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Ethical and Political Problems in Third World Biotechnology

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Abstract *Third World countries are not pursuing scientific and technological policies leading to the development of strong biotechnological industries. Their leaders have been misled into believing that modern biotechnological industries can be built in the absence of strong, intellectually aggressive, and original scientific schools. Hence, they do not strive to reform their universities, which have weak commitments to research, and do not see the importance of having research hospitals able to generate excellent and relevant clinical investigation. These strategic gaps in scientific capability, the lack of governmental and corporate research funding, and the dependent nature of the chemical and pharmaceutical industries of the Third World make the development of competitive biotechnology a highly improbable event. If the present trend continues, underdeveloped countries will continue to be testing grounds for biological materials and agents, sources of valuable germplasm, and markets for high-value-added products and processes invented and manufactured in the First World. This article recommends that the international organizations collaborate in the urgent task of educating the Third World political leaders and administrators in the real problems connected with the generation of high technology.*

Keywords: Vaccines, diagnostic kits, useful and useless science, germplasm robbery, insularity, complacency, international organizations.

Total que la tristeza nos envolvia y nos ponia
furiosos/y otra vez tristes/

Jean Gelman
Operaciones
Malaga (1983)

Biotechnology is a successful, high-stakes game played in the closed private club of the rich countries (Office of Technological Assessment 1984; Olson 1986; Bull et al. 1982; Swinbanks 1987; The genetic alternative 1988; Yanchinski 1987; Kenney 1986; Goldstein 1989). It is based on molecular biology, a scientific discipline that creates the moving edge of useful biological knowledge and furnishes the theory, the concepts, the instruments, and the methods needed to pursue its own development and that of the rest of the biological sciences (Alberts et al. 1989). This new knowledge is immediately appropriated by the pharmaceutical, chemical, agrochemical, and seed industrial con-

glomerates of the central countries, protected by worldwide patents and/or commercial secrets, and transformed into high-value products.

There is no such thing as a biotechnological industry operating in a vacuum and oriented to solve human problems. Biotechnology, the backbone of the pharmaceutical, chemical and agroindustries of the future, is for profit. The developed capitalist countries hotly contest their biotechnological preeminence, because their objective is to turn the knowledge generated by molecular biology into pharmaceutical agents, biological reagents, fine chemicals, and chimeric organisms of high price and universal marketability. The combination of fierce legal battles, tough market competition, and strategic international alliances makes the framework in which modern biotechnology develops (Crespi 1989; McGourty 1988; Sun 1988).

The competitiveness of the First World is based on the existence of a high quantity of high-quality scientific personnel, high governmental spending on science and graduate science education, lots of venture capital available for creating start-off companies, and heavy industrial investments in academic and corporate research (Abelson 1988a, 1988b, 1988c; Hatsopoulos et al. 1988; Klein 1988; Young 1988; Bloch 1986; Mansfield 1988; Investments with an eye on the future 1988; Braben 1985).

The Biotech Propaganda Blitz

While the members of the segregated, all-white, biotech club gather frequently to play with the future, joke about who does what, slice the marketplace pie, and merrily decide among themselves the eating agenda (Newmark 1988), the rest of the world is subjected to a propaganda blitz (National Research Council 1982).

Biotechnology is advertised as the universal panacea, a cure-all remedy, the ultimate for controlling, taming, and exploiting natural resources, the solution to hunger and misery. The biotech propaganda blitz emphasizes "applications," "niches," and "industrial development," as if biotech products could emerge magically from the void. A picture is offered that shows a user-friendly, easygoing biotech, fittingly "appropiated" to the lack of means and resources of impoverished nations, devoid of scientific and legal prerequisites, with no proprietary constraints.

This advertising campaign clearly shows that—judged from the scientific, industrial, and sociological parameters of the countries involved—there must at least be two kind of biotechnologies, one practiced in the First World, and the other reserved for the Third World.

First World biotechnology is based on the "renewable frontier" created by the industrial exploitation of the scientific results generated by the heavily funded, strong, and innovative strategic disciplines of biology—biochemical and structural molecular biology, genetics, cell biology, animal, plant, and microbial physiology, pharmacology, immunology, and clinical science—to create new commercial opportunities and high-value-added products (Koshland 1986).

The biotechnology reserved for the Third World does not need frontier molecular biology and does not require strong academic and industrial research departments. It can prosper with the knowledge generated by a weak scientific establishment, which produces scantily, is repetitive, and lacks originality. Moreover, this biotechnology can thrive in the absence of clinical and agronomical investigation. Third World biotech is devoid of intellectual proprietary problems, and therefore indifferent to the patenting

Table 1
Scientific, Industrial, Financial, and Social Requirements of First and Third World Biotechnologies

First World	Third World
High quality and high quantity of scientific personnel.	Very small number of highly qualified scientific personnel.
Strong molecular biology.	Very weak or inexistent molecular biology.
Massive generation of original and useful scientific results in the biomedical sciences.	Few instances of original and useful scientific results.
Habit of technological invention.	Absolute lack of habit of technological invention.
Quick appropriation of scientific results by industry.	Social indifference toward science.
Globalization of research to capture as many new ideas and technologies as possible.	Insularity and glorification of mediocrity.
Strong research hospitals subsidized by massive governmental and industrial funding.	Absolute lack of research hospitals.
Autonomous and strong pharmaceutical and chemical industries competing for the world market with high-value-added products derived from frontier research results.	Weak and mostly dependent pharmaceutical and chemical industries not involved in the discovery of original drugs.
Strong governmental and corporate research laboratories.	Weak governmental research labs and few research laboratories.
Venture capital ready to invest in "start-offs."	No venture capital for scientific enterprises.
Strong regulatory agencies and consumer interest groups.	Weak regulatory agencies and consumer interest groups.

policies of the First World, and can operate in bankrupt countries without venture capital (Table 1) (Goldstein 1989, 1986).

The advertising campaign targeted on the Third World systematically downplays or totally ignores the need for a strong background on meaningful biomedical sciences for the generation of biotechnological products. It never mentions the problems generated by the overwhelming and all-encompassing patenting of biotechnological products—including the patenting of new animal and plant life forms—and procedures, the extent of commercial secrecy in molecular biology, the present and potential restrictions of technology exports, the rising wave of technonationalism that pervades the politics and the policies of the developed nations, and the scientific efforts being made by the First World to replace crops and products now imported from the Third World by new and powerful biotechnological methods (Straus 1985; Goldstein 1986; Bloomberg et al. 1987; Sun 1986; Rural Advancement Fund International 1988a, 1988b, 1988c, 1987b, 1987c, 1987d, 1986; Blumenthal et al. 1986a, 1986b; Weiner 1986; Krimsky 1986; Bourke

1988; Weissman and Bourke 1988; Weissman 1988; Bouton 1983; Reich 1987; Schmitt 1984; Gladwell 1988; Barber and Morgan 1987; Abelson 1987).

