Science and Technology in Civil Society

Innovation Trajectory of Spirulina Algal Technology

The role of civil society in influencing public opinion towards more democratic and developmental approaches is now well-recognised in diverse fields such as health, education, livelihoods, issues relating to disadvantaged social groups and the environment. Yet, science and technology in India is predominantly seen as the preserve of the state, and more recently the market. In the linear model of innovation, civil society is seen at best as having a role in extension or the delivery of technology produced elsewhere. This paper, a study of science in civil society, questions this assumption through the case study of the work of a civil society-led initiative in spirulina algal technology. It highlights the need for an institutional transformation of the scientific establishment into learning organisations if they are to focus on development with a pro-poor or human face.

C SHAMBU PRASAD

The accelerated pace of environmental, social and technological change has major implications for the poor and their development prospects. In an environment wherein agricultural research centres have to perform broader roles beyond increasing food supplies, the greater challenge lies in the transformation of agricultural research centres into learning organisations, more in touch with field realities and better able to respond to feedback and in this institutional rather than technological innovations are likely to play a larger role. Unfortunately the traditional transfer-of-technology approach to agricultural research that dominates the institutional arrangement acts as barriers to learning. A more fruitful approach would be to recognise the multiple sources of innovation and look for more client-responsive scientific practices. The silence of the agricultural establishment to the recent pesticides in aerated drinks controversy is a case in point and indicates a complacent view arising out of a linear view of innovation that separates research from extension and thereby externalises these problems as failures of delivery or extension mechanisms instead of pointers to a more systemic failure in the practice of science.[1]

Acknowledging the multiple sources of innovation, this paper, an empirical study of agro-processing innovation by a civil society organisation, seeks to further this process of institutional learning and change in agricultural research in India. It looks at the work of the Murugappa Chettiar Research Centre (MCRC), a civil society organisation that rooted spirulina algal technology in India. It profiles the active involvement of a non-governmental organisation in all aspects of the innovation chain – development of the scientific idea (invention), translating that idea into a commercial proposition (innovation) and extension of the technology both into the market and rural communities (diffusion).

Rather than see this initiative as an isolated case of individual genius, this paper seeks to place the efforts of the MCRC as part of a larger narrative on science in civil society that has been largely under-reported both within studies on science and the general civil society literature. It explores the nature of civil society initiatives in science in India and examines their difference vis-à-vis the state and the market in terms of an explicit pro-poor focus in research. It investigates possible lessons for agricultural research in India through an examination of research praxis of an alternative paradigm of learning and innovation in civil society that could inform research project design, research management and practice.

This paper is divided into three parts. The first part outlines the context for the study within three frames – a sectoral understanding of the post-harvest innovations context in India, the historical and social context of research by civil society in India, and finally spirulina as a site for a biotechnological application with a pro-poor focus that has escaped recent biotechnology debates surrounding golden rice as the nutritional alternative in the tropics. The second part of the study maps the various phases of the spirulina algal technology innovation system in India. It seeks to situate the work of the research centre within existing work on algal technology in India highlighting points of departure in research practice. It also explores the nature of partnership in the various phases and the changing role of the main actors in the system. In Part III the research culture of MCRC is examined through an analysis of the technical and non-technical writings by research staff for insights into the conceptualisation of research and development, formation of partnerships, problem definition with an emphasis on innovation and the practice of enabling organisational learning. This is followed by an exploration into the implications of the case for agricultural research in India. It will also explicate how an innovation system's framework can enable new perspectives that can guide research and institutional learning for future activities, especially, in identifying how new players like the agricultural research establishment can enter the system and take it further. It thereby seeks to demonstrate that the case is not just about spirulina or MCRC, but also about a new framework of closer interaction between formal and not so formal science, science by the state and science by civil society.

I
Introduction

Technology transfer in the decentralised rural industrial sector is conceptually and operationally different from the agricultural sector. Few research centres in India handle multidisciplinary problems and the agro- or food-processing area is one of the most difficult for achieving successful commercialisation due to synergy required amongst multiple partners with diverse backgrounds, long gestation periods, non-availability of raw materials throughout the year and many risk factors [Moulik and Purushottam 1986; GoI 1981; NRDC 2003]. Hall et al (2003) have recently argued that post-harvest R&D seems to sit uncomfortably in the conventional arrangements for agricultural research. Unlike the crop improvement research that has clearly identified central scientific personnel (plant breeders, molecular biologists), well-defined products (new varieties), and a clear main client (farmer), post-harvest R&D has no neat categorisation. It covers engineering, food science, pathology, marketing economics, has a large number of players both public and private and diverse stakeholder interests and agendas with different skills responding to different incentives. The post-harvest innovation is frequently embedded in a wider set of relationships and contexts than is implied by the conventional research-extension-farmers' model of R&D. Managing this with a pro-poor policy goal is challenging given its complexity.

Many of the constraints to the post-harvest innovation have been identified as institutional in nature and relating to conventional approaches of R&D planning [Hall et al 2001]. The conventional (and widely criticised) model that much of Indian R&D still conforms to is premised on the desirability of linear relationships linking research and economic production. In this model, investments made in the basic research are assumed to produce knowledge whose value increases through further 'downstream' incremental investments in an adaptive research. The knowledge is finally given to a dedicated organisation (extension) charged with passing it to a technology user who finally applies the new knowledge to economic production. In this model there is institutional separation, with activities associated with knowledge search and generation (research) organised separately from those involved with knowledge transfer and application. There is thus, a division of labour whereby public scientific bodies – seen as the primary source of new knowledge – are organised in a hierarchical structure with a linear flow of resources and information from the top to the bottom. One of the problems that this mindset encourages is the view that civil society should be located at the last stage of the innovation chain (extension activities) disseminating the innovations of others and not as contributing to invention. This case seeks to challenge this assumption.

There is now a wide recognition that assumptions of the conventional or linear model of innovation do not reflect the complex reality of technology development and innovation in the agriculture sector. Instead, this is now understood as a process that involves linkages and feedback between the main actors [Clark et al 2003]; multiple sources of innovation [Biggs 1990]; iterative processes of learning and reframing of approaches and research questions [Hall et al 2003]. Of particular relevance to the focus of this paper on innovation in civil society is the recognition that the actual practice of science depends to a large extent on the different settings in which it takes place. For this reason, understanding the role of organisational cultures in research planning, performance evaluation has assumed importance [Pickering 1992; Feller 2002; Watts et al 2003].

