REVIVING GLOBAL POVERTY REDUCTION: WHAT ROLE FOR GENETICALLY MODIFIED PLANTS?

MICHAEL LIPTON

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Poverty Research Unit at Sussex
University of Sussex
Falmer, Brighton
BN1 9SJ
Tel: 01273 678739
Email: pru@sussex.ac.uk
Website: http://www.sussex.ac.uk/Users/PRU

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Acronyms and Abbreviations

AIDS	Acquired Immunodeficiency Syndrome
CGIAR	Consultative Group on International Agricultural Research
CIMMYT	Centro Internacional de Mejoramiento de Maïz y Trigo (International Maize and Wheat Improvement Center)
FAO	Food and Agriculture Organization of the United Nations
GM	Genetically Modified
IFPRI	International Food Policy Research Institute
NARS	National Agricultural Research System
R&D	Research and Development
USAID	United States Agency for International Development.

Introduction and Outline

In the early 1960s famine caused 30 million excess deaths in China. India, rurally stagnant and having almost run out of spare cropland, barely escaped famine in 1965-66. New censuses, throughout the developing world, revealed a future of accelerating population growth. But crop research, its institutions, and its results responded. Despite some setbacks and huge regional gaps, global poverty reduction—and tropical food staples yields—advanced more in the twenty years from the mid-1960s to the mid-1980s than in the previous century.

The reduction of poverty was partly **caused** by the expansion of food staples production through poverty-orientated agricultural research. That was in substantial part made possible by Sir John Crawford's recognition of the need for institutional innovations, and his patience and energy in implementing and guiding them. That is why we honor him now.

But he would wish us to honor him, too, by realizing that, 28 years after the CGIAR began, a new thrust is needed. Over 800 million people still have too little to eat; many live from agricultures almost untouched by the Green Revolution. Food farming is increasingly dogged by water shortage and diversion. Most worryingly, since the mid-1980s progress against poverty has slowed down sharply, and so has progress in yields of main food staples in developing countries. This now crawls along at barely half the rate of growth, 1995-2020, of people needing work to afford food. Meanwhile, there has been slow, if any, increase in basic yield-enhancing crop research from public funds—while private research has exploded. This has meant that crop research is much less directed towards the food staples of poor people. The most promising potential remedy, based on new science—genetic modification of plants—is accordingly being directed more to the demands of rich farmers and their corporate suppliers than to the needs of poor people: chicken-feed before human food; tobacco before wheat; crops that resist not moisture stress but herbicides.

This lecture presents seven inter-related points.

1. The world's poor depend mainly on farm work for access to staple foods—and on higher yields of main food staples for prospects of escaping poverty. This was true when Sir John Crawford tackled the problem as a founding father of the CGIAR. It is true today. Despite urbanization, it will still be true in 2020.
2. World poverty fell fast in 1965-85—and fell most where, when and be-cause food-staples yields grew rapidly due partly to burgeoning *pro bono* agricultural research and in ways that created more workplaces. The trends have slowed to trickles since 1987, and the four slowdowns are causally linked.
3. There are new grounds for hope, because the fertility transition in South Asia—and recently Africa—means not only slower population growth, but also a rising ratio of adults to children. In East and Southeast Asia since 1965 these extra adults were productively employed, initially in the Green Revolution. Therefore the demographic 'window of opportunity' opened—and, indeed, explained one-third of the region's dramatic rise in income per person, and probably even more of its fall in poverty. The fertility transition has now spread to the heartlands of world poverty, South Asia and Africa, where the coming decades will see a sharp rise in the proportion of persons of working age. But this 'window of opportunity', for these areas to cut poverty, will open only if—as happened in East and Southeast Asia—the burgeoning adults find productive work and access to nearby, reliable food. Adequate, *affordable* and attractive workplaces initially require growth in agriculture (and in rural trade and construction, which rely on rising farm income and expenditure).

4. After 2000 as after 1960, such gains can be realized—and the flagging pace of poverty reduction revived—only if new science boosts *yield potentials* in tropical food staples, and thus output and employment, where the poor live. On their own the alternatives will not nearly suffice. It is cold comfort, for example, if 'there is enough food already to feed the world'. The hungry cannot get at it, except with extra labor income. That is created initially by agricultural growth.
5. Genetically modified (GM) plants can revive yield potentials in major food staples, and thus and otherwise address many problems of poverty and malnutrition. But that will not happen until GM research focus shifts: from *traits* such as herbicide resistance to higher yields and drought tolerance; from *crops* that feed chickens, to crops that feed people; and from huge, low-employment *farms*, to smallholders and farm laborers.
6. GM crops' potential to revive the stalled engine of world poverty reduction will not be fulfilled, unless the next few years see institutional innovation as radical as the development of the CGIAR system, to which Sir John contributed so much. The huge shift of crop science to the private-profit sector—alongside the growth of laws and techniques to protect private intellectual property rights—has created a situation very different from that of the 1970s for which the CGIAR was designed. Then, national and international public researchers had access to most agricultural knowledge of potential relevance to the poor's needs. Today, a growing proportion of knowledge is locked into a few giant GM firms. They do not yet face incentives to direct their huge resources against world poverty. Yet public research will wither if it demonizes or ignores these firms, and hence the vast bulk of GM science locked into them. There are two strategic options; the CGIAR requires to choose between them.
7. Much as we may dislike the arena of popular politics, scientists and economists need to shift the debate about GM foods, from today's sterile confrontation between commercialisers and critics, to serious review of the new institutions needed to achieve the anti-poverty potential of GM crops safely and swiftly. Today, the commercial lobby overstates near-term gains to the poor from GM science in its current, largely profit-orientated organizational structures. Meanwhile the anti-GM lobby overstates the risk from GM crops, and belittles the far greater risk of worsening nutrition in their absence. The critics dominate the media (almost as a notorious patent monopolizes transgenic cotton). They create dangers that GM crop science will be demonized, discouraged or disallowed—whether it inserts a gene for herbicide resistance that adds millions of dollars to glyphosate profits each year, or for beta-carotene that saves millions of children from blindness each year. The commercialisers meanwhile create dangers that the public sector loses access to leading scientists, and to the elite lines that its own research has made possible. Public agricultural research could wither away as it becomes unable to provide competitive varieties that raise and stabilize yields. If that happens, the engine of poverty reduction will probably stay stalled.

Point 1: The poor continue to depend on staples for income and progress, via consumption, prices, nutrition, employment, farm income, and overall rural income

(a) Food staples typically absorb half the *consumption* of people below the dollar-a-day poverty line. That will stay true in 2020. Local production affects staples *price levels* (though this will get less important if agricultural liberalization proceeds)—but, even more, *price stability* (which may well become more important). It is sometimes argued that higher crop yields, by cheapening food, will raise income mainly for urban net food buyers (Abler et al. 1995); but most of the rural poor in Asia, and in much of Africa and Latin America, are also deficit farmers or net food buyers.

(b) Food staples are the main source of *nutrients*, especially for the poor. This argues for GM staples with more vitamin A, iron, and (in goitre-prone areas, and if technically feasible) iodine. It seldom makes any case for GM crops enriched with proteins, or with, say, lysine; only in rare cases—in the absence of dietary energy shortfall—is nutritional adequacy, even among the poor, constrained by inadequacy of protein, let alone of a particular amino acid.