How can the Third World compete in the international marketplace with original pharmaceutical products when lacking the fundamental and clinical sciences needed to circumvalate patents, superate the commercial secrecy, and discover new products and procedures? (Goldstein 1987, 1983).

How will the Third World react to the progressive substitution of the crops that constitute their main export commodities by products manufactured in the First World arising from new biotechnological procedures? (Goldstein 1987, 1985).

Role of the Third World in the Biotech Revolution

Underdeveloped countries are net exporters of several strategic commodities: genetic information (including people), food, biological and inorganic raw materials, flowers, oil, hard currency, manufactured products derived from routine and/or obsolete technology, and bulk chemicals (Gladwell 1988; Barber and Morgan 1987; Sadosky and Goldstein 1986; Lattes and Oteiza 1986; Mooney 1983; Garcia 1982; Schneider 1986). On the other hand, they are obliged to import all those products that make civilized life possible, including capital goods, fine chemicals, pharmaceutical and veterinary drugs and vaccines, advanced technological products (ranging from commercial planes to computers), and technical know-how (Hobsbawm 1968; Chang 1964; Todorov 1982; Pena 1968a, 1968b, 1968c, 1968d, 1968e, 1968f; Frank 1979; Galeano 1984; Katz 1974; Gereffi 1983; Djerassi 1984; Giovanni 1980; Evans 1979; Mintz 1985).

The disparity of prices between the exported commodities and the high-tech imports is staggering. The present prices of some of the most important new drugs released in the 1980s, as well as the prices of some of the export commodities of the Third World, are listed in Table 2.

How many tons of orange juice, flowers, lettuce, plums, or strawberries will we have to export to generate the dollars earned by a kilogram of the clot-dissolving drug of Genentech?

Yet this question does not really matter, according to the native and international wizards of the biotech propaganda blitz. The Third World must concentrate in "applied" research to solve its own health and agricultural problems. The way to do it is through micropropagation, the introduction of new vaccines, and the production of diagnostic tests for indigenous infectious diseases.

The Trivialization of Plant Biotech

The panegyrists and savants of the biotech propaganda blitz have a very clear idea of the sort of biotechnology that is fit for us. Our countries barely survive by producing cash crops. Ergo, our task must be the development of plant biotech.

We are expected to work on micropropagation, in order to improve our agricultural yields, gain better access to our germplasm, and refine the methodologies for its conservation in reliable gene banks. Of course, the genetic information stored in those modernized gene banks should be freely available to everyone, because our genes represent an endowment of Nature and all inhabitants of this earth should have access to them.

There are, then, two categories of biotechnology and two categories of genes. Our plant genetic information belongs to the world at large, but curiously enough, once it

Table 2
Prices of New Drugs and Cash Crops

Drug	Manufacturer	Price[a]
TPA	Genentech	$2,000[b]
Lovastatin	Merck	$600–3,000
Factor VIII	Armour	$25,000
Growth Hormone	Genentech/Lilly	$8,000–30,000
Cyclosporine	Sandoz	$5,000–7,000
AZT	Burroughs Wellcome	$8,000

[a] Per year/patient of treatment, except in the case of TPA, in which it is the price of a single dose.
[b] The individual dose is 100 mg. Price of a kilogram: $22 million.

Crops	Producer	Price[a]
Vegetable oils[b]	Asia, S. America	$0.70
Cocoa[b]	Africa, S. America	$1.40
Coffee	Africa, S. & C. America	$2.70
Vanilla[b]	Asia, Africa	$70.00
Gum Arabic[b]	Africa	$5.20
Orange juice	S. America	$2.70[c,d]
Papaya	S. America	$2.00
Strawberries	N. America	$1.00

[a] $/Kg.
[b] Targeted for biotechnological production.
[c] US $/liter of concentrate.
[d] 1988 prices; 1989 significantly lower.

travels to the North, it changes qualitatively and is transformed in a secret or patentable commodity. Our genes are free, but those same genes, once repackaged in the North, are sold back to us and are very expensive indeed (Mooney 1983; Goldstein 1986, 1988; Levins 1974; Kloppenburg 1988; Rapoport 1987).

The products of our biotechnology will be staples, cash crops, and ornamentals. Latin America is to keep producing orange juice, some sugar, coffee, cocoa, tropical fruits, assorted vegetables, berries, ornamental plants, and flowers. The other role reserved to the region is the maintenance of gene banks for potato, yucca, wheat, maize, tomato, coffee, and other plants of commercial interest to the North. Last, but not least, Latin America must improve and take care of their national parks, which are to become wildlife reservoirs for the preservation of useful genes in their national habitats (Mares 1986; Plucknett et al. 1987; Lewin 1988; Dahlberg 1987; Barton 1982; Roberts 1988).

Nyle C. Brady, a senior administrator of the U.S. Agency for International Development, wrote in *Science:*

> Collaborative research with Third World countries has benefited U.S. agriculture in another way—through the infusion of yield-producing genetic materials into the seeds of our cultivated crops. The center of origin of essentially every major crop that we grow is in the Third World. Consequently, gene diversity is highest there. Through collaboration with developing countries, we help them use the reservoir of wild species to improve their own crop-producing potential. But we can also have access to that same genetic

> diversity to improve our own cultivars. For example, semi-dwarf wheat varieties, the genes of which came from Asia, occupy almost 60 percent of our wheat acreage. The genetic sources of resistance for pests, such as the golden nematode of potatoes, came form Peru. Strains resistant to southern corn leaf blight, corn rust, and maize dwarf mosaic virus resulted from the collaboration with scientists in developing countries, as did the resistance to the soybean mosaic virus. Comparable benefits can be cited from essentially every crop we grow. (Brady 1985).

While the science strategists of the U.S. complain about the lack of attention to plant molecular biology and stress the importance of establishing sweeping reforms in higher education and in federal funding to ensure a steady flow of talented students and scientists to the field (Abelson 1988), the Third World is busily establishing micropropagation facilities.

The program, outlined in Table 3, is straightforward.

We micropropagate, and they modify the plant genes at will. We preserve germplasm and national centers of diversity, and they pick and modify the plant genes at will (Shields 1989; Walbot and Bruening 1988; Goodman et al. 1987; Goodman 1986; Goldberg 1988). We buy their seeds and agrochemicals to produce crops tailored to suit the production profiles and inventories of (their) agrochemical industry and (their) nutritional, commercial, industrial, and taste requirements (Brattsen et al. 1986; Abelson 1987; Schneider 1986; Rural Advancement Fund International 1987, 1989). The hybrid seeds that incorporate the useful genes are made and commercialized in Third World countries by the subsidiaries of the seed companies owned by the great pharmaceutical, agrochemical, and chemical corporations of the First World (Goldstein 1984a). In Argentina, the local seed industry, which produced hybrids of very high quality, was decimated because it could not compete with the marketing power of the transnational corporations. We pay dearly for our own genes.

