Science and technology for sustainable development

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Despite massive input of public funds into scientific research, the lives of the majority in India remain largely untouched by the products of modern science. The causes for this lie primarily within the distorted priorities that characterise the national development process, but also within the attitudes and commitments of the scientific community itself. The primary function of science today has to be the eradication of poverty and regeneration of the environmental resource base. Both these goals can easily be achieved if we set up more appropriate institutions for the innovation and delivery of goods and services that directly respond to the basic needs of the people.

The background

The fifty years of independence and planned development have taken India several steps forward in various areas of human concern. Indeed, the increases in food production, the diversity of our energy, industrial and commercial sectors, and the breadth of our scientific endeavour are widely and justifiably held up as examples of achievement unparalleled in history.

In these fifty years, the official figures show that literacy has gone up from 17% to 55%, steel production from 1.5 million tonnes to 25 million tonnes, electricity generation from 3.5 million kW to 90 million kW, and grain production from 50 million tonnes to nearly 200 million tonnes.

Some 10 million Indians can today consider themselves a part of the global elite, holding their own on every front: material possessions, energy consumption, physical comfort, mobility, wealth and world-wide influence.

Another 100 million people live in relatively comfortable economic circumstance, comparable to those in middle income countries. And perhaps yet another 200 million manage a passable existence, with access to television, telephones and modern transport – if not privately, at least through public facilities.

As a nation progressing towards becoming a modern technological economy, we have something to be proud of.

And our scientists and engineers can well take their fair share of credit for this achievement.

The reality

The flip side of the development coin is however not so pretty.

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A large majority of our people are still on a never-ending treadmill of poverty and deprivation.

The remaining 600 million of our fellow citizens live in conditions that vary from the sub-human to the abysmal, comparable to the least developed economies on earth. Almost none of these people have drinking water sources or toilets in their homes, let alone electricity connections or other modern amenities for their most basic day-to-day needs. Many among the last 300 million, which comprise a population greater than that of North America or Europe, do not have proper homes; nor access to safe drinking water within reasonable distance of their dwelling or virtually any product resulting from modern science beyond safety matches, kerosene lamps, bicycles, transistor radio, etc. and practically no access to any service.

In the language of science, these numbers are astronomical. For example, our country has:

- more than 400 million people living below the poverty line;
- more than 300 million people with no access to safe water supply;
- more than 700 million people without proper sanitation;
- more than 150 million people without proper homes;
- more than 500 million people without electrical connections;
- more than 400 million people who are illiterate;
- more than 1,500,000 children who die each year before their first birthday.

Each of these numbers is now more than double of what it was at the time of independence in 1947. And each is still growing.

The ivory tower

Few decision-makers and even fewer scientists in our country seem to be aware of this rapid downhill slide.

For most of them, the explosion in the numbers of illiterate, houseless or poor in the 50 years of so-called socio-economic development is a fact completely lost within the selective statistics of national achievement.

The best response most officials can offer is, *there are, of course, many more people now.*

But, that precisely is the point. There are more people because there is more poverty. And there are more poor people because most of them have been by-passed by the so-called 'development process'. It is this vicious cycle that our plans and policies have nurtured – or, at least, have chosen not to break. And the scientists have stood by, unable to create a meaningful role for themselves in this development process.

Even a cursory look at the plan allocations for programmes which can create lasting improvements in the living conditions of the poor will quickly show why this is so. There is virtually no money for them. Or for the scientific research needed to make these programmes more effective.

But there are vast allocations for poverty alleviation.

Indeed there are: to respond to the emergencies and 'natural' disasters which take place with frightening regularity, to provide temporary work, and to construct substandard houses, roads and civil works that disappear as soon as the rains come. Most of the money allocated never reaches the so-called 'beneficiaries' anyway.

And *vast* is a relative word. Per capita, these funds are pitiably inadequate to meet even their own ill-conceived objectives.

The question is: how long will it take for us to realize that these palliative measures aimed at superficial cures cannot possibly have any long-term impact. Without deeper, structural changes, the economy cannot provide sustained benefits for those who need these the most. And even if it could, the practical realities – massive leakages, inadequate information and the bunching up of expenditures in the last two months of the financial year – ensure that nothing of permanent value will ever reach the poor.