There have been several compilations on technologies for the rural sector by different scientific organisations such as the Council for Scientific and Industrial Research (CSIR in 1980, 1984, 1995 and 2004), Council for Advancement of Peoples Action for Rural Technologies (CAPART 7 volumes 1986-92), Centre of Science for Villages, Wardha (CSV in 1982 for the Department of Science and Technology (DST) with a women focus), and the Centre for Technology and Development (CTD in 1993 for DST). While most of these compilations have showcased the technologies on offer (or on shelf as there is little information on end use) the latter ones provide more details about the innovation process in the post-harvest sector. Of the above compilations the 1993 database by CTD, though dated, has an interesting compilation of resource persons with their institutional affiliations and subject interest and is shown in Table 1.

The distribution above shows that the mandate of post-harvest technologies has gone well beyond the formal science establishment as represented by the Indian Council for Agricultural Research (ICAR) or CSIR systems. In recent years, organisations such as the CAPART and the science and society section of the DST have emerged as important players. Further, the presence and expertise of NGOs representing civil society is by no means small. What then has been the historical and social context of such initiatives?

Institutional Context of Civil Society Initiatives

The initiatives from organisations outside the formal scientific establishment and the private sector in agro-processing in India have not been documented sufficiently and hence, have escaped most narratives in the history of agro-processing in India. The efforts by civil society have been presumed to be sporadic, small in scale, or trivial in scope and have bypassed academic analysis. As a result possible insights on institutional learning from the practice of science by these institutions have not been part of science or research policy debates.

There have been critiques on public research in agriculture in India since the early part of the 20th century. Some of these critiques were based on an alternate scientific practice like the Allahabad Agricultural Institute (AAI) founded by Sam Higginbottom in 1910. The Allahabad institute had by the 1930s established itself as one of the finest agricultural colleges in India with pioneering research in farm implements, the first-ever degree course in agricultural engineering, one of the earliest schemes of extension projects and a women's programme in home science. Unlike other state-run agricultural schools in India then that were almost exclusively teaching centres aimed at producing staff for the agricultural service with little or no contact with villagers, the Allahabad institute emphasised practical training aimed at producing good farmers [Hess 1967]. The work of Higginbottom is indicative of the kind of institutional innovations in agriculture that were attempted in the early part of the century outside the formal science establishment.[2]

Though Higginbottom's work did not receive state attention, it caught the imagination of nationalists like Gandhi who believed that the agricultural school shared his ideal vocational educational model. The two first met at the historic Benares Congress in 1916 and were intellectual scientific compatriots ever since. Gandhi wanted Higginbottom to later head the agriculture wing of the Congress, an offer given the political conditions of the time Higginbottom politely declined. Years later, as part of a dissenting tradition of scientific intervention with a pro-poor focus, Gandhi constituted the All India Village Industries Association (AIVIA) in 1934. This was the first organised nationwide effort

Table 1: Distribution of Resource Persons in Post-Harvest Technologies

Category	Agro-Processing	Food-Processing	Post-Harvest	Resource Persons
ICAR and agricultural universities	9	12	23	28
NGOs	10	16	13	25
Universities and educational institutions	5	10	10	14
Other research institutes	3	6	6	10
CSIR labs	5	4	7	8
Private consultants	3	8	2	8

Source: Collated from CTD 1993. Many resource persons indicated more than one area of interest hence overlaps.

to intervene on behalf of the poor in the agro-processing sector and yet, the initiative finds no mention in standard readings on agro-processing in India.

The AIVIA can be seen as a pioneer in civil society initiatives and rural innovations in agro-processing. Pointing to the need for a different science for the rural poor, a voice neglected by the formal scientific establishment, Gandhi remarked on the context for such an institutional intervention.

> The field (of village industries) is so vast … that it will tax all our *business talent, expert knowledge and scientific training*. ... I sent a questionnaire to several of our well known doctors and chemists, asking them to enlighten me on the chemical analysis and different food values of polished and unpolished rice, jaggery and sugar, and so on. Many friends have responded only to confess that there has been no research in some of the directions I had inquired about. Is it not a tragedy that no scientist should be able to give me the chemical analysis of such a simple article as gur? The reason is that we have not thought of the villager. ...What kinds of laboratory research shall we have to go in for? We shall need a number of scientists and chemists prepared to lay not only their expert knowledge at our disposal, but to sit down in *our laboratories* and to devote hours of time, free of charge, to experiments in the direction I have indicated [Gandhi 1934: 409-11, emphasis added].

The AIVIA had a board of advisors that included Higginbottom to advise especially on scientific matters. A notable part of the institutional structure is an attempt to broadbase itself by having a number of stakeholders at conceptual stage. These stakeholders were to include lay persons who could be members with no qualifications other than the desire and interest to participate as well as agents who were to market the produce. Such a system necessarily ensured better information flow between the various actors.

It is in the writings of the outspoken Gandhian economist, J C Kumarappa, the secretary of the AIVIA, that we find glimpses of the way research was conceptualised and executed. Kumarappa worked out the details of the kind of questions that this new research and scientists should engage with. These were linked to contemporary issues of food shortage and famine, but were addressed within a much broader context that sought to include non-productive and qualitative concerns like the requirement of a balanced diet for everyone as opposed to a mere increase in food supplies.[3] Noticeable is the conception of research in AIVIA that sought to look at integrated systems and not just on the productivity of the parts. Thus there was an emphasis on the whole plant as food for humans and fodder for cattle; in oil processing too the research was conscious of the oil content of the cake as cattle feed and not just the productivity of the seed for oil. This emphasis on nutrition for the masses as an important consideration for research is noteworthy, a line of inquiry that was picked up by MCRC in the case study. The AIVIA was not a Luddite response to technology that believed in idealised communes cut off from the rest of society. It collaborated with several scientific institutions especially on the question of nutrition even as it fought the state politically. These partnerships with the research laboratories provided an important scientific basis for the critique of developmental practices on promoting nutritionally inferior oils such as Vanaspati that Kumarappa described as a "prostitution of scientific knowledge and for taking liberties with nature, science and progress" [Kumarappa quoted in Vinaik 1987:84].