This agenda for Latin American biotech development is often accepted even by some southern and northern critics of the corporate transnational agroindustry. They argue that we must admit our limitations and restrict ourselves to do what we can do, since it is impossible for us to compete with the biotech big league (Di Prisco and Texera 1986; Arroyo et al. 1985; Fundacion Javier Barrios Sierra/CONACYT 1985; Developmental Dialogue 1989).

From a diagnostic point of view, they are absolutely right. It would be worthwhile to compare the combined strength of Latin America in disciplines such as modern plant

Table 3
The Different Biotechnological Tasks

The First World	The Third World
Studies the physiology, the biochemistry, the molecular pathology, and the molecular genetics of plants.	Makes few plants.
Isolates and clones genes, identifies gene products, characterizes physiological and pharmacological actions.	Stores germplasm.
Exports patented seeds, patented genetic chimeras, drugs and biological agents derived from or developed upon agents derived from Third World germplasm.	Exports raw materials.

biology, molecular plant genetics, phytochemistry, plant physiology, photosynthesis, molecular plant pathology, and molecular biology of plant pathogens, with just a single research institute of an agrochemical corporation of the First World, such as Du Pont, Monsanto, Unilever, Roche (Goldstein 1984).

Yet from a developmental perspective, this is a self-defeating proposition. It leads to a policy of preservation of the status quo, a sure prescription for the development of our already tragic underdevelopment. Latin America is in urgent need of something much more serious than micropropagation.

The Trivialization of Animal Biotech

The future perspectives of cattle production are not a favorite subject of the biotech propaganda blitz, and the impact of biotechnology on the animal farm is always out of focus. The script always revolves around the increase in milk production under the effects of growth hormone, the genetic chimerization of common farm animals to produce expensive proteins, pigs that grow briskly, and giant fish. All this is, of course, true. By the end of 1989, a herd of transgenic goats is expected to be producing all the tissue plasminogen activator needed by the American market in one year.

What is lacking in this bland background is the discussion of the patent problem, which is seldom mentioned. Latin American countries are mildly encouraged to pursue "no-nonsense" objectives and to collaborate in the development of veterinary vaccines. This, translated to the vernacular, usually means to continue being the testing ground for new vaccines developed abroad.

Reality, however, is grimmer. On 17 April 1987, the U.S. Patent and Trademark Office announced its landmark decision of accepting patents of transgenic animals—called "new forms of life"—which are to be considered akin to mechanical inventions.

A transgenic animal or transgene is a genetic chimera made by inserting a piece of foreign DNA in its genome. Conservative estimates indicate that there are now approximately one thousand strains of transgenic mice, created mainly for research purposes, a score of transgenic rabbits and fish, and a few of transgenic cows and sheep (Jaenisch 1988; Van Brunt 1988; Lamming 1988; Marx 1988).

Some of the new constructions could grow so efficiently that they might reduce by 10 percent the cost of raising them. This is such a substantial margin that farmers might find it difficult to survive without these animals. A new strain of chimeric pigs is being raised in Australia which has in its liver several copies of genes coding human growth hormone. The transplanted genes are so prepared as to allow the farmer to induce the expression of the extra genes by the mere expedient of varying the content of trace metals in the diet. The engineered piglets gain 1.3 kilograms per day, and reach 90 kilograms in 17 weeks, instead of the normal 22 to 25 weeks. As expected in animals exposed to high levels of circulating growth hormone, the meat of the chimeric piglets is significantly leaner (Timm 1988).

Transgenes will also reduce deadly and costly epidemics in animal farms. Chickens carrying genes that inhibit the development of avian leucosis could save the industry $50–100 million per year.

These transgenes are patented, and the farmers will be forced to buy genetically engineered animals to stay in business. However, they will not be able to reproduce them freely because, according to the biotech industry, they will be clones of the original animal and therefore covered by the same patent. This means that the farmers will be

paying royalties to the holders of patents not only for the selling of adult animals and their parts (hides, meat, wool, hair, carcasses, etc.) but for all the generations of calves, colts, lambs, chicks, and piglets generated by the patented animals through the 17-year life of the patent (Schneider 1988; Schmeck 1988).

The rapid developments taking place in modern nutrition science and food technology are likely to result in accurate specifications of the ideal chemical profiles of meat. It is highly likely that the chemical specification of imports by the First World will be tailored in such a way that the Third World countries will be forced to buy the patented transgenes if they wish to conserve their shares of export quotas.

The economic consequences of the patenting of farm animals will be the concentration of the animal breeding industry. In the First World, animal breeding will progressively be captured by agroindustrial corporations involved in biotechnology. The price of farm livestock is likely to increase, and the biological consequence will be the increase in genetic uniformity (Rural Advancement Fund International 1987a).

In the meantime, with or without biotechnology, cattle production in Latin America proceeds in the absence of a single high-level research institute strong in conventional cattle genetics, physiology, and biochemistry. The region—and this is valid for the rest of the Third World—does not have the army of bird and mammalian physiologists and geneticists needed to pinpoint the biochemical and genetic basis of desired traits and lacks the molecular biologists needed to genetically engineer animals to create new breeds. The breeding selection criteria are still consumer preference, the perverted tastes of the juries of cattle contests, gross anatomy, and crude measures of efficiency of meat and milk production (Goldstein 1984b).

As a direct result of its strategic deficiencies, Latin America will not be able to design viable alternatives to buying. The real animal biotech is totally out of bounds for the Third World, in spite of the fact that the South also contains a rich reserve of animal germplasm. The useful genes will be picked, unchallenged, by the biotech companies of the academic-biotech industry complex of the First World, and sold back to the South in a variety of attractive and expensive forms.

Underdeveloped Countries as Commercial Targets and Test Sites

Since the Industrial Revolution, underdeveloped countries have been targeted for the export of goods manufactured in the central colonial and industrial powers (Hobsbawm 1968; Pena 1968a, 1968b, 1968c; Frank 1979; Galeano 1984).

Initially, this policy implied the destruction of local industries, when they existed, the abolition of trade barriers, and the creation of financial, economic, political, military, and educational structures that fitted into the general agenda of the central countries. With time, rutinary technologies were also exported to the periphery (Evans 1979). This led to the substitution of certain exports and the use of underdeveloped countries as cheap production and/or assembly havens needed for global market competition and the maximization of corporate profit. The Mexican maquiladora industries and, in the past, the Argentine pharmaceutical industry, are examples of this type of pseudoindustrialization.

Some underdeveloped countries were a source of cheap biological raw materials needed for the production of high-value-added products. In Argentina, some national and transnational corporations extracted, purified, and exported heparin (from bovine liver and lung), insulin (from bovine pancreas), and gonadotrophins (from the blood of pregnant mares). The leading technological edge always remained, of course, in the central

countries, protected by a complex, well-knit, and aggressive policy combining patent laws, commercial secrets, bans on technological exports, and commercial and financial measures to restrain the weaker would-be competitors (Vaisos 1972).