Until a transition is made to those socio-economic conditions where a much larger proportion of our citizens can share the fruits of modern development, 'development', inevitably and inexorably, is and will be a losing proposition.

There exist many underlying causes for this inexcusable state of affairs, but growing population is *not* one of them. Continued and unabated rise in population is the *result*, not the cause of our gradual slide to impoverishment and under-development.

The causes of under-development

This trend is clearly not tenable, nor can the present system which has led to it form the basis of sustainable development.

The failure of development, and the role of science in it, can primarily be ascribed to inadequate policy-level attention to:

- the provision of basic social services such as health, education and shelter, not necessarily by government-run programmes;
- the changes needed in the structures of society, economy and government – most of which are continuations of centuries-old colonial practices, unsuited to the needs of today;
- the need to create systems of local governance and empowerment of communities to design their own futures;
- the choices we must make among possible development goals and technological options;
- the national priorities for scientific research.

In more specific terms, the shortcomings of our past development planning can be ascribed to an over-reliance on imaginary goals such as some arbitrarily chosen growth rate for agricultural, industrial or national development. Most development planning programmes have ignored the real (natural) resource issues, since the term 'resource' in planning practice has generally come to refer only to the amount of money available. These have also ignored the human, cultural and other issues that can only be understood with greater participation of the people, for whom development is being 'planned'. Moreover, the past (and existing) planning methodology has *essentially* been designed to make the rich richer and the poor poorer and alienating both from the land and its natural resources.

Another set of problems comes from the paternalistic form of government we have established, in which public sector agencies provide large numbers of services which should be provided by individual or corporate effort. With heavy reliance on massive bureaucracies and huge subsidies, the people of India have completely lost any sense of ownership or control over their lives. The scientific community too has fallen into the trap of expecting unlimited support from society, without in return helping solve its problems.

Also we have justified our inattention to the needs of poor people with intellectual arguments about 'the lack of absorptive capacity' of the rural sector and its relatively low purchasing power. Almost no practical effort has been made to test these assumptions in a dispassionate or objective manner. There is ample evidence to show that the rural poor wish to, and can, improve their lives, provided they too have access to technological, financial and institutional resources.

Finally, perhaps the greatest tragedy in this profound failure lies in the miniscule role our country has given to science and technology for solving the problems of poverty.

The alternatives

Unquestionably many of these causes and factors are linked with the central issue of population growth. However, the way out of this problem is perhaps to redefine the goals of development.

To balance the growth in population with the opportunities offered by development and the limits imposed by environment, development action must be designed directly to:

- satisfy the basic needs of every citizen;
- fulfil the potential of our children;
- raise the status and self-determination of women;
- create opportunities for meaningful work for all;
- enlarge the possibilities for social advancement;
- enhance the personal security of old people;
- facilitate access to the means of family planning.

Not only is a demographic transition required, but also a solution to all the above mentioned goals requires inputs from the best possible science. The time to change direction is *now*.

The malaise of Indian science

Every scientist in the country can provide a view of why science in our country is not what it should be. Most such debates however, end up in the air with arguments about 'the difference between basic science and engineering science', 'the need to support blue sky research versus practical research', and 'how science is not the same as technology'. However, in the real world of decision-making, everyone understands that we need both pure and applied science. Although in a poor country like India, the first meaning of science has to be the application of the scientific method to the solution of the most pressing day-to-day problems of the people – satisfaction of their basic needs and conservation of their resource base.

There are, of course, other analyses of what ails science in India. Some claim that the emphasis of science in our country on theory and the avoidance of the practical is a result of our long, brahminical traditions. This may be so, but the insight hardly helps us find immediate, operational solutions.

Others cite the hierarchical and autocratic structures of our scientific institutions which prevent younger and more creative scientists from actualizing their potential. This is also true; but science in this regard is merely afflicted by a failure of human relations which is true for all our national institutions.

Still others suggest that the poor infrastructure and the bureaucratic red tape, which prevents scientists from working efficiently, is the main handicap of Indian science. This is also true, but it is the scientists who have chosen to pursue their narrow interests and to leave the control over decisions, crucial to their enterprise, to others.

Yet others mention the lack of job opportunities. This again will continue to be a fact as long as scientists cannot recognize that it is they who must create opportunities for others and thus for themselves as well.