There have been several innovations from civil society since AIVIA. The responses have been diverse, based on their respective institutional contexts. The AIVIA has changed in character since the establishment of the Khadi and Village Industries Commission in 1957 that took over the mandate of AIVIA, making it a state-led and sponsored activity. This has led to a serious erosion of AIVIA's original charter. However, there have been several organisations that have sprung up, especially in the late 1970s, to address a pro-poor mandate in the rural non-farm sector. One of these is the Centre of Science for Villages (CSV) at Wardha, which was set up in 1978.

The 1990s have seen major changes in the agro-processing sectors, with civil society initiatives seeking to establish new relations with the market through diverse products and institutional means. This is in the context of the large-scale failure of state-led efforts in enabling poor farmers to cope with the changing nature of local and global markets in the wake of liberalisation. Some like the Nimbkar Agricultural Research Institute (NARI) in Phaltan, Maharashtra, have suggested diverse uses of such crops as sorghum. The Centre for Technology and Development (CTD) based in New Delhi with years of experience in rural industrialisation is another such initiative. Conceived as a multidisciplinary group with engineering, natural and social sciences backgrounds, this centre has been involved in technology transfer for small-scale farmers in fruit, vegetable and agro-processing. The experience of CTD shows an understanding of the contemporary market that is different from that of the state and corporate interests. A more recent institutional innovation, still in process, is the Rural Innovations Network (RIN) that has sought to approach the problem from a different perspective. The RIN sees itself as providing critical managerial inputs to facilitate the honing of entrepreneurial skills using business models of venture capital in the corporate sector, thereby ensuring both monetary and social returns to rural innovators, donors, investors, research institutions, voluntary organisations, entrepreneurs and rural consumers.[4]

The diverse approach to innovations in agro-processing from civil society is increasingly being realised. Giving greater autonomy from governmental control to research organisations, and giving non-governmental public institutions the space and resources to play a larger, more effective role in research, have been seen as issues of the direct relevance in restructuring the public research system [Vaidyanathan 2000]. This study seeks to explicate this genealogy of constructive dissent through the case study of spirulina algal technology at the MCRC. Why spirulina?

Spirulina as Biotechnology for the Poor

Spirulina algal technology is a rare case of an organisation in India being involved in all stages of development of a technology – conception, commercialisation and extension to social sectors. The work by MCRC on spirulina in India had a prominent place in world developments. India was the only country where large-scale nutrition studies (5,000 pre-school children administered spirulina for over a year) were undertaken and work covered all aspects of spirulina, from simple cultivation basins to the large-scale commercial farms and the earliest to have a standard for the alga. The medical reports from the large-scale trials confirmed that it was a useful supplementary Vitamin A diet putting to rest motivated attempts by corporate science that was keen to push synthetic Vitamin A and that raised doubts on the toxicity of spirulina. The scale of operation (the total number of data points in the study were 90 lakh) of the nutritional study presents a good case for study in technical and institutional partnerships.

Yet, despite several firsts, spirulina has not been seen as part of recent strategies using biotechnology for Vitamin A supplementation through Golden Rice. There are several experiences of the spirulina story including its obvious nutritional possibilities that indicate the need to place the work at the centre of the biotechnology debates. Here is a case where a technology was developed completely indigenously and widely discussed in the public domain. C V Seshadri of MCRC was, in fact, one of the founding members of the Indian Society of Biotechnology in the 1980s. Further unlike the recent field trials that have been shrouded in secrecy here was a case of a high degree of transparency of the large-scale field trials. Here is also a case where the department of biotechnology has played a proactive role in supporting indigenous technology development especially with a social content.

Spirulina has been seen as a wonder food, a high quality food supplement containing Vitamins B_1, B_{12}, B_{16}, C, and E besides protein. With a 71 per cent protein content it is the highest natural source of high quality protein ever known to man. The protein yield per unit area per year is the highest compared to other protein-yielding crops. Spirulina contains all natural vitamins, minerals and growth factors including gamma-linolenic acid and the highest amount of beta-carotene a precursor of Vitamin 'A'. The microorganisms including those pathogenic to humans and other animals are eliminated in the production process of spirulina due to its requirement of a very high alkaline growth medium. Spirulina's preference for tropic and sub-tropic climatic conditions offers a best land use in arid areas and has tremendous potential for use as food supplement (used to combat stress by executives and by athletes for quick energy synthesis), health and medicine (non-insulin dependent diabetes and cholesterol control, Vitamin A, deficiency and malnutrition, an adjunct to cancer patients undergoing chemotherapy, a lactating agent for mothers, etc) as a feed in pisciculture, sericulture and entomology; as a colouring agent in food and chemical essays and also in cosmetics.[5] How was this 'wonder food' developed in India and what was the role of MCRC in it?

I
Innovation Trajectory of Spirulina Algal Technology

The story of spirulina and its transition from a research idea in the laboratory to an applied technology in the form of a commercially produced food supplement is typical of many stories of innovation. It is complex and characterised by the key players entering (and departing) the stage at different times, with champions emerging at critical points, only to fade and let others emerge. It involves basic research and applied and adaptive tasks, but not always in that sequence. And it is highly nuanced and not easily understood without an investigation of the players, institutional and other contexts, and processes that relate to this particular innovation. It might be useful to think of this story as one about the evolving architecture of the spirulina innovation systems. Over the last 30 years or so this has involved different groupings of partners, different relationships, and processes. The main phases of this evolving architecture are discussed below. What is noteworthy about this story is how MCRC emerged as an important player at a critical time and, for reasons discussed later was able to drive the innovation process in ways that may not have been possible in an institutional setting of the formal scientific establishment. Indian work on spirulina algal technology can broadly be grouped into seven phases or stages.

Early Work by IARI

Algal research in India dates back to 1953, when the Indian Agricultural Research Institute (IARI) began research on the use of algae for nitrogen fixation and later to treat sewage and industrial waste. Much work in this period was on taxonomy of algae and their use as bio fertilisers. The organisations involved were Central Food Technological Research Institute (CFTRI) (in 1973 CFTRI entered into a collaboration with Germany to produce a pilot plant), the National Botanical Research Institute (NBRI), Lucknow; the National Environmental Engineering Research Institute (NEERI), Nagpur; the Indian Veterinary Research Institute (IVRI), Izzatnagar; and Auroville, Pondicherry. An All India Coordinated Programme on Algae (AICPA) started in 1976 to cover various aspects of algal production for food, feed, and fertilisers. The work on algal biofertilisers was ahead of its time, and did not fit in with the push given to synthetic fertilisers as part of the green revolution in India. The first spirulina farm in India was established at Navsari, Gujarat, in 1974. Although there were no major breakthroughs in spirulina cultivation, this early work is important because it created a base for the later active involvement of MCRC. It also usefully illustrates the time lag involved in the commercialisation of an idea.