Once Eli Lilly started producing human insulin by using chimeric bacteria in its Indianapolis headquarters, it closed its insulin factory in Buenos Aires. Heparin is no longer produced in Argentina, and the availability of recombinant gonadotrophins will probably affect the long-range competitivity of the natural hormones. Argentina still exports crude fetal bovine sera and horse cardiac muscle.

Peripheral countries are characterized by their lax of nonexistent regulatory agencies. This makes them ideal outlets for selling pharmaceutical and agrochemical products banned in the central countries because of their toxicity and for testing new agents, from hormones to pesticides (Goldstein 1983).

The new biotech products will also be tested in the periphery, and Latin American countries with special trade agreements will be used as production havens for the production of biologicals targeted for the American market.

The New Vaccines and the Third World

In the central countries, vaccines are not an attractive business (Gladwell 1988). Vaccines are administered to many (often millions of) healthy people, in whom side effects and untoward reactions are easier to detect than in terminally ill patients. Any new vaccine—no matter its conventionality or novelty—must be clinically tried before entering the marketplace. As in the case of any new drug or biological agent, it is necessary to determine its effectiveness and detect its immediate side effects and complications.

Problems, however, can be assessed only after prolonged use of the vaccine in worldwide immunization programs. While some of these ill effects can be anticipated with precision—one in every 3.2 million children vaccinated against poliomyelitis with the live vaccine will get the disease, others cannot.

The recombinant vaccines are by no means an exception. They need to be tested before being mass-produced and sold. Moreover, some of them are genetic chimeras, and their biological properties and long-term ecological impact are in fact complete mysteries.

In the First World, vaccination may lead to lawsuits. Claims average several million dollars per case. When the American insurance companies retired their coverage of vaccines in the mid-1970s, the vaccine industry reacted strongly. The four American drug companies involved in developing the vaccine against swine flu refused to sell the vaccine to the public unless the federal government granted them immunity from all suits arising from their product. This was a wise move, since during the decade 1976 to 1986 more than four thousand lawsuits were filed against the vaccine due to the cases of Guillain-Barre syndrome seemingly associated with its use, and the Justice Department had to pay $100 million in damages. In 1986 the U.S. Congress was forced to set up a special fund to pay for out-of-court settlements in liability suits over pediatric vaccines.

This explains why the central countries are interested in developing "joint" vaccine development programs with underdeveloped countries (Antia 1989). New vaccines can be tested without legal constraints on populations which ignore the concept of informed consent and lack the technical, political, educational, and economical capacity to fight legally if the vaccines create incapacitating health problems (Newmark 1988). Moreover, the trials are utterly different when done in the First World (Schneider 1986). The highly

Table 4
Different Modalities in Recombinant Vaccine Trials: The Case of the Vaccinia-Rabies Recombinant Virus

The First World (Belgium 1989)	The Third World (Argentina 1986)
The National Health Council of the Belgian Ministry of Health reviewed and approved the protocol to be employed by the biotech companies.	The national health agencies were not notified neither by the producers of the vaccine nor by the sponsoring private and international institutions involved.
The experiment is directed by Professor Pierre Pastoret of the University of Liege.	No relevant Argentine experts were consulted, and the experimental protocols and the actual trial were neither evaluated nor coordinated by local health and academic authorities.
The new vaccine was introduced legally in the country.	The new vaccine was smuggled into the country.
Ample coverage in the press.	The press was not informed.
The new vaccine was released in a sparcely populated territory which has a high number of cases of fox and bovine rabies in Belgium.	The new vaccine was released without any sort of containment in the richest and most populated of the Argentine provinces, where bovine rabies is not an animal health problem of any magnitude.
The trials are public, and the people of the region know about the environmental release.	The secret trial took place in an experimental stations of an international organization. Workers were not warned about the novelty of the vaccine and were allowed to take to their households' milk from the inoculated cows.

peculiar character of these "joint" endeavors and the double standards which are used in different geographical locations are analyzed in Table 4.

First World scientists receive money from First World governmental and corporate sources to develop their recombinant DNA research. The First World pharmaceutical industry can then proceed to field test new vaccine technologies without risks of liability lawsuits. The production of the new vaccines is to be done in the First World, and the manufacturing pharmaceutical corporations will control pricing and supply.

The Third World contributes its cheap, expendable, and superabundant urban and rural poor, a scientific workforce that is reduced to perform as technicians and in return is graciously granted the right to start pumping money out of the countries as soon as the new vaccines are ready to be bought. The effects of these "joint" ventures in science education and planning are uniformly bad, because scientific objectives are distorted and funds diverted to finance work that is intellectually poor, repetitive, and unimaginative (Table 5).

The result is bad science and worse education of young scientists.

Table 5
The International Division of Labor in Vaccine Development

The First World	The Third World
The new recombinant vaccines are developed in the central countries. North-South agreements do not include the participation of Third World scientists in the vaccine development teams. The research teams that create the new vaccines do not include Third World scientists. If they include nationals from peripheral countries, they are permanent residents or nationalized citizens of the central nation.	No vaccine is developed in the periphery. Third World scientists and technologists are involved in rutinary measurements of immunization responses, a repetitive task devoid of any intellectual interest in which they are not exposed to the know-how of the new technology.
The production of the new vaccines is done in the central countries, without the participation of scientists and technologies of the Third World countries which are the intended markets for the vaccines.	No recombinant vaccines are produced in the periphery.
First World scientists and technologists of the public and privated sector monopolize the know-how stemming from the creation, the development, and the mass production of the new vaccines. The biotech industry and the pharmaceutical corporations of the First World invest heavily in the development of the new vaccines. Governmental funding subsidizes heavily the research effort leading to the production of new vaccines.	Third World enterprises do not fund the development of the vaccines. Governmental funding does not subsidize the research effort leading to the production of new vaccines.

Are All These New Vaccines Needed?

Infectious diseases are the scourge of the Third World, but it is well known that many of the microorganisms that kill and maim the children and the adults of the Third World also infect the inhabitants of the First World with minimal untoward effects. Chronic and acute malnutrition, poor housing conditions, lack of safe water and sanitary facilities, and poor health education are the factors that more often than not establish the difference in outcome.

The infectious diarrheal and acute pulmonary syndromes in the Third World are the product of many different types of microorganisms, and the task of immunizing the whole population to the whole list of possible etiological agents seems impossible to achieve. Obviously, this agenda may seem absurd form a medical point of view, but it certainly is attractive for the vaccine designers (the scientists) and the vaccine producers

(the biotech industry and the pharmaceutical corporations of the First World), which have a sure marketplace in the Third World.

The absurdity of the situation is highlighted by the fact that most of the conventional vaccines, useful for the prevention of many of the common infections that are still rampant in the Third World, are not produced in the underdeveloped countries, and their populations are not adequately protected.