(c) More staples production is the most affordable source of *workplaces*. Employment and self-employment income provides poor people's main claim on food entitlements. Agriculture, mainly staples, remains the main source of employment for over 75% of developing world's rural people and over 8% of their urban people (and higher proportions of poor). Extra non-farm workplaces, even rurally, have higher capital and infrastructure costs than extra farm workplaces. **Table 1** confirms that, even in South and Southeast (S/SE) Asia, most people in 1990 depended mainly on farming for a livelihood; the proportion of low-income people that depended on farming was much higher. Yet poverty in S/SE Asia had fallen sharply in 1960-90 (**Table 2).** So it is not surprising that, on reasonable expectations about growth and poverty, even in 2010 half the developing world's people are projected to look mainly to farming for livelihoods. For low-income groups, again, the proportion will be much higher, partly because the investment and infrastructural costs per extra workplace are less, and partly because of the shift from own-account farming to hired farm employment. Extra cash crops will provide some of these extra workplaces, but most will come from food staples production—to meet demands out of higher incomes, many with still-underfed people, as well as from population growth.

However, more work in food staples production is attractive only if labor productivity grows. So, to advance self- and hired employment in the large and growing majority of rural areas in which arable land is scarce, agricultural research must raise output per worker, but output per hectare—i.e. yield—more, so work per hectare goes on rising. (We need not be concerned that this will bring 'labor shortage'. Workforces are still rising by some 2% yearly in the developing world to 2020; and 'labor shortage' just means that poor workers get more work each, and/or that their wage rises. There are, of course, problems about smoothing peaks and troughs of labor demand—problems that short-duration varieties, perhaps further assisted by gene transfer methods, can address.)

(d) More food staples output is a potential source of *farm income* growth in Africa. Despite the growing salience of hired work relative to own-account farming, the latter remains, in much of Africa and parts of Asia, a main source of income of the rural poor. Lipton and Longhurst (1989) and Kerr and Kolavalli (1999) showed that the green revolution did as much for deficit, poorer farmers as for others, and spread far into rain-fed areas—especially after the research emphasis shifted in the early 1970s from management-intensive, risky varieties suitable mainly for bigger farms, towards tougher varieties like IR-20. Analogous shifts in research priorities will be needed, if GM plant research is to yield similar gains for the poor.

(e) More food staples thus help the poor by raising *rural income*. Higher agricultural incomes also help the rural poor by stimulating non-farm growth (Adams 1999; FAO 1998). This is a big and growing part of poor rural people's income and employment—and is best stimulated by higher agricultural incomes and demand, especially if they come from higher incomes among smaller farmers and laborers (Hazell and Ramasamy 1991).

Poverty incidence remains much higher in rural than in urban areas (**Table 2:** Lipton and Ravallion 1995). So do *numbers* of poor in Asia and Africa. The rural-urban distance, in both intensity and incidence of poverty, has in general not shrunk in the 1980s and 1990s [Eastwood and Lipton 1999a]. Rural poverty will continue to show higher incidence, and almost certainly to affect many more people globally, than urban, in 2010 and probably in 2020. On normal assumptions this means that higher rural incomes are better designed to help the poor than higher urban incomes, especially since intra-urban distribution is usually more unequal than intra-rural.

Better rural incomes may even be best designed to help the *urban* poor (by reducing rural-urban migration—and thus competition for urban workplaces and homes—and the need for urban-rural remittances). Moreover, even in urban areas (both small rural towns and megacities), some 8-12% of people mainly depend on agriculture for work and income; the proportion of the urban poor so dependent, and hence unambiguously gaining from higher food yields as their food deficit declines, is probably much higher. Hence agricultural employment increases may directly help the urban poor. In India in 1957-92, growth in rural consumption or in agricultural production substantially reduced rural *and urban* poverty. Urban consumption growth brought some benefits to the urban, but none to the rural, poor. Industrial growth did little to reduce urban or rural poverty [Datt and Ravallion 1996].

Point 2: 1965-85 saw huge falls in poverty based on rising food yields, employment, and public agricultural research effort; all four have stalled since 1985-90

(a) Poverty declines. The sharp retreat of absolute income poverty in China, (especially in 1977-85), in Indonesia (where it halved in two successive decades), and elsewhere in East and Southeast (E/SE) Asia is shown in **Table 2**. Perhaps less widely known is the progress in South Asia. In what Inderjit Singh has called the 'great ascent', the proportion below the national poverty line in India—after fluctuating around 55 per cent from 1951 to 1975—then fell to around 35 per cent in the late 1980s. Progress in Latin America was concentrated in 1966-80, with slight retreat thereafter. No progress, indeed some worsening, in income poverty characterized most of Africa until recently, but even there health and education indicators improved sharply [Lipton and Ravallion 1995].

There were thus huge, historically unprecedented downtrends in poverty in many developing countries, though with somewhat different timings, within 1960-85. The subsequent slowdown also showed different timings—the late 1970s in Latin America, around 1985 in China, around 1990 in India—but clearly the proportion of people below the dollar-a-day poverty line in developing countries fell very slowly between 1987 and 1998—from about 28.7 per cent to about 24.3 per cent. The proportion remained almost unchanged in sub-Saharan Africa (46 per cent) and Latin America (15 per cent), and continued to decline sharply only in East Asia (27 per cent to 15 per cent) (**Table 3**).[1]

(b) Causes of poverty decline and its slowdown. Most evidence suggests that about half of the international variance in poverty (or its decline) is associated with variance in average real income (or its growth) [Lipton 1998]. However, as we have seen, not all growth is equal; for reasons of employment generation, food price moderation, and poverty location, rural and agricultural growth is better at reducing overall, and probably even urban, poverty *in mainly rural countries with many poor*. There times, and areas, of more staples yield growth are likely to feature faster poverty reduction.

Why did poverty declines slow down after the mid-1980s? In 1965-85, poverty reduction was based largely on agricultural progress. Only a few countries, mostly in E/SE Asia, managed to segue smoothly from basing poverty reduction on labor-using technical progress in agriculture, to basing it on fairly rapid and often export-orientated non-farm growth with a sharply increasing and widely-spread base of skills; such sequencing required not only carefully phased trade liberalization and cautious macro-economic management, but also an earlier base in mass, effective education and literacy. Not only the less-difficult sector for reducing poverty (agriculture), but also the less difficult regions (Punjab, Aceh, SE China), ecologies (water-controlled lowlands) and ethno-linguistic groups (mobile majorities) got out of poverty first—leaving the harder tasks for later. However, falls in growth of food staples yields, in extra

[1] Recent analysis by Dr. raghendra Jha shows that India's rapid economic growth in 1992-7 did far less to reduce poverty than did the slower (but stll significant) growth of 1975-89.

employment per unit of extra output, and hence in employment-based access to local food staples, played a major part in the slowdown in poverty reduction.