MCRC's Initial Work

The MCRC was set up in 1973 as a private R&D centre of the Murugappa Group of companies and was transformed by C V Seshadri who, as its director from 1976, made it into a leading autonomous R&D centre with a range of activities showing strong social concerns. Seshadri brought to MCRC the skills of a researcher and an academic with considerable industrial experience (he had just established India's largest yeast factory in Mysore). In 1977 an Algal Division was set up. An important conceptual leap at MCRC on algal research was the linking of energy and photosynthesis. The research outputs, entitled the Monograph Series on Engineering of Photosynthetic Systems (MSEPS) reflected a philosophy of integrated holism and involved an interdisciplinary team of scientists, engineers and amateurs right from the start.

The point of departure from other research centres in India was MCRC's biomass emphasis and focus on algae as a food instead of as a fertiliser or an effluent treatment. The MCRC preferred algal cultures for their work over conventional plants as they gave high output per hectare, consumed little water per unit of useful biomass yield, allowed for whole cell or plant utilisation, possessed high protection and vitamin output per hour, and were amenable to several engineering improvements because they could be cultured in liquid media.

The algal work was strengthened when Jeeji Bai, an algologist at the Madras University, joined on an honorary basis. The MCRC scientists screened large numbers of algal cultures for a suitable selection and successfully isolated *spirulina fusiformis* from a phytoplankton collection from a pond in Madurai. The isolate was then adapted by growing it in village conditions using unskilled labour. Subsequently, open-pond spirulina cultivation with different nutrient media compositions using cheap raw materials (sea water of varying composition, crude sea salt, biogas effluent, and nutrient bag methods) was tried. Unlike other parts of the world that focused on large-scale cultural systems requiring sophisticated and costly engineering design, the scientists felt that Indian conditions demanded small decentralised algal systems operated by non-technical hands. This approach was also a break from the general practice in Indian scientific establishments that paid little attention to an adaptation to local conditions. Thus, while the CFTRI work with German collaboration was capital-intensive, MCRC work was cost-sensitive. Conscious efforts were made by the scientists to incorporate local materials and local conditions in the design. Feeding trials were done on fish, dogs and calves, and spirulina was found to have an edge over other protein supplements encouraging its trial in MCRC canteen with some popular Indian dishes to determine its palatability. Experiments on algal milk farming (algae and fodder) using solar-boosted energy were also made.

The initial work at MCRC was thus one of vigorous experimentation over a wide range of activities. The simultaneity of basic and applied work and the design of experiments to suit Indian conditions and budgets set MCRC apart, not only from research carried out elsewhere, but also from 'normal' science in India. There was sufficient confidence to increase the scale of operations by 1981.

Large-Scale Cultivation and Commercialisation

Building on the laboratory investigations, a pilot-plant feasibility study was initiated in the early 1980s that indicated promise as a potential rural activity for food and feed production using waste materials. In this phase, the work was directed at mastering the cultivation of spirulina from test tubes to flasks and small outdoor ponds. A separate group of nutritionists developed recipes for use with algal slurry and sun-dried flakes. The technology was sufficiently matured by 1984 for a pilot-scale facility to be commissioned.

The collaboration with the Murugappa Group companies and Industrial Credit and Investment Corporation of India (ICICI) saw the establishment of India's first completely indigenous spirulina production facility. The technical innovations included the 'Prakara pond', the 'Raji' filter system, and a paddle-wheel agitation system that resulted in cost and materials economies. The MCRC was also involved in test marketing the product and in formulating the Indian standard for processing of spirulina alga, IS 12895: 1990. India was then perhaps the only country in the world where such a standard existed. The specifications covered minimum protein and vitamin levels in the dried product besides specifying its contents and tolerance levels.

A severe funding shortage affected the future of the project even as commercialisation began. The timely involvement of NRDC allowed an inspired agreement to be devised to finance the project while protecting the autonomy of MCRC, and ensuring continued interest by the Murugappa Group of companies. The NRDC believed that the process was a breakthrough in indigenous technology development. Seshadri and BV Umesh of MCRC were awarded the NRDC President of India Award for Invention in 1991.

Simultaneous Studies on Village-Level Production

Concurrently there was a parallel effort aimed at the social objective of nutritional self-sufficiency for villagers. The MCRC initiated experiments in downscaling the technology to suit village women. It is the rural client focus of civil society organisations that allowed for such a strategic shift in research direction. The cultures using mud pots were tried out in late 1982. They were chosen because mud pots were easy to handle and good as transient cultures from laboratory to open-air conditions. Along with the technical innovation there was a social innovation. Based on the promising data it was felt that this could be a suitable technology to teach village women and training programmes were initiated. The work carried the idea of nutritional self-sufficiency as spirulina processing and marketing would make it an expensive proposition for the people who needed it most, i e, village women and children. The MCRC believed that technologies developed exclusively for women had a better chance of social and cultural acceptance than technologies that were designed for men, but later 'diluted' for women or for rural areas. The vision was to demonstrate that microbiological skills could be taken down to the personal level for nutritional self-sufficiency [Jeeji Bai 1986; 1992].

Yet another experiment where MCRC did not work directly, but through others, was with the organisation Nutrition on Wheels (NOW). Here MCRC provided the spirulina culture and NOW, in collaboration with Antenna Technologies, identified two villages near Chennai for cultivation. Transtech, whose founder was associated with NOW, later marketed the spirulina under the trade name Progen®. Village-level kits for 4–10 m^2 ponds were distributed amongst selected beneficiaries, and the women were able to augment their income by Rs 100 a month. The programme had to be moved after a year due to the unforeseen social problems and local conflicts in the villages [von der Weid 1993]. This experiment is an interesting case in partnership, and a precursor to MCRC's own extension outreach. Transtech importantly helped to develop the market for the product while creating an awareness of the usefulness of spirulina amongst general public.