A last consideration should be made concerning the emphasis on the development of new vaccines to combat diarrheal and pulmonary infectious diseases in the Third World. The rates of morbidity and mortality due to tuberculosis started to fall in the West before the advent of successful chemotherapy. This was the result of safe milk and better housing and working conditions. The same is true for the diarrheal diseases: safe drinking water and sanitary services were more important than antibiotics in controlling their epidemic spread (Lock 1988; McKeown 1988).

The Mirage of Diagnostic Tests

The availability of new magic vaccines is not the only fixation that haunts the Third World. In Latin America, the quest for diagnostic tests has also reached epidemic proportions. Almost every country in the region is busily engaged in the production of diagnostic kits, mainly for endemic parasitic diseases.

The arguments backing this policy are clear and explicit and apparently flawless. Since the First World does not need this type of diagnostic tests, the Third World must take the task of developing them. The tests are needed for studying the epidemiology of the diseases, to detect new outbreaks, to evaluate the immunization status of the population, and to avoid their transmission by contaminated blood in the blood banks. This point is very important indeed, because it nicely combines the health-care objective with the profit motive.

While nobody can decry these intentions or deny their soundness, the consequences of this policy are disquieting. The development of diagnostic kits substitutes for the study of the biology of the diseases. The few able molecular biologists of the region often become involved in these trivial pursuits, instead of studying the biochemistry and the molecular biology of the etiological agents, their vectors, and their interactions with the hosts. Many good researchers, who might otherwise be involved in these fascinating (and potentially very useful) tasks, are attracted by the availability of research money for diagnostic test development and/or are anxious to show their "social" involvement by working in areas that are considered to be "national" priorities. In this way, they are subtracted from the mainstream of biology and dumped in often uninspiring and uninspired programs.

But this is not all. The false impression is created that the problem of endemic diseases can be solved by diagnosis. This is, of course, a blatant and absolute lie. The wise use of tests can help in checking blood bank contamination, which is certainly an important sanitary objective, but making blood transfusions safe will not erase malaria or Chagas disease. Those who might be spared the risk of an accidental infection through blood transfusion are the people who have access to sophisticated medical services, who are certainly not the majority of the inhabitants of the Third World. In short, the beneficiaries of this drive toward immunochemical diagnosis will be the urban rich and the expeditionary forces of the First World.

The emphasis on diagnosis drains funds and people and obliterates the true high

priorities in the fight against any complex parasitic disease: (1) the study of the molecular biology of the disease; and (2) the elimination of the social and economic conditions which determine the spread of the disease and maintain it unchecked.

There is no convenient scientific shortcut for the Third World to deal with its epidemic and endemic diseases. Parasitism is one of the key open problems in molecular biology (Halstead 1988; Borst 1983). The meaningful study of parasitic diseases can be accomplished only by educating thousands of molecular biologists of the highest quality and devoting them to solve the myriad of fundamental problems in cell biology that enrich the riddle of parasitism. This is a long-term project, yet it will only be through this painstaking, difficult, and ambitious endevour that substantive progress will be made in the fight against endemic parasitic diseases.

This is a task that requires time, money, and serious intellectual work and implies a complete commitment to the upgrading of higher education in underdeveloped countries and the reshaping of their scientific establishments. Removing the social and environmental factors which support the spread of parasitic endemic diseases requires a political agenda and a definite collective commitment to change.

New vaccines and diagnostic tests will not vanquish the scourge of parasitic diseases form the Third World. Vaccines will not be delivered, and diagnostic tests will not reach all the population at risk, because of the operation of the same factors responsible for perpetuation of poverty, backwardness, ignorance, and violence that make underdevelopment what it is.

The Myth of "Applied" Science

Third World politicians and administrators have been thoroughly brainwashed to make them believe in the myth of "applied" science.

This meaningless dichotomy has been emphatically advertised by many "experts" in technological development working for the international organizations and endorsed by most Latin American government officials. Almost to one person, they press for research that produces results which could bring money, immediately and automatically, to their ailing economies.

National grants and international loans are concentrated on "applied" projects, regardless of their scientific value and the track record of the investigators. This bias has fractured the Third World scientific community by inducing the senseless confrontation between those claiming to be involved in "applied" science and the partisans and practitioners of "pure" science. The scant human and financial research resources of the underdeveloped countries are twisted to accommodate to the "applied" priorities.

The present reality and the recent history of the region shows the monumental failure of this policy. After hundreds of millions of dollars and several decades spent on such programs and projects, the push for "applied" science did not solve a single problem and certainly did not contribute either to the development or the improvement of the economy of Latin America.

For certain, the "applied" biological sciences fostered by the international organizations did not put Latin America in a competitive position in the international biotech marketplace.

On the other hand, this ideological deformation contributed mainly to consolidate the inadequacy of our scientific capabilities by perpetuating a degraded, repetitious, unoriginal, and trivial activity called "applied science," to the detriment of the concentration

of resources on good science. As a result, the only discernible effect of the loans received for scientific development has been their contribution to the increase of the foreign debt.

This enthusiasm for the "applied" and the lack of understanding of the working of science and its relation to technology are the reasons why the biotech propaganda blitz made such a powerful impact on Latin America. Biotech was—and still is—pictured as the archetype of the "applied science" and was sold as the rapid fix for solving all the biomedical, nutritional, and agricultural problems of the region.

Yet Latin America is weak in biochemical and structural molecular biology, genetics, cell biology, plant, animal, insect and microbial physiology, bacteriology, mycology and virology, parasitology, immunology, pharmacology, and clinical science. These are precisely the scientific disciplines needed to develop a competitive biotechnology.

Without top schools in these areas, biotechnology is and will be a utopia to be talked and written about, traveled around, but never done.

Useful and Useless Science

Scientific activity in the Third World (both "applied" and "pure") is seldom useful. Suffice to count how many significant biomedical discoveries were made in our countries during the last twenty years.

A scientific discovery is significant when it is useful. The more useful it is for explaining the realities of the world and the working of the mind, the more fundamental it becomes. All fundamental scientific results are applied, because they can be used to solve theoretical and experimental problems.

Significance in science is not determined by decree or by fashion, or by its capacity for generating immediate technological spin-offs. Scientific results are important if they lead to new levels of understanding of Nature and to the solution of problems that matter, either in theoretical or practical terms. These two characteristics automatically separate the useful from the superfluous and the trivial (Bernal 1971; Jaffe 1985; Dixon 1976; Waddington 1948; Comroe 1977a, 1977b, 1977c; Serre 1984, Baxter 1968; Rogers 1977; Rose and Rose 1970; Mayr 1982).

