New partnerships and new paradigms for the new century*

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The new century is upon us. We need to dare to be bold and think in terms that recognize the changing landscape of contemporary science, the risks of the emerging scientific apartheid and the needs of the vast majority of humanity that must have the means to provide food security.

Malthus, Mendel and Beyond

Whatever one thinks about the demographic transition, the challenges ahead are awesome: 840 million hungry, two billion malnourished, and an additional three billion people most in the developing countries by the next generation.

If the Green Revolution fomented by the CGIAR system has successfully risen to the challenge of the last generation, can the promise of Mendelian science be brought once more to lay to rest the Malthusian fears of today? I believe that it can, and in that sense ally myself with The Marquis of Condorcet, the contemporary of Malthus, who predicted that we would be able to meet the needs of ever more people with the same amount of land by technical progress. But technical progress will not occur by itself, we will need a decisive, determined commitment to expand agricultural research and extension work as an integral part of a major renewal of the rural world in developing countries. If we do not do that, we will undoubtedly fail dismally in our efforts to reduce poverty, improve food security for all, protect the environment and lay the foundations for better tomorrows.

The agricultural research situation today

International agricultural research has developed much over the last generation, and is gradually involving many actors. These actors are increasingly collaborating in a web of networks that has done much to advance research. I will return to the theme of the partnerships later on, but let me first say a word about what I see as a double shift in the research paradigm.

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The first of these shifts is the contextualization of crop-specific research. This is well known to all of us, but has not yet been sufficiently implemented: that is the integration of the crop-specific research, which has been so successful in the past, into a broader more holistic vision that brings in the concepts of sustainability and eco-regionality, and looks to achieving results through increasing the productivity and profitability of complex farming systems at the small holder level.

That means increasing the imbeddedness of the crop research into its ecological context and looking for the synergies across livestock, farming, aquaculture and agroforestry. Already dramatic examples on the increased productivity of grains in the semi-arid tropics are noted when the planting is synchronized with the management of livestock for their manure and urine. Similarly, ponds for aquaculture have demonstrated a usefulness in water management at the small-holder level. Multi-purpose trees such as Sesbania have proven very useful due to their nitrogen-fixing properties, their fast growing branches which can be harvested for fuel wood, and their leaves which make exceptionally effective fodder. Finally, the socio-economic characteristics of the farmers themselves must be taken into account.

The second shift is to bring to bear the most cutting-edge work associated with genetic mapping, molecular markers and biotechnology to accelerate the breeding process and achieve the promise of all that science can do for the poor and the environment. This is, of course, the hottest area of controversy as well as promise today. It is largely driven by the private sector, and transgenic crops are becoming a reality. Over the period 1986–1997, some 25,000 field trials of transgenic crops were executed. Of these, 10,000 were in the last two years! Similarly, acreage planted in transgenics grew from an insignificant amount a few years ago to 7 million acres in 1996 and 31.5 million acres in 1997. So this topic deserves a bit more elaboration.

On the science itself, important work is being done on genomics, genetic mapping and the identification of quantitative trait loci (QTLs).

The new biotechnology work takes the sequence of steps of the conventional work in a reverse order. The old paradigm started with the phenotypical expression of the gene, then proceeded to try to find the gene that has the desired trait. The new biology starts by mapping a gene and then identifying its phenotypical expression.

The availability of high powered computers and software combined with the detailed understanding of modern genetics and molecular biology has multiplied the power of analysis far beyond what could be done a generation ago. What is more, the pace of discovery and accumulation of knowledge is rapidly accelerating.

The question about the application of this knowledge to our scientific mission raises challenging possibilities that have been recently sketched out in a paper by Steven D. Tanksley and Susan R. McCouch, published in the 22 August 1997 issue of *Science*.

The gist of their argument is that by locating quantitatively inherited traits (QTLs) in the wild relatives of major crop species, and using these in plant breeding, it will be possible to make major advances on the yield front. QTL-based breeding, based on screening exotic germplasm for relevant QTLs, they argue, is more important than the traditional method of phenotype-based screening. Genetic linkage maps based on molecular markers have made it possible for QTLs to be identified, studied, and applied in crop breeding.