(c) Staples yield upsurge and slowdown. The trends are shown in numbers in **Table 4**, and in graphs for cereals in **Table 5** and for roots and tubers in **Table 6**. The turning points vary among regions and crops, but the 'total cereals' and 'roots and tubers' yield trends for developing countries shows clear flattening from the mid-1980s (as do main staples crops individually).[2]

(d) Causes of rising and flattening yield trends. The substantial improvement in yield trends of food staples yields in much of the developing world around 1961-85 took place in face of downtrends in world prices of staples, relative to manufactured goods and farm inputs. The main reason for the rise was the availability of land-saving, cost-cutting technical progress in the form of dramatically improved varieties of wheat and rice, and to a lesser extent other staples.

Why the deterioration in staples yield growth from the 1980s? There are many causes. Price trends continued unfavorable. Second, staples production was extended into more marginal areas, reducing average yields (and their sustainability). Above all (and crucially for the need to develop a new source of yield growth such as GM plants might offer), while the more readily available yield gains from dwarfing were achieved first (leaving new gains progressively harder to find), there was a necessary shift from yield-enhancing to yield-protecting research, because:

- Pests responded, to varieties with high but single-gene resistance, not only by developing new virulent biotypes (which in turn provoked breeders to counter-attack with newer high-yielding varieties) but tolerant biotypes of each of many pests, each type taking too little of the crop to justify searching for new sources of crop resistance, but together depressing yields.
- High levels of macro-nutrient fertilization and yields caused and exposed micronutrient depletion; and when one micronutrient constraint (say zinc) was removed by further fertilization, another (perhaps manganese) began to bind.
- The prospect of high yields, and short-duration varieties permitting double- or triple-cropping, provoked further competitive private water extraction, especially of groundwater, lowering the water table.

Not only was varietal research necessarily switched from enhancing to defending yields; there was a slowdown in public-sector research expenditure for developing countries, on which staples yield growth there—especially but not only for self-pollinated crops—critically depends. Such expenditure fell absolutely and sharply from the early 1980s in sub-Saharan Africa and Latin America, and there was stagnation after 1986 in CGIAR funding—which was also heavily redirected from plant breeding towards other priorities.[3]

[2] Data are best fits (in logs) to a time-trend for exponential growth between the dates at the start and end of the period. Several dates were tried, and two sets are shown that avoid start and end years with sharp 'blips' due to isolated variations in climate or relative prices (even with a least-squares fit, such years 'draw' the regression towards extreme start or end values, leading to perhaps unduly high or low beta estimates). Data for specific crops are available on request; note that, contrary to what is often said, maize is not an exception to the rule that developing countries as a whole showed a flattening of yield growth in the 1980s.

[3] CGIAR spending is only 4 per cent of all agricultural research outlay in and for developing countries, but it counts for much more—partly because the NARSs depend heavily on CG-generated germplasm for their own adaptive breeding, partly because CG expenditure is increasingly coordinated with (or done alongside) NARSs, and partly because a large and growing part of NARS's work, especially in Africa, is severely harmed by low and fluctuating funding, of which an increasingly excessive share must be devoted to salaries and wages with minimal material research support..

(f) Employment and yields. for wheat and rice, an extra 10 per cent of yields in the mid-1970s in the developing world typically meant an extra 4% of workplaces. By the late 1980s it meant typically only 1-1.5 per cent [Lipton with Longhurst 1989: 111-4]. So not only is faltering yield growth reducing cheap, accessible local food staples growth. For each unit of extra yield, there is less extra labor income to enable poor people to buy the extra food.

The leveling-off in growth of yields, and thus in growth of farm employment, is a main cause of the slowdown in poverty reduction. So it is natural to ask whether, by GM or otherwise, agricultural research can revive the employment-intensive growth in food staples yields in developing countries.

Point 3: Fertility transition opens a 'window of opportunity' to complete the task of eliminating food poverty

(a) Must researchers hoe the poverty/staples-yield row forever? There are, however, two ultimate limits to attainable yield growth in food staples. On the supply side, the sources of yield growth in the last 50 years—heterosis, then dwarfing, now gene transfer—ultimately face land, water, and sunlight ceilings. 'Ultimately' is a long time, but each approach to a static asymptote carries rising cost. On the demand side, *only up to a point* will low-income groups opt for poverty reduction via new workplaces in growing tropical food staples, even if higher yields make it more attractive to employ or self-employ these workers. As SE China and Malaysia shifted from agricultural growth to industrial growth, they ended first food poverty, then much moderate poverty. This can turn low-income countries with many food-poor, into middle-income countries with few food-poor, but carries us only that far. In Britain or the US, even in Uruguay or Thailand, even the worst-off 20% are not so poor that they cannot eat properly, nor so needy that they demand work in agriculture even if they get no more than, say, 1.5 times their family's basic needs. Also in these countries when income rises, even among the poor, they do not consume much more food staples.

Since neither supply of research to sustainably raise staples yields, nor demand of even low-income groups for farm work and calories, is limitless, agricultural researchers—having twice responded to the challenges of world poverty reduction, first with maize hybrids, then with rice and wheat semi-dwarfs—can reasonably ask for some assurance that this third request, to pull the remaining 800 million out of hunger, will be the last. If GM research is turned round—properly restructured to meet their basic nutrient needs through a 'third round' of higher, more stable and more widely spread staples yields—will that be the end, so that researchers can escape diminishing returns by moving to different and in the long run more manageable tasks? Or are the food-poor always with us, always increasing, always seeking more farm jobs and staple foods, and ever less researchable, or less sustainable, rises in staples yields from scientists?

Some reassurance is provided by the huge reductions in Latin American poverty around 1965-81, and in Asian poverty around 1970-89. But dramatic progress in yields remains largely limited to wheat, rice and maize, and to reasonably reliably watered areas—despite serious research for other agro-ecologies and food staples (more in the CGIAR than in many national systems). Africa—where the poor's main crops are millet, sorghum, cassava, yams, and white maize, usually in ill-watered areas—remains little affected outside a few growth islands.

(**b) The 'demographic window' for GM-based yield growth to end food poverty.** There is a more important sign that 'one more heave' from agricultural research, if it can raise yields over a wide area, can virtually end food poverty—by providing income from labor-intensive farm work to just two more generations of the poor (**Table 7**). China's fertility transition is almost complete. South Asia's is well advanced**—**India's total fertility rate (TFR) fell from over 6 in 1951 to just above 3 today. Also, Africa's long-delayed fertility transition is under way. Of the African countries with acceptable data, nine have seen moderate to large falls in TFRs of 1.5-2 or more in the last 20 years (Kenya, Rwanda, Zimbabwe, Botswana, S. Africa, Cote d'Ivoire and Senegal), with smaller falls (0.5-1.5) in thirteen more.[4]

Why is this a 'window of opportunity', suggesting that a third, perhaps GM-based, upsurge in labor-intensive staples yield growth can permanently end the severest forms of food poverty? National cross-sections, based on household survey data, suggest that in the 'average developing country' a reduction in birth-rates of 4 per 1000—typical of what developing countries achieved in the 1980s—lowers poverty ten years hence from 19 per cent to 14 per cent (the falls being about equally divided between the effect of higher growth and of more equal distribution) [Eastwood and Lipton 1999b]. This raises the real prospect that by 2050-2060 the growth in need for dietary energy—and, among the poor and hungry, for more farm work, made attractive by ever higher yields, to earn it with—will stop.