Watson and Crick changed the history of humanity and the science of biology by proposing a three-dimensional structure of DNA that could explain the general mechanisms of replication, mutation, and recombination of the genetic material, as well as define the nature of the genetic code (Watson and Crick 1953a, 1953b; Watson 1968; Crick 1988, 1966). The model and the functional hypotheses turned out to be astonishingly useful; they gave the explicit blueprint for discovering the biochemistry of replication, recombination and repair, and the genetic code. For the first time in history, biology became predictive. Watson and Crick elevated biology to the realm of natural philosophy, and molecular biology established the set of rules and principles able to predict and explain the behavior of things biological.

The discovery of bacterial sex did not only revolutionize microbiology (Lederberg 1986; Zuckerman and Lederberg 1986) but also allowed Jacob and Monod to elucidate the molecular mechanisms involved in gene expression and its regulation (Lwoff and Ullman 1979). This led to the complete understanding of the fundamental framework of genetics and resulted in genetic engineering (Watson et al. 1988).

Even though the examples coming from the history of molecular biology are the most glaring, I would like to call attention to some examples of useful science made in Latin America.

Angiotensin and Bradykinin

Fifty years ago, Argentinian and Brazilian biomedical researchers discovered angiotensin and bradykinin, two biologically active peptides with opposite actions.

E. Braun Menendez and his collaborators in Buenos Aires found that the hypertensive action of the renal proteolytic enzyme, renin, was due to the generation of a vasopressor peptide, angiotensin (Munoz et al. 1939).

This discovery inaugurated a whole new chapter in biochemical pharmacology, which forty years later, became the much populated and fashionable field of peptide physiology and pharmacology. Thirty years later, another group in Buenos Aires found that renin and angiotensin are also present in the mammalian brain (Goldstein et al. 1970; Fischer-Ferraro et al. 1971; Finkielman et al. 1974).

M. Rocha e Silva and his team, in Sao Paulo, found bradykinin, the hypotensive peptide generated by the action of a proteolytic enzyme, kallikrein, on a plasma substrate (Rocha e Silva and Rothschild 1974).

The biologically active octapeptide angiotensin II itself is generated by the proteolytic cleavage of an inactive decapeptide, angiotensin I, catalyzed by the angiotensin converting enzyme, which is the same protease that splits and inactivates bradykinin.

Thus, two antagonistic peptidergic systems share an enzyme, which activates the hypertensive pathway and inactivates the hypotensive peptide. An inhibitor of this key enzyme should be a potent hypotensive agent, since it would block the generation of angiotensin II and the destruction of bradykinin. Rocha e Silva and his collaborators soon found that the hypotensive poison of some Brazilian snakes contained peptides that inhibited the angiotensin converting enzyme, potentiating the action of bradykinin. Chemists and pharmacologists working at Squibb's corporate labs designed in the 1970s the first generation of clinically useful hypotensive agents which acted through the inhibition of the angiotensin converting enzyme (Horowitz 1981).

The economic importance of antihypertensive drugs cannot be overestimated. Twenty percent of the world population is hypertensive, and it is well established that the only way to avoid the deletereous effects of high blood pressure—accelerated arterial aging, cardiovascular and cerebrovascular accidents, and their invalidating sequelae—is life-long therapy. These two facts are well reflected in the staggering size of the market of antihypertensive drugs, which in 1987 was $15 billion. A substantial part of this phenomenal market has been captured by the inhibitors of angiotensin converting enzyme.

Braun Menendez and Rocha e Silva were not involved in "applied" research. Their aim was understanding the biochemical mechanisms which gave rise to hypertensive disease. They were interested in solving the clinical problem, because it was the only way to design useful drugs for controlling high blood pressure (Goldstein 1985).

The Biosynthesis of Complex Sugars

L.F. Leloir and his school, working in Buenos Aires, discovered the biochemical mechanisms involved in the biosynthesis of simple and complex oligo and polysaccharides (Paladini 1988; Leloir 1981).

Once the biochemical pathways for the synthesis of sugar polymers became known, their regulation, modification, and inhibition became attainable technological targets. Leloir did not pursue his quest with a commercial objective in mind, although it is obvious that once the mechanism of the biosynthesis of strategic molecules such as starch and gylcogen were known, the number of technological options became limited only by

the imagination. The discovery of the biochemistry of lactose synthesis, for example, led to the identification of the biochemical basis of a crippling human genetic disease, galactosemia, a condition that will soon be amenable to specific gene therapy. There are no theoretical impediments for the in vitro synthesis of starch molecules in industrial scale, which could lead to obvious changes in rural economy.

Leloir's work also contributed to a very important aspect of modern biotechnology. Most of the protein molecules with commercially appealing functions are glycoproteins —proteins which have complex sugars attached to their peptide backbones. These sugars often determine how the protein folds in space, conditioning its biological activity, and its intracellular behavior. Sometimes they contribute to the immonogenic profile of the protein, while in other cases they determine the way in which the molecule interacts with its receptors. The rate of degradation of circulating glycoproteins is mostly dependent on their carbohydrate moiety.

Wild type bacteria do not glycosilate proteins and therefore cannot be used to produce recombinant glycoproteins. On the other hand, each eucaryotic species has its own distinctive pattern of protein glycosilation. Eucaryotic chimeric cells synthesize foreign proteins with correct primary structures but with different sugar motives, which might result in inactive proteins, or molecules with different pharmacokinetics. Tailoring the biochemical profile of cells and organisms in order to made "good" glycosilators, and the custom glycosilation of proteins in vitro will be one of the future developments of biotechnology, and it will be based on the fundamental biochemical framework laid by Leloir and his school.

All useful science is applied. The "applicability" of a scientific discovery is a function of its usefulness. This is the only real standard against which scientific results are measured in the civilized world. Mainstream scientific results are always applied. In fact, applicability is what defines the usefulness of a theory, from mathematics to biology.

The Development of Underdevelopment

During the first half of this century, Latin America had a very limited biomedical scientific activity, but some of it was peculiarly original and generated results that were extremely useful. This success story was made with very limited funding.

In Argentina, the school of Houssay (Nobel Prize) flourished with Braun Menendez, Leloir (Nobel Prize), and De Robertis. Caldeyro-Barcia, another student of Houssay, made pioneering contributions to obstetric physiology in Montevideo, Uruguay. Monje and Huidobro revolutionized the physiology of high altitudes in Peru. Brazilian pharmacology, inspired and led by Rocha e Silva, was astounding. Whittembury in Venezuela played a pivotal role in modern kidney physiology, and Mexican clinical cardiology excelled.

An important question to be asked is why Latin American science has became lately so stale and sterile, even though the amount of money invested in science and the number of active scientists in the region have grown markedly since the 1960s. This is a phenomenon that merits a systematic study: the more attention was given to science and the louder the insistence on "applied" science programs, the more insignificant and trite became its returns.

On the other hand, during the last twenty years Latin America experienced a remarkable increase in the rate of expatriation of scientists, due to the combined effect of bloody

military dictatorships, the obsolete and crystallized university structures, and the economic debacle of the region.