MCRC-led All India Coordinated Project

In 1990 MCRC approached the government for large-scale field trials. The department of biotechnology (DBT) evinced interest and an All India Coordinated Project was initiated in 1991 with MCRC leading it. Of the four components of the programme the biggest was the large-scale nutritional supplementation (LSNS) with spirulina alga. Prior to LSNS experiments were done at the National Institute of Nutrition (NIN) but initiated by MCRC had demonstrated the toxicological safety of spirulina and the bioavailability of beta-carotene [Annapurna et al 1991]. Later, with a view to exchanging notes among the larger community involved in spirulina and reviewing the state of the art in India, MCRC hosted a national symposium titled 'Spirulina: Ecology, Taxonomy, Technology and Applications (ETTA)' in 1991. This broad-based symposium resulted in the publication of a comprehensive treatise [Seshadri and Jeeji Bai 1992] that is cited extensively in contemporary spirulina literature. The Indian effort was the only large-scale endeavour in the world dedicated to the therapeutic uses of the whole alga.

As part of LSNS, a well-monitored nutritional supplementation programme using spirulina was undertaken in a rural population of 5,000 pre-school children in Pudukkottai district, Tamil Nadu, for over a year. The unprecedented scale of operation of this programme required major institutional innovations from the MCRC that went beyond its professional mandate as a research organisation. It involved collecting and analysing nearly nine million data points. Recognising the need for beta-carotene administration in the form of a natural foodstuff, the MCRC introduced 'Spiru-om', a mixture of spirulina and 'omum' or 'Ajjwain' (*Trachyspermum ami*) mixed with icing sugar. This was administered to the children in the form of noodles and results monitored.

The study showed statistically significant reduction in Bitot's spot and night blindness with several interesting anecdotal results as reported by Anganwadi (community childcare centre) workers and teachers in schools. The study demonstrated a cost-effective substitution of expensive imported Vitamin A and provided conclusive proof of the benefits of spirulina, setting to rest the motivated efforts by several multinational companies that sought to show spirulina as a toxic and their own vitamin substitutes as more effective. The cost was estimated at Rs 1.5 per dose that could be reduced to Rs 1 and even further if the product was made locally [Seshadri 1993a; Seshadri and Thomas 1993].

The LSNS experiment is an interesting example of partnership by an NGO that was ahead of its time and involved a wide range of actors from scientific bodies, research institutions, universities and medical colleges, to local health workers, extension workers, teachers, parents and children in the villages.

Extension Activities – Spirulina as Income Generation

With the potential of spirulina having been demonstrated, scientific agencies such as the DST and DBT sought to extend its possibilities through such specific projects as biotechnologies for scheduled caste (SC) and scheduled tribe (ST) women. This was first tried out in villages in Pudukkottai district amongst nine women using medium-sized ponds. The concept was then extended as part of earthquake relief in Latur in Maharashtra under a project called Spirulina for Employment Generation and Rehabilitation of Victims of Earthquake (SERVE). Two hundred women were trained and a decentralised production facility, the first of its kind, was established.

Work at MCRC on spirulina has more or less stopped in recent years, although the organisation maintains the culture, and is willing to train NGOs. The spirulina work now has gone beyond MCRC in non-linear ways. The NGOs inspired by the nutritional potential of spirulina have taken to village-level production. The extension of spirulina production in the 1990s is noticeable for the diversity of approaches in construction of tanks, processing, products, marketing and distribution. It has entailed technical and institutional innovation beyond mere replication.

CSV in Wardha, Maharashtra and Auroville in Pondicherry are two NGOs that have been involved with spirulina activity for 20 years. Ripley Fox initiated CSV's work at Karla in 1982 through an integrated system involving sewage in the nutrient medium. There has since been a product diversification into skin creams (a combination of beeswax and spirulina) and face packs for the local market, apart from the usual tablets. At Auroville the work has had a revival in the 1990s. The seven 30-m^2 ponds now in operation harvest 500 kg annually. The farm uses solar power for water pumping and over a thousand people consume spirulina regularly. Auroville has also trained several people to set up their own farms.

The Antenna Trust based in Madurai with technical support from Antenna Technologies, Geneva, is a leading training centre in spirulina cultivation with a well-equipped laboratory. An interesting case of innovations in the extension of a technology is the work done by the Reorganisation of Rural Economy and Society (RORES) in Kolar, Karnataka. Enthused by the potential through an article in the journal *Health Action* [Anonymous 1997] that described the potential of the alga in combating malnutrition, RORES contacted MCRC for technology transfer. Stabilising the production involved an iterative process of experimentation and visits to the Antenna Trust and a spirulina factory apart from the contact with MCRC. The technology has been modified substantially through several ingenious applications for an expanded capacity of 6 kg per day. The irregular rural electrical supply necessitated local innovation wherein the paddle agitator was solar-powered using an unused photovoltaic panel from a local NGO. The agitator was designed using high-grade stainless steel 316 blades chosen for its inert media and proven anti-corrosion properties. The 'high tech' blades and the motor were procured second hand from a Bangalore scrap market and suitably redesigned.

The spirulina activity fits in well with the NGO's agricultural extension activity. The laboratory for spirulina does additional work on soil analysis. Greenhouses for the nursery were incorporated for solar drying of spirulina. Markets are both rural and urban, the latter cross-subsidising rural consumption. Farmers are encouraged to use spirulina for cattle feed, and there has been a positive effect on cattle fertility. RORES feels confident about transferring the technology to innovative farmers, but state support has not been forthcoming [RORES 2002]. The RORES case highlights the iterative process of technology transfer where field conditions have given rise to interesting innovations in the process. This innovation by a local NGO has taken spirulina production far beyond what MCRC had envisioned.

The spirulina cultivation has now spread to many production centres in India particularly in the south. In northern India, a university botanist – Pushpa Srivastava, a participant in the ETTA symposium – has innovated the use of spirulina for income generation by women belonging to the SCs and STs at Bassi near Jaipur, Rajasthan, and a larger experiment on the lines of Latur for Gujarat earthquake victims. It is thus evident that much activity is going on at the field level with diverse results and experiences in use and even in the health benefits of spirulina. Most of these activities have been without state support and some are now sustaining themselves. The field level experiences also indicate the possibility of greater scientific involvement especially with regard to exploring heath care uses of spirulina. These grassroot workers would like to undertake studies to validate what are now largely anecdotal experiences with the notable exception of the study initiated by Antenna Trust [Thinakarvel and Edwin 1999].