Not only does this pending demographic shift mean that the third, GM-based, thrust to higher sustainable food yields may be the last we need. As excitingly, the shift means an improving ratio of adult workers and savers to dependent children. In 1960-95, East Asia's rising ratio of adult workers and savers to dependants added about 1.3% to its yearly rate of growth; this will happen in South Asia in 1995-2025 [Bloom and Williamson 1997] and in Africa in 2000-2035. The balance among age-groups will be revolutionized in 1995-2025. In Bangladesh, under-fifteens will decline from 40 per cent to 25 per cent of persons; numbers of working age (15-64) will rise by 82 per cent, while under-fifteens decline by 4 per cent. In Kenya in 2000-2020, the UN's 'medium variant' projects population growth in 2000-2020 at 2.2 per cent per year, from 30.3 million to 47.0 million. But children under 15 will increase at only 0.9 per cent per year, as against over 3 per cent for prime-age adults (15-64). Thus the ratio of prime-age adults—the main workers and savers—to children will rise from only 1.24 in 2000 to 1.87 in 2020.[5]

But the demographic window opens on sunlit uplands only if, as happened in East Asia in the 1970s, rapid staples yield growth permits more attractive workplaces for the extra workers, savings prospects for the savers, and affordable food for all—i.e. if farm research (and reasonable policies) attract the workers to work, and the savers to save. The gains but will be realized only to the extent that public policy permits and creates options for people *rewardingly* to convert potential into extra production per person. In particular, the anti-poverty benefits of demographic transition will be realized only to the extent that public policy stimulates the labor-intensive use of resources in ways that create income-based entitlements to reliable, affordable and locally available food staples.

Point 4: The 'window' is useful only if yield potential revives for tropical food staples

(a) Despite words of false comfort, tropical food staples output growth must revive. There is an odd similarity between three messages wrongly taken to imply that we need not or should not worry about reviving output growth in tropical food staples, because there is and will be 'plenty of food to feed the world'.

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[4] Malawi, Tanzania, Zambia, Cameroon, Burkina Faso, Ghana, Benin, SW and NE Nigeria [Cohen 1998: 1431-5, 1454-61], N. Sudan [Cleland et al. 1994], and for women aged 15-34 in Namibia, Niger, Madagascar and Uganda [Kirk and Pillet 1998: 5]. Only Mali shows no fall; this is also claimed by Cohen [p. 1435] for Madagascar and Uganda,, but the Demographic and Health Surveys—the reliable source of most of these data—show falls in TFRs per woman aged 15-34 of, respectively, 0.9 in 1978-92 and 0.6 in 1971-88 [Kirk and Pillett 1998: 5].

[5] See [UN 1998b: 501]. Kenya has still a high total fertility rate, but exhibits one of the faster declines in Africa. One reason for choosing Kenyan projections is that the 1996 data are corrected to allow for the impact of AIDS. Unfortunately country-specific age-structure projections from the later (1998) UN revision are not yet available.

- The first is the message of demographic analysts [e. g. Dyson, National Academy of Sciences 1999]: world population growth has peaked; Asian and even African fertility transitions (with their rising adult/child ratios) are well under way. So (even if 'food security for all' ever *was* constrained by the size of the 'pile' of global or even national food staples vis-à-vis the population, which is doubtful), that will not be a problem in future. 'Malthusian optimism' is misconceived because the problem is entitlements [Sen 1981].

- The second is the message that staples markets work, and will, on present trends, equate staples supply and demand at affordable prices even for the poor (except perhaps in Africa) for the foreseeable future [Mitchell, Ingco and Duncan 1997].

- The third is the message—often stated by those who deny that GM plants are a tool for poverty reduction—that there is plenty of food to 'feed the world' and all we need to do is improve its distribution. It is often added that increasing food supply by intensive, especially large-farm, agriculture—as is allegedly implied by GM development—will make the rich richer, will not help the poor and may make them poorer, and will endanger the environment.

These messages contain elements of truth, but are one-sided, and do not reduce the need for employment-oriented, yield-raising research into tropical food staples:

- *The demographic message*: Malthus understood, and wrote, that population and workforce growth harmed the poor mainly by depressing their wages and keeping staples prices high. Correspondingly, demographic transition will provide enough food for the poor only if they acquire enough extra work to earn 'entitlements' and local, affordable staples [Lipton 1991]. If staples output does not grow, the extra workers per dependant will be underemployed, underentitled and therefore underfed. Also, poor people and workers enjoy mortality declines (and female education) last, and therefore reduce fertility last. Thje therefore remain especially vulnerable, for longer, to failures in employment-based entitlements to food staples.

- *The market message* asserts only that staples will be supplied to meet *demand*, not to meet *need*. Projections for IFPRI's '2020 Vision' [Rosegrant et al. 1995] show desperately slow reductions in global undernutrition in the wake of market-only development, unless there is a revival in investment and public research. Staples markets also have little relevance to many poor people in non-liberalized economies, or in areas (including much of Africa) where transport costs impede long-distance food trade.

- *The distributive message*: the more redistribution, and the more growth, the poor can get, the better. Labor-intensive rural growth can sometimes be redistributive too. But pro-poor redistribution is always limited by political possibility. There have been few cases lately in which the poor have gained durably from major redistribution of formal access to food, except in circumstances such as those of China in 1977-85, when radical land redistribution to family farms was feasible *alongside rapid, small-farm-favorable, employment-intensive technical progress* and reduced repression of farmers' prices.

All three messages—demographic, market, distributive— are too optimistic about poverty trends *without* revived cereals output growth, because the messages take too little account of three things. The first is the gradually falling availability of water to agriculture—as irrigation systems decline, as new ones become more costly and yield less, and as water is diverted to urban and industrial uses. The second is the growing diversion of cereals from food to feed, as rich people's incomes grow. The third is that, over time, each unit of farm growth is producing fewer workplaces—even though much more than other sources of growth.

This is not to deny that demographics, markets and redistribution can help the poor. It is to assert that their range is often incomplete, slow and imperfect. It remains vital to reverse the slowdown in staples yield growth, and the locking into private monopolies of the secrets of its renewal.

(b) Tropical staples output growth will not revive unless yield growth does. There are fewer and fewer areas, even in West Africa or South America, where 'spare land but scarce year-round labor' is a convincing diagnosis. So more staples output and employment increasingly means higher yields. Moreover agricultural research, planned now, may take 5-15 years to produce results (though GM, if applied, speeds this up). In ten years, workers per unit of farmland in most developing countries will have risen by over 20 per cent. Whether those workers occupy farmland, or move to towns (which expand into farmland) and demand staples from others who occupy it, its scarcity will rise. Research designed today must concentrate on raising yields, in most of the developing world to allow for today's land constraints, elsewhere to allow for tomorrow's. That means higher yields.