Criticisms of Indian science, such as these, are frequently heard and have been heard for the past three decades at the numerous symposia on subjects like 'The Problems of Indian Science' and 'Why have Indian scientists not been able to make a contribution to national development?'. Almost all of them address the superficial symptoms and rarely tackle the root causes.

Eminent scientists often complain of inadequate funding and lack of support from society for their valuable endeavours. However, few are in a position to describe what their community actually contributes in return for such support. Scientists clearly feel no more compulsion to be accountable than any other privileged group in our country.

While the younger scientists cannot look beyond their salaries, promotions and trips abroad, the older ones spend their time climbing the professional ladder, preparing their post-retirement pastures and keeping the younger ones in their place. Very few scientists are prepared to place their science at the service of society.

The roots of failure

The root causes underlying the fact that Indian science has made so little impact on the lives of our people are so numerous that a short list of the more important ones can only be arbitrary.

First, there is very little science that can be truly called 'Indian' science, grounded in the realities of our own country. The great bulk of the work that goes on in our laboratories is imitative. Given the resources put into our science, the output of genuine breakthroughs and opening of new scientific fields of inquiry is pitiably low. Science in India has now become a default occupation for those who could not get into the IAS or business – or, at the most, a passport to emigrate as far away as possible. This means that studying science at school or college is no longer considered socially desirable.

While there is unquestionably room for basic research of a much higher order and in many more fields than exists today, the quality and mix of R&D efforts must now be radically changed. The change must favour indigenously designed programmes, based on indigenously defined goals. Apart from the relatively successful scientific efforts in the field of agriculture, virtually no scientific institutional framework presently addresses the problems of sustainable national development. The host of evaluations and review committee reports over the past three decades have, by and large, addressed minor, peripheral and irrelevant issues rather than provide suggestions for the deep structural changes required.

The imperatives of sustainable development now require us to redesign development so as to benefit the largest possible number of people. This will require complicated and difficult decisions on consumption patterns, investment allocations and other socio-economic choices which lie outside the direct purview of science policy itself. However, the scientific community will have to play an infinitely stronger role in helping the Government and the people of this country in making this transition. This can only be done by a massive increase in expenditure on research aimed at solving the problems of the poor.

The immediate job of relevant science and technology is to enable India to eradicate poverty while strengthening its competitiveness in the global economy. Government policies for science must build up a solid institutional capability to undertake new kinds of innovation that can enable us simultaneously to meet these twin objectives. Existing S&T structures need to be transformed to meet today's needs; new ones need to be created to get the country ready for tomorrow. To make this happen, our policy-makers must broaden the spectrum of planning inputs they are getting. They can no longer rely only on the advice of the mutually-supportive and well-entrenched scientific establishments. We need to bring in a much larger range of younger scientists who are more in tune with the realities of today and who can articulate the wider needs of the nation as well.

External factors

The 'external factors' are those policy interventions, institutional frameworks, etc. which lie outside the control of the scientific community, but which nevertheless impact the scientific enterprise.

Perhaps the most fundamental among these is the choice of societal goals. Few nations have been able to define their overall objectives in specific and concrete terms, and India is no exception. However, implicit choices are constantly made by any society whenever a specific policy or decision is made. The underlying patterns which emerge from an analysis of Indian development planning decisions clearly show an implicit bias towards issues concerning the more privileged of our country, and this has deeply influenced the choices and decisions relating to science and technology.

Another fundamental set of largely implicit choices relate to the selection of technology, and thus to the way we manage resources and impact the environment. In almost every sphere of life, there are many possible technological solutions. Given the differences in factor endowments (land, labour, capital, etc.), in culture and in social expectations, the choice in any case should be endogenous. In India, we have tended largely to adopt solutions which were adopted earlier elsewhere, usually in the West. The shortcomings of many of these solutions are beginning to be apparent and many groups in the countries of their origin have started questioning their value. As in their adoption, so in their rejection India lags behind.

The third major external factor is institutional design. For a variety of reasons, our choice of organizational frameworks for science invariably betrays deep cultural prejudices. The existing and unquestioned assumption that the only possible way to make progress is to depend on the public sectors, whether it is to innovate, teach, produce or distribute, is a fallacy which our country is paying dearly for. Government policy on science and technology appears to be blind to virtually any possibilities for innovation or R&D outside government or publicly-controlled institutions. The fact that these public institutions have tremendous inefficiencies and inherent losses, and that other mechanisms may be far superior for producing effective and timely results, need to be explored.