Future of Spirulina

If the story of spirulina so far is anything to go by, the innovation trajectory may yet take new directions and present new possibilities. Thus, while many of the funding agencies have been looking at the spirulina work as technically closed, with activities restricted to extension alone, field visits indicate that this is hardly the case. There have been several ideas at MCRC and elsewhere that have not been tried and in need of scientific intervention. (e g, processing spirulina in the form of easy-to-make processed foods like curds or cheese). Similarly, no major effort has been made to repeat the nutritional study in another district or state on a similar scale. Even if not on that scale, it is clear that spirulina consumption has been taking place in rural India for several years. No scientific input has gone into trying to assess its health impact or to make scientific sense of the wide range of anecdotal experiences in these areas. There is much work to be done.

Table 2 captures the evolution of the innovation architecture of spirulina in India. Quite clearly, not only was MCRC critical to the spirulina innovation trajectory, but there was also something unusual and valuable about the way MCRC viewed the task of innovation and its role in that process. In the following section this work is placed in context and the research culture that enabled the development of this technology by civil society is explored.

II
Innovation in Context: Research Culture at MCRC

The spirulina work was shaped by the unconventional research culture at MCRC. A central influence shaping the philosophy of MCRC was its director during this period – C V Seshadri, who was an extraordinary individual, a gifted visionary whose ideas (almost always) challenged conventional thinking and received wisdom on issues even as fundamental as the laws of thermodynamics and the concept of time [Seshadri 1993b; Balaji 1996; Visvanathan 2002]. However, it is important to recognise that there was more to the research culture of the place than the genius of an individual scientist. The heuristics of such a culture of science is revealed in many of the technical notes of the organisation and merit attention for their role in enabling innovation.

The earliest evidence of this unconventional research problem definition is in the first monograph of MCRC [Seshadri 1977]. This monograph not only outlines the philosophy of research work at the centre, but also calls for the articulation and definition of an engineering problem based on a keen sensitivity to the social issues of a developing nation. This philosophy of 'holistic invention' was to form the key to the MCRC approach to problems of science and technology and rural development. Some of the features of this research culture at MCRC are discussed below.

Importance of Visions

A guiding feature of research at MCRC was the way it was driven by visions of an extraordinarily ambitious kind. The technical ideas presented in the first monograph were novel in their use of energy analysis to determine the choice and definition of research problems at the centre and ahead of its time. The idea to use both the energy of stock gases and the materials to fix the carbon in one of the most efficient photosynthetic systems, namely, algal culture, was indeed novel. Even though the actual application of stock gases for algal photosynthesis did not fructify, the philosophy behind such an approach shaped the day-to-day practice of science and the research culture of the centre.

In a rather bold and ambitious statement on the role of the engineer-scientist in a developing country, Seshadri proposed, creating integrated systems of sophisticated and appropriate technologies by marrying the 'vices' of modern technology possessing unlimited growth-oriented devices with the 'virtues' of traditional resource-conserving technologies as the way for the future. He outlined two proposals based on such a reading. The first, an integrated technology to grow food, fodder, fertilisers, and fuel, and the second, to use the wastes of sophisticated industry for agricultural application. He argued that the need was to have the best of both sets for an optimal mix, stating that this kind of synthesis was 'necessary to better understand how affluent technologies can help sub-affluent people'. Sophisticated technology, to Seshadri, propagated unlimited growth-oriented devices, whereas the average Indian is used to working in a non-growth situation in a conservative fashion. The marriage of the two technologies was to Seshadri and MCRC the challenge of our times.

The agenda for the future work on algal research at the centre was based on this vision. This included feasibility studies for a pilot plant of food and fertiliser-grade algae using waste materials and energy from large power plants, and integrating aspects of low-cost technology to minimise capital investments and employing as many skilled and unskilled workers as possible. Seshadri added a caveat to this broad agenda that realised the need for play and flexibility in its actual implementation warning that the division into objectives was not to be the basis of priorities, rather the attempt was to think of integrated systems of technology to maximise common good.

The monograph is important for two reasons. First, conventional sociology of science and science studies tend to ignore the sources of creativity and the invention part of the innovation chain focusing more on the social dimensions of the diffusion and innovation processes. Secondly, the spirulina story outlined in the previous section cannot be sufficiently understood as a process without an appreciation of the philosophy of work of the research centre and how this translated into practice. Here is a rare conception of an engineering problem with a keen sensitivity to social issues at a very early stage and not after the technology is in place. It also illustrates that often enough not all ideas at an early stage translate into reality in the project or research centre. Some are, in fact, ahead of their times. Ideas that seem outlandish are best not rejected too early.

Valuing Failure

Conventional project evaluations with a strict success failure framework do not value processes and 'failures' of ideas. Seshadri from MCRC argued against the research practice in India of treating knowledge as a 'finished product'. The failure to MCRC was 'an essential part of innovation, an important part of learning' [Seshadri in PPST 1990]. Interviews with MCRC scientists and reporting mechanisms in technical and project reports indicate an openness to share not-so successful experiments. This was valued both as research culture and philosophy. In fact, the centre had planned internal reports as a forum where such ideas would nevertheless find articulation.

> It is intended to publish periodically technical notes in the interests of dissemination of information and to interact with other groups working in the areas of low cost technologies. *These notes will reflect both our successes and failures*. Final reports on finished

Table 2: Players, partnerships and process: Evolving Architecture of the Spirulina Innovation System

	1953–72	1973–78	1978–84	1984-91	1991–93	1993–98	1995–2002
Activity focus	Taxonomy, maintaining cultures	AICP on algae; sewage water treatment, food, feed and biogas	Vigorous and diverse experimentation, cost-sensitive Indian designs	Innovation towards commercialisation, India's first plant	AICP on Spirulina including a large-scale studies among 5,000	Demonstrated possibilities of income generation	Extending outreach of spirulina to the poor, spirulina for export
Process/ defining feature	Setting the stage	Diversified knowledge generation	Rooting Spirulina in India	Commercialisation of Technology	Broadening the spirulina base	Extension to new social groups	Diffusion by non-public agencies
Main actor	IARI	IARI	MCRC	MCRC	MCRC	MCRC	None
Other actors		Other public research institutes MCRC	Murugappa Group and few research institutes	Financial institutions industry, NGOs on nutrition	Scientific agencies, health departments, village level institutions	Scientific agencies, local NGOs, earthquake victims	Private industry and NGOs
Innovation system	Single actor basic research focus	Expansion through multi-institutional division of research separation of basic and applied emergence of new player	Integrated basic and applied research, collaborations contextualisation. Concurrent work village scale	Partnerships with NGO, industry and research centre. Partners bring agendas and expand domain	Diverse partnerships between research and non-research actors allows for large-scale expansion	Social innovation for new groups – quake affected, women	MCRC not active player, new entrants, lack of ownership of innovation system No involvement from public research

devices will be published separately [emphasis added, MCRC Technical Notes no 1, 1977].