I was one of many who in the 1970s, observing the adoption lags among smaller and poorer farmers and in rain-parched areas—and the often input-demanding, management-intensive and risky nature of the earlier HYVs—advocated a shift from yield improvement as a research goal to yield stability and spread. The CG institutions had seen that point well before I did. By 1972 improved resistance to moisture stress was defined in its Annual Report as IRRI's main task. The farmers were there even before the researchers; rice varieties like IR-20 and rust-resistant wheat semidwarfs spread to rain-fed lands beyond their initial target area [Lipton and Longhurst 1989]. Also researchers, seeing varieties attacked by a range of new pest biotypes, turned towards defensive, yield-maintaining breeding. As regards wheat yield for the period 1950-86, the green revolution was the culmination of an era in which wheat breeders achieved rapid increases in yield potential accompanied by higher yield variances—but the later post-green revolution era saw slower mean yield growth but relatively rapid improvement in yield stability [Traxler 1995]. This confirms recent work by Byerlee [19xx], showing that the rising yield instability for Indian wheat in the early green revolution—identified by Hazell from 1982 [e.g. Hazell 1987]—had been reversed. There is also evidence that in the later years, for rice as well as wheat, yield gains came increasingly from shifts to new areas, and less and less from growing yields in given areas.

Without resiling from the case for shifting to stability and spread in 1970, I think *the numbers now show the clear need for a shift back to emphasis on yield enhancement*. This will mean enhancing yield *potential*. It is a myth that yield can be substantially enhanced without higher yield potentials from new science—that stupid farmers or stupid extension systems are failing to use safe and economic innovations 'on the shelf'. They are on the shelf for good reason. The old mantra—earlier ploughing, Scotch carts, massive manure additions and all that—have been uselessly preached at African farmers for decades, as contour bunding once was in India. The gap between yields in farmers' fields and the *economic* maximum yield in most of Asia is now small. In Africa the gap is often larger, but real risks, inappropriate fertilizers, and access, transport and marketing problems prevent sensible farmers from raising yields. The reason farmers reject manuring, early or no tillage, etc. is that they do not pay with low-yielding germplasm. Governments can persuade farmers to approach closer to static yield potentials by correcting price biases against agriculture (but most of that has been done) and by building more rural infrastructure (but that is increasingly costly, the most cost-effective being usually put in first).

In brief, yield potential—and economic optimum yield well below it—are asymptotes. If yield potential rises only slowly, so, sooner or later, will farmers' yields. And yield potential has risen disturbingly slowly for main staples since the mid-1980s at least. Alarmingly, this is most strongly the case in lead areas.

This is in part because—while public-sector NARSs declined in real terms in Africa and Latin America in the 1980s and one awaits the 1990s figures with trepidation—the CG system has experienced 'mission creep' without the resources to finance its new missions. CGIAR investment in increasing productivity fell steadily from 74 per cent of outlay in 1972-76 to 46 per cent in 1992-96 and 39 per cent in the latest year, 1997-8 [CGIAR Secretariat, pers. comm., 1999]. The CGIAR's crown jewels—germplasm enhancement and breeding—fell from an already severely attenuated 24 per cent of their outlay in 1992 to 18 per cent of much the same real outlay in 1996 [Anderson and Dalrymple 1999: 12].

This is not to deny that the new tasks imposed on the CGIAR system are laudable. Spending on 'protecting the environment' and 'saving biodiversity' rose from 6.5 per cent of CGIAR outlays in 1972-6 to 17 per cent in 1997-8 [CGIAR Secretariat, pers. comm., 1999]. But with CG funding static in real terms, and increasingly tied up in special projects, such trends are bound to mean absolute falls in the system's capacity to revive yields, and indeed to maintain security against biotic and abiotic stresses. *'Mission creep' without funding creep protects neither the environment nor the poor. Rather, it contributes to the bleeding of lead science out of the public sector, and the accompanying and worrying sluggishness of yield potentials, and hence of yields, in tropical food staples. Unless this is redressed, more marginal lands will be overcropped, and more poor people underemployed.*

Point 5: GM plant research is a key tool for breeding to improve staples yield potential, stability, spread, sustainability and employment—but is not being used well

If the yield potentials of tropical staples—and their field yields—are now growing at more normal rates, historically speaking, than in 1965-85, it is very unlikely that this is because scientists, any more than extension workers or farmers, are making silly mistakes. But what is to be done?

Crops derived from gene transfers went commercial in the USA only in 1994, and in 1999 were found in over half the US's processed foods, and globally were planted on over 70 million hectares (up from 25 million in 1998: C. James, pers. comm.), including most US maize and soybean plantings. There appears to have been no health or environmental damage *directly* linked to GM crops, and the scientists with whom I served on the Nuffield Committee [Nuffield Council 1999] appeared to concur that there was in principle no difference between possible environmental and health problems from GM varieties and those from others.

While over 90 per cent of GM crops are grown in the developed world, this is changing. China has substantial areas under GM maize, rice, cotton, and until recently tobacco. Argentina has several million hectares under GM crops legally, and Southern Brazil illegally. Farmers and consumers are still voting with their purses for GM crops (though this may change). Also, the technology has shown the power to insert genes for many purposes, from increasing beta-carotene[6] and iron absorbable by humans, to killing targeted insects, to rendering a crop immune to specific herbicides. Characteristics depending on many genes, such as resistance to moisture stress or yield potential, are much more complex to modify through gene transfer. However, this can insert, into a plant type grown in a particular ecosystem, genes from outside that plant type—as Borlaug did when he crossed rye (for cold-tolerance) with wheat (for yield potential) and produced triticale, and as all wide crosses do, but with more 'width' and (to the extent that gene functions become known) more accuracy. Perhaps latency at the time of anther formation might be transferred into maize; perhaps much higher yields might be transferred into robust coarse grains hitherto adapted to survive at low yields in adverse environments. No wonder Conway [1997] argued that GM crops might well raise yield potential, and field yields, in just those difficult, low-progress areas least touched by the green revolution.

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[6] Xudong Ye, S. al-Babili, A. Kloeti, Jing Zhang, P. Lucca, P. Beyer and I. Potrykus, 'Engineering the Provitamin A (beta-carotene) biosynthetic pathway intoo (carotenoid-free) rice endosperm, *Science*, 287: 303-305, 14 Jan 2000.

Nobody, certainly no economist or other unnatural scientist, knows what GM plants can do to cut world poverty by providing tropical food staples with faster-rising yield potential, more robustness, more amenability to small farms and labor-intensive use. But if the duck we are shooting is the third great breakthrough of the century in tropical staples—after maize hybrids and wheat and rice semidwarfs—then GM plants quack plausibly, and are the only duck on the block.

But GM research, which may well have enormous potential to reduce malnutrition and poverty, is being largely directed by people for whom the employment-intensive enhancement of yield and robustness in main food staples, especially if grown by poor farmers who can retain seeds, can never be a main motive. GM research is therefore being steered to crops, traits, and types of farm that are not very relevant, and that may sometimes be harmful, to the poor. A related set of problems was tackled in the 1960s and 1970s as international and NARS breeding priorities changed to accommodate the critics of early 'museums of insect pests' like TN1 and even IR8 rice, best suited to the needs of big farmers. But at least these were already food staples. It will need a different approach, and institutional innovation, to tackle today's problem due to the privatization of so much agricultural research—and knowledge.

To explore this approach, we need to ask what it is about the products of GM crop development that fails to benefit the poor in developing countries. The answers, and the exceptions, will point to the reasons, and the possible solutions. In general three things about *within-GM priorities* are inappropriate for poverty reduction: crops, traits, and target users.

