FROM THE GREEN TO THE GENE REVOLUTION: BIOTECHNOLOGY AND THE INTERNATIONAL CENTERS

By Harvey Bialy

By alphabetic deletion and transposition, one may change *green* into *gene*. Similarly, designing a policy to effectively integrate biotechnologies into the International Agricultural Research Centers (IARCs)—the institutional embodiments of the green revolution—requires deleting aspects no longer productive and rearranging the remaining structure to make it more responsive to the rapid transformation of agricultural sciences by molecular biology.

Until now, however, the IARCs and their financial supporters, the Consultative Group on International Agricultural Research (CGIAR), have maintained an intellectual-property policy that barred the centers from acquiring the proprietary technologies of others or developing proprietary discoveries or technologies of their own. This "open-door" policy—more suited, perhaps, to the idealism of the 1960s and the green revolution than to the heady pragmatism of today's gene revolution—effectively prevented significant interaction with the private sector and therefore made any attempt to define a real biotechnology agenda an expensive academic exercise.

But September seems to have been the month for the dissolution of previously formidable ideologic monoliths. A policy meeting in The Hague—convened by the CGIAR Taskforce on Biotechnology and the International Service for National Agricultural Research—finally resolved this key issue in favor of the modern age. Although participants reached consensus on few other matters, it was clear that a policy acknowledging the obvious was due: some centers had already begun negotiating with the private sector. Now that the CGIAR is prepared to accept intellectual-property law, what are the other steps necessary to complete the transformation of green into gene?

The IARCs were formed *to benefit the countries of the south* in three ways. They were to be instruments to rapidly implement the best current technologies for increasing agricultural productivity, centers of education and research in which those technologies were adapted to local conditions, and to serve as custodians of the infinitely rich genetic diversity of the south's flora. The task, then, is to realign each of these missions with the opportunities presented by the gene revolution while preserving the successes and avoiding the mistakes of the green revolution.

The IARCs saw their most dramatic success in the production and distribution of high-yielding rice and wheat varieties. But these victories came at the expense of a trend to genetic uniformity and a heavy reliance on agrochemicals. These breeding programs are fertile fields for biotechnology's genes. Progress in plant transformation and the isolation of disease- resistance determinants is almost exponential. Biolistics, for example, can now be used to transform immature embryos of important indica rice cultivars (see the research paper by Christou, *et al.*, in this issue). With similar results for corn and wheat just around the corner, essentially every major mono- and dicot crop species will be amenable to direct genetic modification. And the list of desirable genes to introduce keeps pace. Coat-protein-mediated resistance to an ever widening variety of positive-strand plant viruses and *Bacillus- thuringiensis*-toxin insect tolerance are now joined by nucleocapsid-mediated resistance to negative-strand viruses and single-gene resistance to fungal pathogens (Goldbach, *et al.* and Schell, *et al. Bio/Technology*, in press). With the major practical impediment removed, the immediate transfer of these technologies through the IARCs should be in every way encouraged. Introducing such resistance genes into important local cultivars will not only result in substantial yield improvements, but, because extensive backcrossing is not required, will have a minimal negative impact on genetic diversity.

Other single-gene applications to increase yields are analogous to the green revolution's reliance on chemicals, and the wisdom of quickly adopting them is less obvious. A risk-benefit analysis of herbicide resistance, for example, is complicated by unpredictable ecological, economic, and political factors.

As research and training institutions, the IARCs have been noticeably less successful than as breeders. They have produced little in the way of original science and have the general reputation in their host countries of being isolated and elitist. The gene revolution's prescription is to take a large dose of plant molecular biology and an oath of reaffirmation of basic principles. The former will lead to gene discovery and properly position the centers to take advantage of coming advances in multi- and targeted-gene delivery systems. The latter will open the door to developing a spectrum of important local applications, from biofertilizers and biopesticides for farmers to useful transformation technologies for national centers.

But it is in their capacity as custodians of Third World germplasm that the IARCs have been most severely criticized, and it is in this area that the remedies of the gene revolution are most radical. The IARCs should begin to divest their germplasm collections. Turning them over to institutes in the client countries able to care for them would free the centers from the coming contention of how to deal with the complex proprietary issues of distribution, and, more importantly, allow them to focus on the gene revolution's germplasm equivalent, *maps and probes*.

The IARCs must invest significant resources in the construction of molecular genetic maps of the most improved cultivars. Germplasm collections need to be transformed into probe and sequence collections. The advances in gene isolation that will come, in part, from having a transformation-competent DNA library of *Arabidopsis* (see the paper by Ludwig *et al.*, also in this issue) will translate into valuable commodities as the genes determining complex phenotypes like drought tolerance are identified. The old Dutch trading companies properly appreciated the value of maps. Likewise, today's seed companies spend heavily to acquire map-making expertise and invest lion's shares of their R&D budgets in mapping projects.

Treating their maps and probes as proprietary property will permit the centers to enter these strategic projects as equitable partners. The disagreeable appearance of the IARCs serving as purveyors of Third World genes need not be repeated. The potential financial return of these mapping initiatives is so significant, the CGIAR would do well to host a few meetings with representatives of the public research institutions, companies, and client countries to develop appropriate policies.

The power of the gene revolution resides as much in its catalytic potential to integrate the world's economies as in delivering technological solutions to problems of hunger and disease. On this matter the CGIAR is finally smoking; it may yet catch fire.