Tanksley and McCouch have stated that 'using phenotypic evaluation to determine the breeding value of an accession is likely to be misleading, especially with respect to quantitative traits. Thus, we have been screening germplasm in a way that fails to explain its potential. A corollary is that exotic germplasm is a likely source of new and valuable genes capable of increasing yield and other complex traits important to agriculture, and that molecular linkage maps will enable us to find them. The paradigm needs to shift away from selecting parents on the basis of phenotype to evaluating them directly for the presence of useful genes. The tools that make such an analysis possible are molecular maps and the integrative power of QTL analysis'.

If we accept this thinking, then it argues for the expansion of our efforts at genetic rather than phenotypical screening and characterization of our germplasm, based on the relevance of the traits for particular agronomic characteristics. Close collaboration between IARCs and NARs in this area would also be eminently desirable.

It is also notable that the work of this type would benefit from crossing the traditional commodity-specific lines. Indeed we are discovering that the architecture of the genomes for monocots has much in common across species, an observation that also holds for dicots such as tomatoes and potatoes. Thus, not only is there some possible benefit of working across nations, IARCs, NARs and AROs, in order to maximize the speed with which breakthroughs can be effectuated.

So where does this leave us? Let us review the agricultural research continuum and the actors active in each part of it. From there we can perhaps sketch out some partnerships that could be profitably pursued for maximum effectiveness.

The agricultural research continuum

If we were to classify the needed agricultural research tasks in a continuum going from the most abstract to the most directly applied at the farmers field, we could construct a recognizable pattern that also parallels degree of abstraction and complexity in research. Note that farming may be a very complex enterprise, but it does not constitute complexity in research.

This continuum overlaps with the conventional view of the spectrum of research going from basic to strategic to applied to adaptive research, but uses slightly different links that are more specific to the research paradigm being used and the one that I hope we will be going towards. Thus, this is not an abandonment of the previous spectrum but variations on the theme.

At the top of the spectrum, in terms of complexity and abstraction would be basic research in disciplines that are not necessarily part of agricultural research, but actually feed into it, such as informatics, molecular biology and biochemistry. This type of basic research is the domain of the universities and while some developing country universities may play a role there, the predominant role will be held by the AROs in the industrialized countries. Basic research can also be more directly linked to the agricultural research enterprise – for example, work on the mapping of the genomes of particular plants, including the mapping of the Arabidopsis genome, which is likely to be used as a template for many other searches.

Next in the level of abstraction and complexity, comes the characterization of the genetic material in particular plants and species and varieties. The characterization at the molecular level, to come to specific genes or promoter and terminator sequences, or more generally to focus on particular quantitative trait loci (QTLs) is feasible but requires marshaling immense resources involving knowledge of molecular maps, informatics programmes for both manipulation and storage of the data, and, of course, some direct link to the other researchers working on these problems elsewhere in the world. Here, IARCs and their partners in the NARS have much to offer. At the same time, some of the best AROs are very active in this area: CIRAD, Cornell and Max Planck, to name but a few. Also the private sector in the industrialized countries and biotechnology companies are active here. This leads to the next level of complexity and abstraction.

The third level is the transformation of the genetic material, by conventional breeding techniques or by recombinant transformation of the genetic material, to create transgenic crops.

In the short-term, this is where most of the current efforts of agricultural research go. In most NARS, this is done through conventional breeding aided by marker selection, tissue culture and other mainstream biotechnology methodologies.

In the near future, it is likely to be dominated by the patented work of the large multinationals, and other recombinant DNA technologies. The IARCs and some of the NARS are also beginning to be active in this area.

In the long-term, this is going to be a segment of the research continuum where synthetic plants are actually designed, with new genomes constructed out of the building blocks of particular parts of the genomes of the various plants, much as one assembles the pieces of a lego set: drought tolerant varieties, nitrogen fixing cereals, basic foods with particular nutritional characteristics, etc. The dreams can go on and on, but the day will come, and it is not too far in the next century.