The new great exploits of Latin American biomedical scientists were made abroad. Benacerraf, (Nobel Prize, Venezuela), Yunis and Llynas (Colombia), Sabatini, Poljak, Solbrig and Milstein (Nobel Prize, Argentina) did their pioneering work abroad. This also holds true for physics and mathematics.

Since Latin America's science was so fertile and Latin American-born scientists working in the First World play protagonistic roles in molecular biology and biotechnology, the present regional inadequacy cannot be attributed to genetic factors. This discrepancy of a performance indicates that our problems are environmental. The same argument holds for the rest of the Third World.

Therefore, the problem that we are facing with biotechnology is more political than scientific. We need to create a new environment in which useful science can thrive again. This is the necessary condition for any meaningful development in biotechnology.

The Sin of Complacency

Underdeveloped countries depend entirely on imported technology, have a much reduced capacity for technological innovation, and have very weak higher education and scientific establishments. However, their governments periodically assert their wish to develop, by themselves, very ambitious programs in different technological areas, including biotechnology.

In the last decade, practically the whole region expressed its wish to carry out a policy of substitution of imports of biological agents elaborated by the methods of genetic engineering. Two of the more talked-about targets were insulin and interferon. It is obvious that few of these programs have reached industrial maturity, and none of them have succeeded so far in having these recombinant proteins in the marketplace.

This sad reality apparently does not deter most of the scientific planners, administrators, and scientists of these countries, who stubbornly insist that they have the manpower and the know-how needed for carrying on their plans without any sort of external help.

While in the central countries there is a permanent and anguished analysis of the quality of their science education and the real performance of their high schools, universities, and research institutions, neither the governments nor the private sector of the Third World care about the poor quality of their schools and universities, and about their scant and mostly irrelevant scientific production (Table 6).

This pervading indifference results in the continuous deterioration of higher education and in the public and private funding of local projects which are condemned to failure due to the sheer lack of people able to conduct them.

In fact, this uncritical confidence has acquired ideological overtones. Any industrial project that explicitly considers the collaboration with, or the hiring of, research boutiques of the central countries to reach a new, real, and competitive biotech product, is labeled as "contrary to the national interests." Enterprises and scientists that propose this sort of project are marginal, and if and when they are carried out, they are almost clandestine operations that might result in the improved commercial performance of a particular enterprise but do not leave to the country any technological and/or educational benefit.

Table 6
The Different Meanings and Motivations of Science

The First World	The Third World
Science and technology are the basis of commercial, political, and military hegemony.	Science and technology are not needed because there are no explicit objectives for commercial, political, and military hegemony.
Science is absolutely needed to maintain industrial competitiveness and preserve national security, through the development of original technology.	Industrial competitiveness is based on low wages, the exploitation of the working force, and weak regulatory environments. All relevant technology is imported.
The social validation of science is total. The population at large knows that money invested in research results in concrete technological progress and strengthening of national security.	The population knows that the useful science is made abroad, and that all technological innovations and useful developments stem from foreign research.
Governments shape their science priorities according to the needs of the national economic policies.	Countries do not have global economic policies.

As soon as genetic engineering became a reality, the pharmaceutical and chemical corporations admitted their ignorance of molecular biology and established an agenda for solving this key problem.

They made strategic alliances with the budding biotechnological start-ups to learn molecular biology and modern immunology, and jointly developed the new biochemical and engineering protocols required for the scaling up of the production of new biotech products. To secure permanent access to the technological frontiers, they either acquired interests in biotech companies, or directly bought those which they needed most.

Simultaneously, they revamped their obsolete corporate research laboratories, and made strategic alliances with the leading research universities of the world, both national and foreign. They built new research institutes in the best universities, helped in the formation or the consolidation of new university departments, and funded projects involving whole departments.

As a result of this policy, the pharmaceutical and chemical corporations of the First World now have access to practically all the emerging biochemical, biophysical, and genetic technologies, are able to recycle their scientific staff in the leading research departments of the best universities, secure automatic consulting from the leading experts to solve technical problems and detect future trends, and have secured wide, strategic windows to follow closely and intently the new scientific developments which are sprouting at a tremendous speed in all relevant areas of biology. In this way, the results of public and corporate-sponsored research are quickly appropriated and transformed in costly, highly competitive products for the national and international markets.

Complacency and futile pseudonationalism combine very efficiently to sterilize real biotechnological development. It would be not at all surprising if the regional biotechnological "joint ventures" of the future will consist in the local packaging of products designed and produced in the First World. Once the technology involved becomes trivial,

some products will eventually be manufactured in the Third World, while the new generations of biotech drugs will necessarily be imported at high costs.

The presumptuous arrogance of underdevelopment is a condemnation to failure.

The Internationalization of Research in the First World

The corporations of the First World have long realized the strategic need of tapping the worldwide spread of expertise and talent, crossing national boundaries to take advantage of the intellectual excellence of their competitors (Table 7).

Their foreign research institutes, directed by eminent scientists, are situated near key foreign universities and centers of excellence. They recruit local talent, follow the trends of science, and learn about the new discoveries.

Table 7
The Universalization of Corporate Research

Corporation	Country	Research Institute
I.B.M.	U.S.A.	Tokyo, Japan
		Kanagawa, Japan
		Zurich, Switzerland
Du Pont	U.S.A.	Yokohama, Japan
SmithKline & Beckman	U.S.A.	Welwyn, U.K.
Parke-Davis	U.S.A.	Cambridge, U.K.
		Mississauga, Canada
Monsanto	U.S.A.	Oxford, U.K.
E.R. Squibb	U.S.A.	Oxford, U.K.
Dow	U.S.A.	Gerenzano, Italy
		Strasbourg, France
Cetus	U.S.A.	Amsterdam, Holland
Pfizer	U.S.A.	Sandwich, U.K.
		Tokyo, Japan
Merck	U.S.A.	Quebec, Canada
Hoechst	West Germany	Cambridge, MA, U.S.A.
Boehringer Ingeleheim	West Germany	Ridgefield, CT, U.S.A.
BASF	West Germany	Boston, MA, U.S.A.
Schering	West Germany	Cambridge, U.K.
Fidia	Italy	Washington, DC, U.S.A.
ENI	Italy	Princeton, NJ, U.S.A.
Glaxo	U.K.	Durham, NC, U.S.A.
Burroughs Wellcome	U.K.	Durham, NC, U.S.A.
Hoffman-La Roche	Switzerland	Nutley, NJ, U.S.A.
Ciba-Geigy	Switzerland	Summit, NJ, U.S.A.
Sandoz	Switzerland	Summit, NJ, U.S.A.
		Palo Alto, CA, U.S.A.
		London, U.K.
Nestle	Switzerland	Paris, France
Rhone-Poulenc	France	Princeton, NJ, U.S.A.
Pharmacia	Sweden	La Jolla, CA, U.S.A.