Staff of the centre remarked in interviews that "the nature of the problems often was so unconventional that we had to make mistakes and learn from them". One scientist remarked that when he first joined MCRC he was asked to make paper from silk cotton. The work involved crude experiments with tools such as pressure cookers that helped determine what the technical constraints in the process were. These experiments by an amateur later led to one of the more innovative projects at MCRC. All of this could not have happened if there was no research culture that did not promote learning by 'thinking with hands' and making mistakes.

Interdisciplinary Research at MCRC

The above instance of an amateur aeronautical engineer working on problems not of direct disciplinary relevance was not atypical. There were several such instances in the spirulina research as well. The multidisciplinary teams of scientists, technologists and amateurs were at work in the centre from very early times. Such teams did much of the early scientific work on spirulina with little physical infrastructure. The research centre emphasised multifunctionality of tasks and there were several instances in the spirulina story where physicists were engaged in marketing, scientists in training and extension, etc. Resource constraints often created conditions for institutional innovations. There were also programmes in the centre that enabled this meeting across disciplines and getting the scientists outside their laboratories. Periodic campus cleaning drives and activities that involved manual work that cut across disciplines and involved everyone in the organisation were carried out with a vision of working with nature and thinking with ones hands, both seen as important activities of the centre. The research culture encouraged staff to drop their disciplinary labels.[6]

Problem Definition and Accent on Innovation

The way problems were defined indicated an approach that set MCRC apart from conventional R&D centres. An insight into this is provided by Balaji in his Seshadri memorial lecture 'Inventing the Future'.

> That famous dictum – 'Technology is the solution', or 'technology is the answer' – was often questioned by Dr Seshadri, who asked, "Where is the problem, first?" Technology or invention must arise out of a problem, not as a result of market pressure or organisational restructuring alone … they must address a very serious developmental issue. And, with this, he went around nurturing inventiveness and innovativeness in all kinds of people. School dropouts, semi-literates, and PhDs all came with some kind of a new product or the other, some kind of new idea, under his guidance' [Balaji 1996].

Seshadri was once asked in an interview, a promotional video on MCRC titled 'Reinventing the Wheel', "Are we not trying to reinvent the wheel?" to which he responded by stating that if you do not invent the wheel you will not have the maintenance manuals. You need to reinvent the wheel to understand the process of innovation, creativity and technology and to write the operation manuals in our conditions. Importing a technology will not solve the problem. Much of the work at MCRC revolves around this accent on invention and the need to introduce a culture of invention both at MCRC and the communities that they worked with. This accent on introducing a culture of invention has parallels in Gandhi's views on creating a 'charkha atmosphere' or a public culture of experimentation [Shambu Prasad 2001]. There was an attempt to open the black-box called invention. There were thus no blue prints for invention either but approaches that they sought to follow in their work.

Institutional Learning across Projects

One of the features of MCRC is the cross fertilisation of ideas across projects. From the narrative of the spirulina project it is noticeable that there were major shifts in research directions especially in the manner of applications. A closer look at the projects of MCRC in the last 25 years indicates several activities happening simultaneously on different projects. This enabled learning in the spirulina project and vice versa. One of the outcomes of the earliest projects on nutritional and energy self-sufficiency in rural areas was the notion of 'Integrated Energy Systems', a concept used in the spirulina project. Similarly, training women in using workshop tools lead MCRC to try out spirulina production by rural women. Several small-scale experiments, especially on nutritional requirements, fed into the large-scale trials both in spirulina and in other projects.

At another level, developing algal cultures gave the group a chance to explore a whole range of renewable energy devices for agitation of cultures and drying algae or biomass-based digesters. From each of these innovations a further set of devices and technologies grew. The work on biogas enabled identification of cellulose-degrading bacteria that led to development of a pulping process for papermaking, solar drying to development of water-distillation units, etc, [Thomas 1996]. The MCRC viewed all its activities (both research and development) as learning exercises and because these different sets of activities "talked" to each other this learning could be used to stimulate innovation.

Seshadri and MCRC believed they were responding to the Indian innovation context wherein an import substitution was overemphasised without looking into cultural contexts that brought about innovations. Creativity and innovation, they believed, could take root in such a scenario. For MCRC 'invention could not be categorised, classified, displaced and disposed of, and could take place anywhere'. Reflecting on the culture of science being a preserve of the state Seshadri commented that 'a sad feature of the profession (of science) is the way private sector scientists are treated by government scientists with a lot of suspicion and hostility, almost as though they were not Indians' [Seshadri 1984]. The MCRC was also critical of the lack of judgment on converting an idea into a product in rural areas. The MCRC was thus responding to science being viewed as exclusive and an activity of the scientific establishment with the rest having to fight for their legitimacy in their practice of science.

Science and Innovation in Alternative Institutional Settings

This paper began by suggesting that post-harvest innovation processes are characterised by a degree of complexity that conventional R&D arrangements in the public sector have difficulty coping with. In contrast, despite being overlooked in policy debates on this issue, it was argued, civil society organisations are active in this domain and, in fact, are practising science and promoting innovation in ways that holds many lessons for research policy. This case amply demonstrates the systemic nature of the innovation process features of which are summarised below.

Evolving groupings and diversity of players and roles: The spirulina story demonstrates the way innovation involves a large number of diverse players both formal and informal, research and non-research actors with diverse and flexible roles of actors over time. These players change, with groupings or partnerships that emerge and evolve and changing roles of actors. The innovation system started with the agricultural establishment in India being the major player initiating basic research in the 1950s, changed to the current situation, where the scientific establishment had almost no role. In between there has been one major player – MCRC – that has transformed the way spirulina was seen in the country, a role now taken on by other organisations. MCRC has played a scientific research role, but also that of disseminating technology. RORES, an NGO involved in extension, became an important source of technical innovation when it became involved in developing village-based production system. In either of the cases there has been no linear progression from a research to a dissemination role. A key feature of the innovation system associated with spirulina has been the way both the composition of players and their roles evolved over time.