The fourth level of complexity involves imbedding the new varieties into the complex farming systems at the small holder level. This is a non-trivial task, since the synergistic effects of the farming systems have to be brought into play, while paying particular attention to the ecological realities. Many of the poorest small holder farmers in the developing world are living on very fragile ecological systems

CGIAR centers, the IARCs, and the NARs are key players here. This is essential to think of in terms of the entire NARs, not just the NARIs, especially linking the different components of the system, i.e. the NARI, the Universities, the NGOs, the farmer associations, the private sector.

The challenge here is essentially both a local and a global one. The eco-regional aspects and the inter-thematic links (livestock crops–agroforestry–acquaculture) are more than local if one is to benefit from broad analytical and diversified research findings. Yet it is also a very local phenomenon. The specifics of each micro-ecology and the specific sociocultural and economic realities of different farming communities need to be factored in as well, both to set priorities and to define avenues of research as well as to bring insights to the broader international effort.

Fifth is the imbedding of the varieties into a real socio-economic and ecological context that suits the target problems. This is the second shift in the paradigm: the imbeddedness of commodity-specific research in the contextual reality of the eco-region and the farming systems of small-holder farmers.

The challenge here is to develop an appropriate range of varieties. This is also where the Doubly Green Revolution, or the Evergreen Revolution will come into its own. It will be the occasion to broaden the food basket, to balance cereals and legumes, to rehabilitate these misnamed 'coarse grains' and recognize them for what they really are: 'nutritious grains'. What will set this work apart from previous efforts to do this kind of breeding will be the analytical characterization work at the genetic rather than the phenotypical level, and the use of the most efficient techniques available for transformation.

This transformation of old varieties into new varieties with desirable traits, however, must – and I must re-emphasize it – be imbedded into the complex farming system at the small holder level, taking due account of the eco-regional specificities.

Here the real work of conventional breeding buttressed by the new biotechnology tools can produce the new elite cultivars, the new parents that would be released for the development of regional, national and locale-specific varieties.

The key actors in this domain are going to be the IARCs and NARs, as well as the NGOs, the private sector and the farmers themselves. It is not clear that either the international private sector or the AROs have a particular comparative advantage in this domain.

All this work leads us to the next step: Adaptive work by locale. This is development of the new range of desirable varieties that express the traits that were sought in a manner that can interact effectively in the expected surroundings. This is the conventional responsibility of the NARs supported by the IARCs, but to a much lesser degree than was the case a generation ago. I stress here that the NARs means the full range of institutions in the country including the NGOs and the farmers themselves.

The next is actual work at the farm. All that we have been discussing is prologue, to the extent that the transformed and presumably suitable varieties and farm practices do not get translated into reality on the farmers' fields, and the presumed benefits to humanity will not materialize. That is why it is important to involve farmers at all levels of the process to the extent that this is feasible.

Clouds on the horizon: Scientific apartheid in the 21st century?

But the scientific climate of the new century is likely to be very different than the one in which the CGIAR thrived and was able to achieve so much working with the national agricultural research systems of the developing countries.

Beyond the income inequalities between the rich countries of the OECD and the poor developing countries, there are other inequalities that are even more troubling. The world of the knowledge-based societies and global linkages is one that will favour the nimble, the educated and the powerful.

There is a vast and growing gap in the availability of scientists and engineers in the North and in the South (3800 per million population in the USA vs less than 200 in the South, as of 1990). This is purely on the quantitative side, and does not speak of the quality of the training or the resources at the disposal of the scientists. In the United States alone, there are 200,000 academic researchers funded to the tune of some $6 billion annually.

But these disparities are just part of the problem.

Ill-equipped as they are, the scientists in the South are confronted by an amazing information explosion, matched by an explosion in computing and communications.

Today in the United States, there are more computers than cars. There is more e-mail than regular mail, and the volume of traffic on the Internet is doubling every 10 months.

Ironically, just as the informatics revolution makes more information more accessible to more people than ever before, the very nature of the scientific enterprise is changing. More and more, the new breakthroughs in science and technology in domains such as informatics and biology are driven by the private sector, especially in the United States. With enormous energy, imagination and drive, these entrepreneurs of knowledge are creating new realities that will doubtless bring enormous benefits to many. But the manner in which the research is carried out, including the need for intellectual property rights (IPRs) to recoup their investments, will make it impossible to practice the open exchange of information and germplasm that have been the hallmark of the past. Collaborations between scientists will increasingly be governed by carefully drafted legal agreements, no matter how easily connected they are.