Unless these external factors are changed, the specific interventions to improve the doing of science in our country can be no more than a superficial, unproductive exercise.

Internal factors

Among the 'internal factors', namely those which are amenable to decision-making processes within the scientific community, certainly the most important are the relevant priorities and allocations assigned to different S&T areas. Society supports scientists in their work because of an expectation that the returns will amply pay for the investment. Looking at the allocations for the different sectors in the economy, clearly the assumption among our scientific decision-makers is either that only the rich can make use of scientific innovations or that science has no possible relevance to lives of the poor.

But, the priorities in allocation in the future will have to be radically different from what they have been over the past 50 years. We need at least two orders of magnitude increases in expenditures on research and development for the problems of over 650 million fellow citizens who have traditionally been entirely ignored.

The second internal factor which primarily impacts the possibilities for application of science to practical problems is the lack of linkages between the innovation, production, and marketing processes. Neither in the conventional scientific institutions (CSIR, IITs, universities or other publicly-funded research organizations), nor in 'Science for Society' does there exist a single mechanism for getting needed products and processes into the market on a large scale. Less than half a dozen existing corporate R&D institutions are capable of addressing this problem effectively, and even these require extensive restructuring.

Moreover, major redesigning is required for the management of our scientific institutions so as to overcome the difficulties faced by scientists as described by themselves and enumerated in the section above, 'The malaise of Indian science'.

The problem of national, academic and industrial research laboratories can only be addressed by fundamental changes in their mandates, stated objectives, personnel policies, infrastructural endowments and result orientation. The evaluation of their performance must allow for the lead time any scientific discovery must have before becoming successful in the market. It is for this reason that 50 years of public R&D, costing several tens of crores and nationwide efforts, have not been able to produce improvements in handloom technology, which were recently achieved by a small corporate R&D effort involving a tiny team of young technologists with a budget of Rs 10 lakhs and a timescale of two years.

The responsibilities of the scientific community

Another issue confronting the scientific community in India is the particular responsibility it has, because of its knowledge and expertise, to identify emerging issues and alternative approaches for sustainable development. The community as a whole has to play a much stronger role in this respect, and the institutional frameworks needed for this must be strongly supported by Government, even though they might be the cause of considerable inconvenience at certain times.

While export orientation and internationalism are extremely important to maintain the quality of science and technology in the country, the future scientific thrust areas must be geared to the indigenous needs for development, and must be indigenously chosen by the scientific community. Self-reliance must not be simply a planning shibboleth but a fundamental movement for grass-roots involvement in the identification and solution of people's material problems.

The problem of absorptive capacity has to be solved by investing in entirely new kinds of institutions, capable of using the methods and tools of modern science to focus on the real issues confronting our nation: poverty removal, population growth, and proliferation of resource depletion.

The distinction between basic science and applied science is spurious to the issue of sustainable development. An effective scientific effort for a positive impact on sustainable socio-economic development has to take into account scientific excellence with societal relevance, professional reward systems that attract the very best scientists for research on societal problems, and efficient management systems.

Thus, in future scientific research institutions must go beyond the traditional and irrelevant dichotomies, such as:

- The public vs the private;
- The big vs the small;
- The modern vs the traditional;
- Basic research vs applied research.

Technology for sustainable livelihoods

To be more specific, the central goal today for any developing country must be to create sustainable livelihoods, rather, large numbers of sustainable livelihoods. For example, to close the unemployment gap by the year 2010, India will need to create more than 12 million, perhaps as many as 15 million, off-farm jobs each year, starting today.

The second goal, for India at least, is to accelerate the rate of growth of its economy. While the nation's planners debate whether this rate should be 6% or 7% per year, eradication of poverty within a reasonable timeframe will require growth rates in the double digit region, perhaps as high as 15–18%.

The 'modern', formal sector is not capable of creating this many workplaces. Or these kinds of growth rate. Today, it can hardly create one million jobs and 6% real economic growth.