Crops: three crops still dominate GM plants in the field—maize, soy beans, and cotton.[7] Unfortunately the yellow-maize varieties and the soy beans, grown with GM, are almost all fed to animals rather than being used as staples for poor people. In general, commercial GM seed suppliers will show little interest in self-pollinating crops unless they can protect their IPRs.

Exceptions: Rice may become a massive exception to the rule that GM research does little to cheapen or improve the staples grown and eaten by the poor. That is due to Chinese researchers, the Rockefeller Foundation, the Swiss reseacrh on beta-carotene-enriched rice, and the recent transfer by John Innes Institute of the wheat-dwarfing gene into rice. It remains to be seen, however, whether these public efforts—still small beside the GM budgets of the Big Five for animal feeds—suffice to achieve major breakthroughs applicable over large areas, or to rice with currently low or unreliable yields.

Traits: the trait most widely spread by private-sector plant GM research is <u>herbicide resistance</u>. Relatively to higher yield or greater robustness under moisture stress, this is a very low priority for the poor. Absolutely, it displaces labor—especially if used to permit no-till farming [Naylor 1994]—and (except in some impoverished uplands where herbicide is unlikely to be used) adds little to yields. <u>Insect resistance</u> via a gene to express Bt toxin is the second main trait inserted; this or analogous traits would, if inserted into appropriate crops, raise small-farm yield and create productive (harvest) employment, but single-gene resistance, especially if it destroys the attacker, notoriously induces new pest biotypes and poor farmers are not best placed for swift response. <u>Shelf life</u> and other high-end quality features (as in FlavrSaver tomatoes) also typify the GM traits produced responsively to the demands of the well-off.

Exceptions. What poor farmers do want is genetic modification to raise yields, or to permit good plant types to grow in formerly recalcitrant environments. The few striking examples of GM carrying these traits come mostly from the public sector—Fan Shen yield-enhancing rice hybrids in China, with Rockefeller support; insertion of citric acid secreting genes against aluminum toxicity into Mexican wheat; and of

[7] Tobacco is another significant GM crop (only partly for experimental reasons relating to transferability of traits). I am sometimes asked whether GM crops pose health hazards. I refer such questions to real scientists, but add that one such crop must qualify. If you become addicted to cigarettes based on GM tobacco, you have a 1 in 6 chance of dying as a result. That is also true for non-GM tobacco.

virus-resistant genes into Colombian potatoes and Kenyan sweet potatoes. Rockefeller/Swiss beta-carotene (and perhaps iron) enriched 'golden rice' has characteristics of huge value to millions of children at risk each year of blindness from Vitamin A deficiency (and to pregnant women endangered by anemia) but it will be important to turn these consumer gains into active consumer demand, if farmers are to face incentives to adopt such GM varieties.

Targets: commercial researchers and suppliers of GM crops aim, rightly, to meet market demand, and to select farmers who are readily able and willing to transport and pay for inputs, preferably with scale economies and avoiding dealer costs. This strongly targets large, and therefore seldom labor-intensive, farmers and by-passes most small farmers (and most of their landless employees). These access advantages of the large farmer in obtaining (normally private-sector) GM seeds are much likelier to be long-lasting than were the advantages she enjoyed in the first green revolution (initial capacity to take more risks and obtain credit for seeds).

Exceptions: even in developing countries (Argentina, Brazil), adopters of GM crops have been mainly large farmers, often seeking herbicide-resistant crops and (presumably) displacing weeders, human and/or rotary, with Glyphosate. China is probably an exception, dominated still by fairly equal family farms, though the distribution of GM crops by farm size is unknown. And if Rockefeller's 'golden rice' is fed into the system via the CGIAR and NARSs there is no reason why it should not be as welcome on small farms as on big.

Point 6: Proper application of GM on plant research to help the world's poor requires radical institutional innovation in agricultural research

Several things are also inappropriate to poverty reduction about the *public environment for GM development*. Above all the corporatization of property rights in plant materials may threaten both farmers' lines and international and national public agricultural research, and increasingly lock elite lines into private quasi-monopolies, eroding the competitive viability of public and farmers' plants alike. Yet some such corporatization may be needed, to create incentives for the 90% or more of GM plant science now in the private corporate sector.

The problem is that GM development appears to be the most promising route to staples yield enhancement for poverty reduction—yet is locked into a system where it is not used for such purposes, and where a few large firms are competitively bound to protect their investments by means that, at present, threaten public research. Attempting to outlaw or demonize either GM science (an absurd though popular undertaking) or the huge number of top-class scientists seeking to practice it privately, will get nowhere. So how is the demise of competitive and public action for world poverty reduction to be avoided?

Current privatizing and lock-in trends range from patenting, via F1 hybrids that rapidly lose vigor if kept by farmers for re-use, to GURTs, 'traitor' technologies or chemical activators.[8] Where there is competitive public and private supply, these methods need not threaten small farmers (or poor consumers). These, long before GM, did very well out of privately but competitively developed and distributed maize hybrids in the USA. Also, there is no persuasive evidence that the lock-in technologies threaten farmers or environments directly.[9] But the increasing monopolization, and the impending protection by a wide range

[8] The voluntary abandonment by Monsanto of plans to develop one of the four currently patented ideas for a v-GURT—which can be rescinded at any time—is a welcome response to critics, but does not make much difference to the development and use of a range of technical lock-ins as and when profitable.
[9] If the v-GURT gene is dominant it could in principle cross-pollinate with non-GURT plants and reduce their germination rate, but the number of such occurrences would be relatively small—probably not

of technologies, of specific elite traits (hardware) does appear to threaten, albeit gradually, 'the demise of public-sector research' [Swanson and Göschl 1999]—and of competition from other private seed suppliers—as a succession of leading-edge varieties, embodying progressively further advances from other varieties with elite traits, is developed, based on locked-in hardware, by the Big Five or their even fewer successors.

Are the losses due to reduction in competitive public and private research, in the wake of protection of GM plants via IPRs, outweighed by the larger volume of research induced by such protection? The incentive from IPRs, legal or technical, demonstrably raises the amount of private research, as the expansion of private wheat research around the 1970 UPOV legislation showed [Pray and Knudsen 1994; Swanson and Göschl 1999]. But 'technical IPRs' such as GURTs create property rights that accrue to, and encourage research by, only final developers. Incentives do not reach originators—whether the farmer-researchers who selected seed over generations, or the NARSs and CG institutions that developed it and passed seed (usually free) to private researchers. It is far from clear that providing the latter (via GURTs or otherwise) with total 'appropriability', and downstream breeders with none, is economically optimal—or even tenth-best—even on simple efficiency grounds, i.e. leaving ethics, income-distribution and externalities aside for a moment.

Is it really an efficient system of plant breeding incentives, if the final researchers in such a vertically integrated R and D system appropriate (say) 70 per cent of selection-effort value free, add 1-30 per cent of value, and then obtain the rights, by law or technology, to collect economic rents on 100 per cent by value? In this context it is relevant to recall that the CGIAR (presumably CIMMYT) originated germplasm in over 40 per cent of North American and Australian wheat in early 1990s [Byerlee, pers. comm].