In addition, the whole range of traditional knowledge and its wisdom, as well as the experience of many, will be marginalized in this new, dichotomizing world of 21st century science. The poor, public goods and the environment may be the victims of this emerging scientific apartheid, where over 80% of humanity in the South could be almost permanently locked out of the major developments of the scientific enterprise. We cannot allow that to happen.

We need a new paradigm of research, where the synergies in agricultural research will unite all the actors, national and international, private and public, in rich and poor countries, and the formal and informal institutions of the civil society. All have their contributions to make. The newly created Global Forum for Agricultural Research is an important first step in that direction.

Intellectual property rights

Let's review what is happening. A huge transformation in biotechnology is taking place, with an enormous increase in market capitalization in the last year. In the United States, market capitalization of biotechnology firms increased by over $30 billion to reach over $83 billion. In the United Kingdom, it jumped from ECU 261 million to ECU 1.2 billion. This is being accompanied by a consolidation of the big private sector companies, dominated largely by the big pharmaceutical companies, and with a large number of smaller 'niche' specialty biotechnology firms. In the US these biotechnology firms now employ over 120,000 employees and spend about $8 billion annually on research.

Patents are essential for these private sector firms to mobilize the funds to make the huge investments they are making. They will recoup their investment only if they are able to market it. Efforts are underway to further extend the life of patents, and the Moorhead–Schroeder bill in the United States Congress is seeking to extend the life of a patent more than 20 years.

What is covered by a patent is also in the process of being defined. The so-called Markman hearings where judges hear witnesses and decide the exact coverage of the patent before going to adjudicate whether infringement has occurred, are helping to develop case law on the coverage of patents. In addition, a number of lawsuits involving the primary actors in biotechnology are helping define the boundaries or the rules of the game.

So the situation, even in the United States, is far from clear. The definitions are fluid and changing. The situation in Europe is different with a strong public sentiment against biotechnology, reflected in a recent non-binding vote in the European Parliament of 407 to 4 opposing advances in certain areas of biotechnology. To add to the confusion, many countries in the South do not permit the patenting of plants and animals.

The situation is very complex. For instance, over forty companies hold two or more patents relating to the *Bacillus thuringiensis* (*Bt*) gene – a total of 410 patents and counting. Egypt has recently filed for a patent of its own concerning *Bt* gene resistance. Another indication of patenting complexities is that six collaborating companies are also engaged in lawsuits over patent rights infringements. Nobody said this was going to be easy.

Those who argue for the patenting of such research point to the experience with computers and informatics a massive explosion of new products and technologies, ever lower prices, and a wider reach to serve everyone. Those who challenge the use of patenting of both process and product point to the patterns observed in other industries, such as the pharmaceutical industry, where breakthroughs are few and far between and the costs can be considerable to both the producers and the consumers. Which is it likely to be?

Remember the stakes – 840 million are hungry, 2 billion are malnourished, there will be 3 billion more people on the planet in a generation, 95% in the poorest countries. It is irresponsible to simply hope that developments will be more like informatics rather than pharmaceuticals.

Possible actions

So what do we do? The international system must play a role in ensuring that

(i) access to the potential benefits of new technologies remain guaranteed for the poor and the environment; and

(ii) the risks of biotechnology are not minimized and adequate biosafety provisions are made for developing countries that want to benefit from this additional tool.

This means intensifying certain things IARCs and NARS have been doing. It means adding to our critical mass of scientific efforts in the area of biotechnology, but not at the expense of the heartland issues of people-centered policies, inclusion of the farm community, natural resource management, and biodiversity. Let us always remember, too, that biotechnology is a tool, to be used in conjunction with other tools, not an end in itself.

Can we now move towards a consensus on how to act? This requires the willingness of the international community to recognize the need for an increased public involvement with biotechnology without diminishing its support for the current agenda of international agricultural research.

Note that in the United States, the country most dedicated to the idea of IPR and the primacy of the private sector, real federal spending on science (as defined by the National Academy of Science) has declined in all sectors except for biology, where it has gone up.