Partnerships: The spirulina story also demonstrates some of the reasons partnerships are important to innovation and shows that important partnerships are often between research and non-research actors. The case of partnerships by MCRC with village women and later the NOW initiative and the LSNS work illustrate this. The value of partnerships has been to:

(a) Bring new agendas to the research process that go beyond the scientific focus and perspective of the researchers involved. In this case the client focus (rural women) of research was sharpened.

(b) Bring new skills, resources and networks. The collaboration with NOW helped MCRC develop the market and bring greater awareness amongst the public of the benefits of spirulina. Similarly, the LSNS study enabled greater access to the medical community leading to several independent studies on the health benefits of spirulina.

(c) Raised the levels of accountability of MCRC and the spirulina innovation system. MCRC could no longer rest on its glory of commercialising the product, but had to become an important player and partner in a new system with different norms of accountability for nutrition in rural areas. While MCRC always believed in the concept, the partnerships actualised the possibilities.

An important point here is that the spirulina innovation system has a capability that is more than the sum of its parts and concerns levels of skills and resources, but also concerns the way the system behaves – i e, the agendas it pursues and the patterns of accountability it responds to.

Reworking the stock of knowledge: The MCRC experience suggests that innovation is all about drawing from the existing stock of knowledge and using, adapting, and diffusing it in new ways. Algal technology had originally been conceived as a bio fertiliser that was reworked by MCRC to produce a food supplement technology. This was subsequently reworked to meet diverse objectives such as rural employment, enterprise development, nutritional security and disaster relief – all innovations on the spirulina theme. As Edquist (1997) points out, innovations involve creations, which may be brand new, but are more often new combinations of existing elements.

Responding to evolving opportunities: The spirulina story indicates innovation is often a response to emerging opportunities and that successful organisations are those that can seize these opportunities when they arise. So for example, there has also been a gradual evolution of objectives and trajectories along the way – food, fodder, energy, large-scale, small-scale. The use of spirulina for the earthquake relief work was another response of this type.

Iteration between research and technology tasks: The spirulina case also shows that there was no linear relationship between basic and applied research, or between applied research and diffusion. There has been a lot of iteration between these stages that are conventionally compartmentalised as strategic and applied tasks. The idea of innovation as a systems concept does not diminish the importance of science, but instead, locates it in different relationships and points in the innovation trajectory.

Learning: Many of the points above allude to an underpinning process that seems to be driving forward the innovation process and the trajectory that it follows. This process is learning and it confers the evolutionary dynamic that characterises innovation systems. Learning comes from different contexts – for examples, from the experience of NGO's establishing village level production systems. Not all of these lessons are technological but institutional, i e, how to do something, who to work with, how to test results and validate findings. Often it was necessary to fail in order to learn how to move forward. In fact, many of the ideas and designs failed, but provided useful information and insights. Learning is thus a fundamental property of the innovation system. Watts et al (2003) have recently pointed out that institutional contexts and professional behaviour that can take a constructive approach to failure and learning have much to recommend them.

At MCRC cooperation and communication was encouraged across the organisation reducing internal barriers and hierarchies facilitating learning across projects. Learning across projects was helped by an organisational culture that saw research as capacity building for the whole organisation. The value of a flexible approach to professional mandates especially in evolving innovation scenarios was demonstrated at MCRC. The involvement of trained physicists in marketing, or the involvement of amateurs in research teams broadened the research. The close contact of MCRC with field-level realities on the one hand and scientific organisations on the other were the strengths that facilitated better problem definition.

The case of spirulina work at MCRC shows that there is a need for a change in organisational culture that encourages broader-based pursuits across the basic to applied continuum and that values failures, allowing for learning across projects and disciplines. Conceptualisations of non-technical and non-quantifiable aspects of research need to be encouraged amongst scientists. A reflexive element needs encouragement more than greater allocation of resources for R&D. In other words, there are learning possibilities through case studies of institutional and innovation histories that need to be more fully explored by science policy-makers. In general, research activities need to be conceived as part of the larger process of innovation. Concepts such as the innovation systems could usefully be employed to help map out the architecture of these systems, helping identify missing links, and institutional failures. Research policy needs to pay more attention to building the capacity of these systems. In this task institutional innovations will be critical.

The notion of innovation as systemic phenomenon [Freeman 1987; Hall et al 2001, 2003] allows the consideration of the role civil society to go beyond the dualities of formal versus non-formal science. There is nothing in the spirulina innovation trajectory that represents single ownership of ideas or concepts. For far too long, civil society and state science in India have seen each other's activities as in opposition. With the increasing realisation that there is a lot of technical content in extension, (as indeed this case has demonstrated) formal science needs to extend the domain from whence it picks its problems and research ideas. Within the new framework of the innovation system, creativity can be celebrated, irrespective of its institutional contexts. More than any increased funding allocation this requires a change in approach in the way state science looks at the field and the complexities of technology transfer. Formal science needs to recognise the 'hidden histories of science' in civil society initiatives and incorporate them as part of the 'legitimate' narrative if science has to have a pro-poor human face.[7] The spirulina case study, in fact, illustrates a critical and underutilised role of an alternative paradigm of learning and innovation. EPW

Email: shambup@yahoo.com

Notes

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1 The pesticide residue debate in India following the Centre for Science and Environment (CSE) findings has often been seen in terms of regulation of multinational companies and ignores the larger question of agricultural practices that brought about the contamination of groundwater in the first place. For a similar silence on agricultural science on cotton farmers' suicides see Shambu Prasad 1999.

2 One finds elements of such constructive dissent in Albert Howard's *Agricultural Testament* (1940) as well. The pioneer of the organic agriculture movement in India had sought to see agriculture as an art. He argued for a new type of research investigator who needed to be both a farmer and a scientist. In both Higginbottom and Howard we see the need for the iterative element in the innovation chain with scientists having to get ideas from the farms and not just in their laboratories.

3 Kumarappa argued that the prime consideration in any programme of food planning would be in 'getting the maximum of nourishment out of the food consumed' [Kumarappa 1971: 299, 423].

4 For more details on the Nimbkar Institute see www.nariphaltan.virtualave.net and for the Rural Innovations Network see www.rinovations.org, also see www.sristi.org.

5 On the various applications of spirulina see www.nrdcindia.com, www.*Spirulina*source.com and Seshadri and Étagère 1986.

6 For a fuller discussion on the difficulties in implementing interdisciplinary research in universities, see Feller, 2002.

7 Chattopadhyaya's (2002) recent dictionary of Indian scientists, for instance, has no mention of either Seshadri or Higginbottom.

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