The reasons for both these failures lie in our industrial structures, which we have adopted, without adaptation, from the West. The capital costs are too high and the gestation periods too long. The average cost per workplace created exceeds $ 100,000. In India, plants of this kind can take two to six years to bring into operation.

Further, because of labour problems, the technology is specifically designed to replace labour by machines; to decrease jobs, not to create them; and to exclude the poor, the unskilled and the marginalized. Thus with continued emphasis on large industries, the numbers of unemployed can only grow over time.

There are, of course, sectors for which the economies of scale only work with large, mechanized units. These probably include steel-making, oil-refining and automobile manufacture. But, despite the admonitions of economists, most industries can be commercially viable even at quite small scales. Even if the full costs of the processes and resources used in manufacturing and delivering products is taken into account, and no subsidies are allowed for energy, transportation, financial and other services, small-scale production can become highly competitive.

In any case, only small and micro-enterprises (SMEs) can do the job that needs to be done on the job front. What is more, they can also accelerate economic growth. Since their return on investment is usually much higher than for a larger industry and, need only small amounts of capital and gestation for each unit, they can proliferate much faster.

As evidence of this, SMEs already form the backbone of national economy. They account for more than 60% of the industrial production in India, and for more than 65% of industrial exports. They account for more than 70% of industrial employment. They could account for an even larger share but for the price distortions introduced by highly skewed subsidy systems and infrastructure investments.

However, being small, dispersed and largely unregulated, their environmental and social impacts are often quite negative. To overcome this, they need access to better technologies as well as other supports.

Many of the technologies that are needed for such enterprises already exist. So do the markets for their products. What prevents such enterprises from being set up and becoming profitable is lack of financial capital, infrastructure and marketing channels. Much more public investment is needed to provide these, but probably not nearly as much as is being made today for the benefit of large, urban industries.

Even without all these conditions being fulfilled, if SMEs had access to adequate technology, credit, marketing channels and management expertise, they would largely overcome the other barriers. For enterprises to be profitable and sustainable in the longer term, they need to set up basic production and marketing facilities which cannot be done without a basic minimum investment. There are innumerable technology-based micro-industries that could be set up today and run profitably, which require capital ranging from Rs 20,000 to Rs 10 lakhs.

Such enterprises can usually create several workplaces, each at a cost of less than Rs 20,000, plus a similar number of upstream or downstream jobs at an even lower cost. Such workplaces, in the village or small town, yield incomes for workers whose purchasing power is comparable to, if not better than, those created at a hundred times the cost in large urban industries. At the same time, they permit very high returns on investment, often with payback periods of less than a year.

Funding science for sustainable development

There can be no better investment for a society than its people: their health, education, and well-being. But one other investment that comes close for potential returns is scientific research.

All successful economies recognize that scientific innovation is an essential component of any major economic activity. Experience in the USA, Japan and Germany has shown that expenditures on R&D pay for themselves many times over through higher efficiencies, better productivity and improved resource conservation. Moreover, national competitiveness is closely correlated with expenditures on science and innovation.

For almost any sector of the economy in these countries – construction, transportation, communication, industry, agriculture, etc. – the normal expenditure on R&D comes to between 1% and 4% of the total turnover of that sector. In special science-intensive areas like space, electronics, computer software, defence, pharmaceuticals, these R&D expenditures can quite easily get above 10%. Even the private sector recognizes the need for investment in research and contributes a sizeable portion of these funds.

Since the 1950s, the Government of India too has recognized the importance of research and has made a major commitment of public funds to R&D. During much of this period, it has devoted close to 1% of its GNP towards science, although this figure is now declining somewhat. This is a larger budget for science than in any other developing country, and indeed bigger than in many developed countries.

Most of this money has been spent, however, on supporting science, which can only benefit a small minority in our country. It goes to space research, atomic energy, defence, high technology for industrial needs, input-intensive agriculture and curative medicine. Apart from a small fraction of the research in agriculture and medicine, very little can be shown to have a direct or even indirect impact on the lives of the poorer two thirds of our people.

Currently, the total amount of money allocated for 'science and society' programmes of the Department of Science & Technology is about Rs 5 crores per year. A fair portion of this goes into activities other than research, like training, pilot projects, and demonstrations. The total support to research of any relevance to the poor from other agencies like DBT, ICAR, ICMR, CAPART is around another Rs 15 crores. Thus, the total annual expenditure on scientific research aimed at the problems of poverty, environment and sustainable development is no more than Rs 20 crores per year.