The selective development and use of increasingly enforceable and 'technified' IPRs, often defined widely and encompassing others' intellectual property as well as one's own, has an even more serious effect than these possible efficiency distortions. As elite lines are locked in, public research is gradually squeezed out, despite its high returns [Pinstrup-Andersen 1985; Alston et al. 1998], *and despite its unique incentives to work on items that serve many countries, poor and dispersed farmers, and remote areas.*

Swanson and Göschl [1999] argue that—because it is in developing countries that seed companies are least able to enforce patents—techniques such as GURTs should induce 'a disproportionately greater increase in R&D expenditures on varieties suitable for use in developing countries', and this would apply to any enforcement, legal or technical, of IPRs that could be successfully implemented in such countries. It might indeed work for big, rich, low-employment farmers in S. Brazil and N. Argentina. But it would not induce them to grow food staples, to be labor-intensive, or otherwise to benefit the poor; nor would it address the mass of farmers in developing countries. It is not just low appropriability of seed benefits that renders such farmers unattractive targets for a big private input supplier; it is that they are often costly to service, because often tiny, diverse, risk-averse, hard to reach, illiterate, or hard to deliver to and recover from. Such features are inelastic to GURTs or even patents. The composition of seed research will become much less pro-poor of public and small-scale private competition is eroded by the monopolization of GM traits with technically enforced IPRs.

Moreover, though in the developed world private-sector research increasingly swamps public-sector, the reverse is still true in the poorer countries of Asia, and in Africa. They, especially their poor, would lose out from the competitive demise of public NARSs there, denied—like the CG system—the cost-cutting

noticeable among the many cases (and causes) of non-germination. Further, obviously, dominant inherited non-germination is self-eliminating—the reverse of evolutionary selection! Indeed, GURTs should reassure those who—surely wrongly—regard genetic drift from bred varieties to other plants, including those of related species (e.g. from herbicide-resistant rape to wild radish weeds), as somehow more dangerous from GM varieties than from other varieties.

GM varieties that had been developed and corporatized out of its free germplasm. And in Asia or Africa the extra volume of private research might not equal the lost volume of gains from public research, quite apart from the lost distributional benefits of the latter.

These trends have worrying implications for the poor. GM staples present a major prospect of helping them through revived food staples yields. But who will be concerned with future research to enhance the nutritional quality of food staples, or the resistance of African maize cultivars to moisture stress? Even if the scenario of 'demise' of public agricultural research is far-fetched or very long-term, will not the growing rewards of plant breeding in the patent- or technology-protected, monopolizing firms—alongside the fall in such work in the CG system and many NARSs—increasingly deplete the public sector of leading-edge, GM-related scientific skills? Is that not bound to accentuate what needs correcting: the systematically wrong traits, crops, and farms emphasized by purely profit-seeking research; the huge incentives to turn public goods into private ones; the grotesque concentration of GM research, as of medical research, on the often peripheral preferences of the wealthy, to the neglect of public goods as well as of the basic needs of the poor?

What remedies exist? NARSs or international public agencies could themselves secure patents (as the CG is considering), or even GURTle or otherwise technically lock in their releases (a course that the CG has rightly rejected). Either course would level the competitive playing field between public and private sectors, but would defeat some of the objectives of having public research at all.

Assuming the CG follow its traditions, and seeks public-access development of the GM plant science to serve the needs of the poor in the developing world, there appear to be two strategic options.

One is to work with the half-dozen developing-country NARSs with substantial GM research capacity to design and finance a major expansion around agreed crops, regions, traits, and types of farm target. This is attractive, but big money may be needed, there are problems with excluded countries, and private lock-ins make success doubtful.

The other is to build on big GM firms' need for better public image and their growing recognition that current arrangements for GM research are not working globally [Raven, pers. comm.]. The public sector—with the CG system in the lead—could explore a number of routes to collaboration with the private sector to secure the objectives of poverty reduction, public-goods provision, and the capture of spillover effects. One route is for NARSs jointly, or the CG, or both, to define specific breeding tasks likely to require GM inputs, and to put the completion of these tasks, or the achievement of field-proven varieties with certain characteristics, out to competitive tender. Another is to offer substantial prizes—tens of millions of dollars at least—for developing such varieties. Companies could in either case of course use their patented or protected germplasm as an input, but the final product (the seeds) would have to be free of technical restrictions on retention for re-use (other than, with F1 hybrids, loss of hybrid vigor). A third approach is to build on the practice of at least one of the 'GM giants' of attracting scientists by allowing them to use a part of their time (about 15 per cent) for self-prioritized research using company real capital; perhaps a CG or NARS institution could buy into that approach. Fourth, joint public-private funding is feasible for certain tasks.

Finally, to cite Conway and Tonniessen [1999]: 'Big life science companies [could] license IPRs over certain key techniques/materials for use in developing countries at no cost (e.g. privately held genomic data about rice); and negotiate agreement to share financial rewards from IPR claims on crop varieties or crop traits of distinct national origin, e.g. South Asian *basmati* rice.'

But this, like all the above suggestions, requires that the GM giant companies believe they have something to gain by agreeing, and that NARSs believe—and plan—that the poor's interests are advanced. There is clearly a danger of 'strategic behavior' by companies or NARSs and that is why the CG has to hold the ring and seek ground rules. The first need is to take a strategic decision to go with lead NARSs, with lead GM companies, or (very difficult but excellent if feasible) with both at once. I doubt if more than 5 per cent of the necessary shift of GM research to the interests of the poor can be achieved by appealing to companies' goodwill. Ultimately companies must satisfy the market. Thus the remaining 95 per cent of the need can be met only by shifting the incentives and institutions that lead to market responses.

Point 7: Realigning the public policy debate about GMs

All these prospects could go for nothing. The evidence presented to the Nuffield Council [1999] suggests that in Britain, as in other parts of Europe and indeed India and Africa, a great anti-scientific wave, launched by such disasters as BSE, might swamp—or at least severely delay—GM development, pro-poor or not. Can the concerns of many of the critics for environment, accountability and poverty be turned to support of selective, open development of the 'right' GM crops, traits, and targets? Should, and does, the CGIAR system lead?

There are several crucial areas for review. One is the precautionary principle: it may make sense to take no extra risk for a longer-life tomato, but it makes no sense to take no extra risk to avoid blindness due to Vitamin A deficiency;[10] it may make sense to apply some fairly extreme version of the precautionary principle to all products of plant breeding, but not to apply it exclusively to GM varieties, already the most regulated, though safer than, for example, mutagens or wide crosses.

However, it may be an unwise strategy to couch the argument about GM plants in terms of a confrontation between scientists and critics. The critics may well be, and in my judgement are, wrong and unscientific on risks to health, environment and biodiversity; GM offers opportunities, rather than dangers, in these areas if well used. But the critics are right in being concerned with the economic effects, especially on the poor, of the current corporate structures that determine the use, composition, and distribution of GM plants.

