the atomic energy establishments the world over quite insular and BARC is no exception. This has been perfected into a fine art so that automatically the glass window with one-way vision provides an excellent shield from public gaze.

While BARC has been outstanding in setting up departmental industrial undertakings to exploit their technology, the umbilical cord between these undertakings and BARC is stronger and more permanent than that between our private and public sector industries and their foreign collaborators. Are we seeing Indian kangaroos? If the protection available to private and public sector undertakings is dismantled can they continue for other enterprises for long?

When most government-aided organizations have been shifted from breathing normal air to rarefied atmospheres where they are gasping for breath, how long can others continue to be connected to pure oxygen? While admiring the healthy, robust body of BARC, can one miss the shy, almost impish, side glances of Manmohan Singh at the muscular calves supporting the solid body.

The fact that we are not bad at English may at times turn out to be a disadvantage since we are then tempted to work on things which are fashionable or hot (or cold) in Cambridge or California, Zurich, Houston or Salt Lake City, thereby skewing our goals and diverting our limited resources. That BARC is not above it is perhaps a gentle reminder of the human face of BARC science.

Is the vibrancy and vitality provided

by regular injection of bright, fresh blood in the earlier periods still intact or is it getting dampened by the increasing average age of scientists at BARC? Does the birth of the offspring (IGCAR, VEC, CAT, NFC) help or aggravate the problem?

Another barometer worth watching is one which records trends of experimental versus theoretical work, equipment development versus purchase, work focused on main DAE mission versus others, grants-in-aid versus earned income, earned income from departmental undertakings versus income from others, etc.

Opportunities

The passing away of P. R. Roy, whose death anniversary is being commemorated as also of N. S. Satya Murthy and S. N. Seshadri at the peak of their careers and in their forties shocked the entire Indian scientific community. Many organizations require all their staff in their forties to undergo a thorough medical check-up. Could such tests have saved Roy, Satya Murthy and Seshadri for BARC and for the country? Such tests may equally be useful for institutions as they age, for introspection, stock-taking, redefining goals in the light of strengths, opportunities and challenges, reorganizing for slimness and efficiency.

Another challenge in the foreseeable future is that the leadership of BARC will shift from a generation directly trained and nurtured by Bhabha and Sarabhai to a generation which hardly knew them. The emerging leadership should participate in the evolution, redefinition and enunciation of philosophy, goals and procedures as BARC approaches the dawn of the 21st century and its own golden jubilee.

The departmental undertakings born out of and nurtured by BARC, some of them for over a quarter century, must be ready to enter into a more mature relationship, such as that of contractor-client, when the client defines the problem and pays for the usable timely solution the contractor provides. The client, accustomed to free service, may initially pay only a fraction of the cost of the solution but must gradually pay a larger fraction till ultimately the real cost of the solution is charged to the client. This will lead to a mutually satisfying, responsible relationship and make the accountability of BARC transparent. The client may

even seek help outside BARC, in order to make BARC not only competent but competitive.

The time is ripe for BARC to start cashing in on its immense storehouse of knowledge, competence, expertise and image in processes, products, instruments, methods, standards, etc., by offering the same to Indian industry. Some of the work may require specific adaptation, attractive packaging, user friendliness, complete debugging, thorough documentation and, most importantly, aggressive and creative marketing. If the village woman is being induced to take out her gold from the bank locker to buy gold bonds, should not the nuggets in the BARC cupboard come out to make it rich in current income? This is an area where BARC may consider taking the help of agencies who have a track record of successful transfer of commercial technologies and who have a nose for exploitable products and processes. The results may make BARC kick itself for not doing more of this sooner!

The above two steps, viz., client-contractor relationship with the departmental public sector undertakings and marketing of commercial technologies, should make BARC gradually less dependent on outright government grants, except for undisclosed tasks assigned by the government. This is one more area where BARC can become a pace-setter by gradually decreasing grants-in-aid from the government, before being asked to do so.

During the process of introspection, BARC may identify tasks which are not crucial for its main mission or which have become very routine and standardized to be shed and taken over by others, so that the goals remain in focus and challenges become escalated. Similarly, they may identify areas where greater transparency of their activities is possible and imaginative ways to enrich, and at the same time utilize, the educational enterprise for true mutual benefit.

To conclude, all the statements that I have made are based on a personal admiration for BARC—its philosophy and achievements. Any questionable statements are only due to lack of deeper personal knowledge.

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