The budgets of the ministries working directly on the problems of the poor and the marginalized – the Ministries of Rural Development, Welfare, Woman and Child, etc. – add up to more than Rs 30,000 crores per year. Conservatively assuming that the government budget for this sector accounts for one-third of the total economic flows in it, the money flowing through this sector is easily Rs 100,000 crores per year. Although this is less than 10% of the national product, it is still a sizeable economy in its own right.

Thus, the R&D budget concerning issues of real poverty is well under 0.02% of the sectoral turnover – a figure that needs to be multiplied by a factor of at least

50 to be meaningful. Even then, it would be so small as to be within the normal variations in overall plan allocations and certainly less than the monies that lapse each year from the unspent budgets of scientific ministries.

Another interesting calculation is the relative funding available from government for 'science and society' as a percentage of total allocations to scientific research. Total scientific allocations today are approximately Rs 10,000 crores per year. Allocations for science, relevant to the problems of the poor, amount, as shown above, to less than Rs 20 crores. Thus, again, it would appear that, in the eyes of our decision-makers, research to solve the problems of 70% of the people of India appears to merit less than 0.2% of the allocation made for the remaining 30%. On a per capita basis, we place 1,000 times as much money for research of interest to the rich, urban middle class as we do for research aimed at the problems of real people.

Under these circumstances, the rich will inevitably get richer and the poor can only get poorer. Our science policy serves therefore directly to accentuate the disparities in our country and runs completely counter to the national goals of equity and social justice.

This is clearly ridiculous. Arguments have been often given against raising the allocation of funds for scientific research on the problems of sustainable development. These are usually related to issues such as 'the need for urgent action rather than research'. None of these arguments has any substance. For example, money on research in glamorous areas has been forthcoming in huge floods – witness the atomic energy programme, the space programme, the electronic programme, the super conductivity programme, the green revolution programme and many others. None of these had absorptive capacity at the outset. It was rapidly built up by making massive investments in it.

We now need the same commitment and investment in research aimed at poverty eradication and livelihood generation – at sustainable development – and absorptive capacity will automatically get built up. And only thus can our scientific effort begin to address the nation's priorities.

An institutional framework for sustainable technologies

At the local level, we need new forms of institutions that are capable of fulfilling social objectives and working in a business-like way. NDDB, C-DAC, C-DOT provide excellent examples. For such institutions to deliver successful results, they can be neither in the public sector nor the private. Or rather, they must have the best of both. One such independent institutional framework has been designed and is currently being implemented and tested in India at Development Alternatives.

At the national level, a full-scale commitment is needed to set up institutional machineries to place the scientific development of sustainable technologies at the centre of the country's agenda. The Atomic Energy Commission, the Space Commission or CSIR provide examples of what should (and should not) be done.

In essence, we propose that a completely autonomous institution be established, which will comprise a network of local units throughout the country, capable of dealing with geographically or topically relevant societal problems. In terms of the coverage, the concept could be modelled after the CSIR network of national and regional research laboratories. However, in scope of work, mode of operation and linkages with the economic sectors it deals with, its structure and functions will be entirely different from that of CSIR.

It will employ a 'corporate R&D' approach to identify and solve basic societal development problems. This means that, unlike CSIR, it will not only undertake laboratory and prototype-level R&D, but will go all the way through productionizing and proving commercial viability by actual operation of model enterprises.

Its capacity to attract the best scientists and strong financial support will be maximized by establishing the right mix of basic and applied research and by freeing the organization from unnecessary bureaucratic hurdles.

Taking a systemic view of its mandate and work, such an organization, will, if it is properly designed, be able to have an impact on the lives of the poor, which is several orders of magnitude higher than that of any existing institution in this field,

The absorptive capacity of this institution can easily be built up within a few years to employ a reasonable fraction of the good scientific minds presently underemployed in the country and to utilise funds similar in magnitude to those currently being spent on conventional scientific research. Only thus can we begin to hope for the needed improvement in the lives of the majority of our people.

And every measure necessary must be taken with the highest urgency to attract the best young minds in our country to the study of science.

Precise design of these institutions and policies/ programmes should be commissioned by the Prime Minister.

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