Further, while GM plants probably do not present *special* problems of health or environment,[11] there are huge issues around both, presenting special problems to developing countries. It is much wiser to focus efforts on such issues, using GM as a catalyst, instead of insisting pedantically (i.e. scientifically) that GM does not create such issues. For example, the lentil Lathyrus sativus used to cause many million cases of lathyrism in India, and is creeping into Ethiopia. How is such damage to be prevented from creeping into the food chain? Many developing countries have millions of tiny farmers, food processors and retailers, and limited capacity for central regulatory management. Into this situation GM crops enter; suddenly health, environment and biodiversity standards are proposed that should apply all round (antibiotic markers are an immeasurably smaller problem than the feeding of antibiotics to animals, let alone misprescribing). The law-based regulatory methods of Europe and the US may be less appropriate than extension, science and consultation, with the law as last resort.

Not only should GM be a catalyst, through which the CGIAR, FAO and WHO could jointly attack such problems; GM plants could even be developed to help address those problems and solve them. The debate is best served by saying: there *are* health/environment issues, especially hard for developing countries, exemplified by the GM debate but going beyond it; can public and private skills, using the

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[10] Is precaution served by stopping research into GM-based beta-carotene-enhanced rice, or even by delaying release during years of tests, while children go blind? My next monarch dismisses such arguments as 'emotional blackmail'. Facts do not go away because they are called names; facts are facts, however uncomfortable.

[11] For example, standard IRRI rice varieties that biochemically resist BPH-III are as likely to poison non-targeted insects as are GM varieties with Bt gene to poison monarch butterflies.

enlightened self-interest of all food industries in not poisoning customers, help? CGIAR/FAO/WHO should engage biotech companies—often with health as well as agricultural interests—in the debate on how to improve health/environment regulation in developing countries.

Afterword

Another agricultural pioneer, Thomas Jefferson, warned that national Constitutions needed adaptation, from time to time, to new situations. What is true of constitutions is true of institutions. Sir John Crawford would surely have said today that, 28 years after the birth of the CGIAR, radical institutional innovation in agricultural research is again needed, to match the new science and the new economics. As when Sir John addressed the issue, so again now: poverty reduction and public agricultural research face a shared 'crisis', in the medical sense—a turning-point after which they will either decline or recover. Then as now, a good outcome will redirect the potential of new science, and the talents of private as well as public research, towards labor-intensive production of tropical food staples.

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Table 1. People depending on agricultural incomes as a share of total population, 1960-2010.

	1950	1960	1970	1980	1990	2000*	2010*
Developing	79.0	73.7	68.9	63.3	57.9	52.3	46.8
E SE Asia	76.2	70.7	63.5	55.8	50.8	44.9	39.6
LatAmer & Car	55.4	50.1	42.8	34.9	26.2	21.1	16.7
South Asia	75.9	71.3	69.0	65.8	60.1	55.2	50.0
Sub-Sahara	87.0	83.7	80.6	73.9	69.3	63.5	57.8

Source: FAOSTAT 1998 *Estimated

Table 2. Absolute poverty 1970-90 for selected Asian countries.

		Number of absolute poor (millions)			Incidence of poverty		
		1970	**1980**	**1990**	**1970**	**1980**	**1990**
China	**Total**	275	220	100	33	28	9
	Rural	267	211	95	39		11
	Urban	8	9	5	5		2
	%Poor in rural areas				97	96	95
Indonesia	**Total**	70	42	27	60	29	15
	Rural	56	33	18	58	28	14
	Urban	14	9	9	73	29	17
	%Poor in rural areas				82	80	66
Korea	**Total**	7	4	2	23	10	5
	Rural	6	1.5	0.4	28	9	4
	Urban	1	2.5	1.6	16	10	5
	%Poor in rural areas				84	37	20
Malaysia	**Total**	2	1	0.4	18	9	2
	Rural	1.7	0.9	0.3	21		4
	Urban	0.3	0.1	0.1	10		1
	%Poor in rural areas				85	85	85
Phillippines	**Total**	13	14	13	35	30	21
	Rural	11	11	10	42	35	27
	Urban	2	3	3	20	18	11
	%Poor in rural areas				85	75	77
Thailand	**Total**	9.5	7.9	9	26	17	16
	Rural	9	7.4	8.5	30	19	20
	Urban	0.5	0.5	0.5	9	5	4
	%Poor in rural areas				94	94	94
Six Countries	**Total**	377	289	152	35	23	10
	Rural	351	265	132	40	27	12
	Urban	26	24	20	13	9	5
	%Poor in rural areas				93	92	87

Source: Johansen (1993)

Table 3. Population living below US1$ per day in developing countries, 1987-98

Regions	Population covered by at least one survey	Headcount index (percent)				
		1987	1990	1993	1996	1998*
East Asia and the Pacific	90.8	26.6	27.6	25.2	14.9	15.3
(excluding China)		22.9	15	12.4	8.1	5.1
Eastern Europe & Central Asia	81.7	0.2	1.6	4	5.1	5.1
Latin America & the Caribbean	88	15.3	16.8	15.3	15.6	15.6
Middle East and North Africa	52.5	11.5	9.3	8.4	7.8	7.3
South Asia	97.9	44.9	44	42.4	40.1	40
Sub-Saharan Africa	72.9	46.6	47.7	49.6	48.5	46.3
Total	88.1	28.7	29.3	28.5	24.3	24.3
(Excluding China)		29.6	29.3	28.5	27.3	27.3

Source: ‘Poverty trends and voices for the poor’ World Bank, 1999

Table 4. Rate of yield growth (%/year): Cereals, roots and tubers, 1961-1998

Cereals

	Africa	Developing	E SE Asia	LatAmer &Car	South Asia	Sub-Sahara
1961-71	1.03*	2.76	1.96	1.43	1.88	(0.29)
1971-81	1.98	2.76	2.03	2.38	2.33	2.04
1981-91	(0.75)	1.86	1.67	0.74	3.09	(-0.07)
1991-98	(1.13)	1.55	0.86	2.72	1.7	(0.97)
1966-82	1.94	2.7	2.36	2.23	2.3	1.76
1982-98	0.75	1.67	1.35	2.05	2.69	(0.06)

Roots and tubers

	Africa	Developing	E SE Asia	LatAmer&Car	South Asia	Sub-Sahara
1961-71	0.65	2.95	(0.4)	1.57	4.13	0.65
1971-81	1.52	1.19	2.92	-0.77	1.73	1.44
1981-91	1.95	0.73	1.06	1.07	1.62	1.91
1991-98	(0.34)	0.99	(0.09)	1.02	1.09	(0.25)
1966-82	0.61	1.12	2.38	-0.56	2.04	0.52
1982-98	1.42	0.7	(0.21)	0.87	1.5	1.42

Source: FAOSTAT. Best-fit linear trend growth rates over period. ( ) not significant; * significant at 10%; others significant at 5%.

Table 7 Demographic transition 1980-1996

	Crude Birth Rate		Crude Death Rate		Population Growth	
	1980	**1996**	**1980**	**1996**	**1980**	**1996**
East Asia and Pacific	22	19	8	7	1.5	0.9
Europe and Central Asia	19	13	10	11	0.7	0.2
Latin America and Caribbean	31	23	8	7	1.9	1.4
Middle East and North Africa	41	29	11	7	2.9	2.1
South Asia	37	27	14	9	2.1	1.5
Sub-Saharan Africa	47	41	18	14	2.8	2.5

Source: African Poverty Status Report, Word Bank, 1999