This requires exploration of partnership modes through which the work of the private sector will be channeled into programmes that fully involve NARs. This also calls for both the pros and cons of biotechnology development to be continuously kept in review.

Partnerships

The NARS/IARCs must develop new partnerships with the powerful scientific engines in the AROs and the private sector, especially the large biotech industry that has developed in the US and Europe.

The starting point is a hypothesis, that the IPR regime will continue to move along its current orientation, that this will be largely defined by US case law, and that it will then find its way internationally through the TRIPs agreement and the WTO to a global system.

In parallel, a very large number of genetic sequences and all technology transfers will be patented. Thus despite much greater knowledge being available worldwide, the accessibility of that knowledge for the transformation of crops for the poor in the developing countries will be very limited except to the extent that the NARS will be able to obtain license agreements from the patent holders.

If this hypothesis comes to pass, then the poor and the future generations are likely to be cut out, as we move more and more to a proprietary science regime, where patenting will dominate the flow of germplasm and technology. The days of free access will be numbered.

The CGIAR that was so successful in promoting a regime of free flow of germplasm and open access for all, will have been overtaken by events. The new global regime will impose its rules that will inevitably favour the large multinational corporations that have the wherewithal to undertake such a large investment in biotechnology.

That is why a new approach is needed to establish a parallel system of case law and open the door on the technologies of the future. That approach is one based on research consortia between the North and the South.

The consortia would build on partnerships between the AROs, the IARCs and the NARs at the upstream end, which would result in proper characterization of the germplasm at the genetic level. This in turn would give the IARCs and the NARs the strength to enter into a partnership for the transformation of the material with private sector and other factors.

Such consortia would be based on ex-ante agreements that would have clear objectives, and legally binding frameworks to share the results of the research, both in terms of technologies as well as material, with ex-post sharing divided along geographic lines: the IARCs/NARS get the rights in the developing countries, and the private sector companies get it in the industrialized countries. The IARCs/NARS would then make it available to all in the developing countries.

This would be a different means of promoting the same objectives that the CGIAR has maintained for the last quarter century: science in the service of the poor and the environment, maintaining a free flow of germplasm and open access to knowledge. Different times require different means to pursue the same objectives.

The future: Designer plants!

If we project current trends in research we are not far from being able to create totally new species of plants, assembling their genomes from pieces of genomes, like a Lego set. This dramatic development will be possible in the next 25 years or so. The technologies that would make it possible to grow plants using briny (if not salt) water, in sand and having a high protein content for fodder is conceivable, but – under current trends – it is likely to be proprietary technology, owned by big multinationals. The question is what can we do to ensure that the new biotechnology revolution will benefit the poor and the environment?

Conclusions

If we do not challenge the contemporary models, if we do not shake ourselves out of our lethargy, we will be overtaken by events which will be largely driven by a dynamic private sector agenda that does not always coincide with the concerns of the CGIAR and the NARS to reach out to the poor and to protect the environment.

The future IPR regime and the thrust of the research agenda will be driven by the market-oriented forces of private investment.

We must complement the thrust of the private sector by bringing our talents to bear on the problems of the public goods and the market imperfections that require public intervention.

The way forward is to turn the rhetoric of partnership into reality. This will require the partnership of IARCs/NARS throughout their involvement with the cycle of research, joining with the AROs upstream, with the private sector at the transformation level and with the local private sector and the NGOs at the downstream level.

Clearly there will be interactions at all levels involving all the other actors, but this is intended to highlight the prominence of certain actors at certain parts of the seven steps of the research continuum that I described above.

Finally, these research consortia have to be built up in the next ten years or so. I believe that the way the developments in biotechnology are presently going, the big private sector firms will not be interested in the availability of exotic germplasm in 15 years or so, since combinatorial techniques at the molecular level will probably enable them to assemble genetic sequences and reconstruct genomes of particular species, if not invent entirely new species, without having to remain limited by transformation or conventional crossing of related species.

The new century is upon us. We need to dare to be bold and think in terms that recognize the changing landscape of contemporary science, the risks of the emerging scientific apartheid and the needs of the vast majority of humanity. We must have the means to provide food security for all in an environmentally and socially sustainable fashion.

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