J.G. Bednorz and K.A. Muller, the 1988 Nobelists in physics, work at the Zurich I.B.M. research laboratory. The great attraction of Zurich is its Polytecnic, one of the most powerful research centers in cybernetics, physics, and chemistry in Europe.

The Hoechst Institute of Molecular Biology is in the Massachusetts General Hospital, the most important research hospital of the United States, affiliated with the extraordinarily strong Harvard Medical School.

The Roche Institute of Molecular Biology, one of the leading centers in molecular biology and neurosciences in the United States, is related by multiple links with the main universities of the East Coast.

The Fidia-Georgetown Institute of the Neurosciences, functioning in Georgetown University School of Medicine, taps the great intellectual resources of the experts in neurochemistry working at the U.S. National Institutes of Health and the U.S. National Institute of Mental Health.

E.R. Squibb and Monsanto went to Oxford to have access to the talented British school of pharmacology and the expertise in glycoproteins of the University's department of biochemistry.

BASF is constructing its $60 million biotech research laboratory near Boston, because of the strategic advantage conferred by the proximity of M.I.T., Harvard University, the Massachusetts General Hospital, and the Dana Farber Institute for Cancer Research.

While the central countries go beyond their frontiers to maintain their competitivity, underdeveloped countries, which lack expert scientific personnel in all areas of modern biology and are practically devoid of research universities, curiously insist on preserving their scientific "independence" and their technological "purism." The result, as history shows, is almost no relevant science, certainly no frontier technology, and a continuous loss of people, ideas, and data.

Dubious international research agreements open the few active spots of the underdeveloped research establishments to the central countries, which absorb gratis people and data, in return for some charity sojourns in prestigious laboratories. The scientists of the periphery gratefully accept these invitations to work in decent surroundings for a short while, with salaries that, although very modest by First World standards, allow them to save some strong currency. This means a lot when translated into the debased currencies of their native countries. Thus, research priorities are subtly shaped, and the intellectual and financial resources of the periphery become tightly harnessed to the interests of the center.

In short, while First World countries go abroad to expand their access to the frontiers of useful knowledge, the Third World establishes international cooperation agreements that result in the deepening of dependence and in the loss of eventually significant information.

The Scientific Isolation of the Third World

In January 1988, some of the leading molecular biologists of the world gathered in Tokyo, under the auspices of the leading scientific journal *Nature*, to debate the present and future of molecular biology (Newmark 1988). The width and the scope of their discussion was fantastic, ranging from mapping and sequencing of the human genome to protein engineering. All the subjects had obvious industrial and commercial applications.

Similar events occur weekly in the First World, covering the most diverse areas in

fundamental biological sciences. Many of these conferences have relevance for the Third World, because they deal with problems related to the production and industrial use of raw materials and staples that underdeveloped countries export and which constitute their main source of income. Since the Third World is not in the mainstream of contemporary biology, few of its scientists are invited to participate in these conferences. They are not in the audience, because the scientific administrators of debt-ridden countries cannot afford financing costly foreign trips while the salaries of their scientists decay and lack enough budget for maintaining their laboratories operational.

Many of the scientific programs discussed in these conferences sooner or later will become incorporated into technologies that more likely than not will affect the economies of the Third World. However, the politicians, the economists, and the diplomats of underdeveloped countries do not grasp the vital importance of learning the strategic scientific planning of the central countries and the need of keeping abreast with the scientific trends of the First World.

In the underdeveloped world everyone dreams of technological forecasting, a sterile and utterly unsuccessful activity. On the other hand, there is almost no evaluation of the impact of known and developing technologies on their economic life, which is not only possible to analyze, but of priority interest.

As a result of this combination of poverty and ignorance, the Third World fares blindly in the midst of explosions of knowledge and power that will mean the inexorable deepening of their social, economic, financial, and political disasters.

A Tale of Two Sciences

For the First World, ever since the seventeenth century, the creation of scientific schools and the generation of scientific results of the highest quality were strategic objectives. Science has always been the mainstay of the military, commercial, and financial power of the central countries, the basis of their colonial and neocolonial expansion, and the ultimate element of negotiation and control first in the intercapitalist struggles for hegemony and later in their relations with their global adversaries.

Since its inception, modern science has always been concerned with the technical problems of its day. As J.D. Bernal pointed out, the revolutionary technological innovations that broke the medieval means of production raised an extraordinary array of new problems that modern science was created to solve. And it succeeded, indeed, in proving its worth, and became an integral part of the new civilization (Bernal 1974).

The colonies, however, were systematically excluded form science and technological innovation and remained scientifically blind. At most, their technicians (engineers, physicians, and chemists) were trained to assemble and eventually adapt and keep running the imported technologies—from railroads to therapeutic drugs.

The former colonies are still hostage to the central world, which preserves their scientific weakness and their technological dependence. In most of them, science and technology became national issues only in the last few decades. In general, these attempts to develop scientific establishments fit into the general picture of the "modernization" campaigns, in which scientists are token symbols of progress—like modern airports, jet airliners, skiing, automated bank tellers, fax machines, tennis, and jeans.

On the other hand, some underdeveloped countries have been struggling to remedy the ruinous tradition of scientific neglect and illiteracy inherited from the colonial era. They have devoted important budgets—relative to their gross national product—to the

creation of a minimal scientific structure. However, the fact remains that these new scientific establishments are alien to the main political, economic, and social forces that shape their countries.

Scientific production in underdevelopment has no practical effect. The better Third World scientists are, the more isolated they become in their own countries. Neither the politicians and their economic advisors nor the industrialists understand the practical implications of excellent, useful, fundamental science. Useful scientific results are not recognized as such by the social body, and are taken—gratis—and incorporated into the science, the technology, and the products of the First World. Science and scientists drift away with beautiful automaticity, and the Third World is still unable to estimate the extent of the intellectual treasures given away.

In the underdeveloped world, nobody who matters cares about local science. The industrial sector depends on foreign technology for making whatever it does, and the top industrial and engineering aspirations are "adaptation" and "import substitution." Exports' competitiveness is based on reduced labor costs and modernization of the productive structure by the incorporation of modern foreign technology. Not a single drug has been invented and developed in the Third World. Latin America imports everything that has strategic meaning, from jumbo jets to chemical catalysts for the petrochemical industry.

The Latin American economists who struggle with the problems of foreign debt do not consider indigenous science a sensible investment, or a strategic element for our economic survival. They do not have experience in planning and managing economies in which science is a prime mover. They are administrators of low-value exports, trained in the commercialization of products derived from rutinary technologies, and now are becoming experts in borrowing and negotiating decay. These activities are science-free.

And they are not to be blamed for this indifference. The social validation of science depends exclusively on the capacity of science to solve problems, to perform a socially useful service. Yet everyone in the Third World—from the humblest peasant to the negotiator of multibillion dollar loans—believes that the existence or the absence of local science is wholly irrelevant to their lives. The Third World does not have any scientific and economic success story for the social validation of its local science. We have learned this through very clear social experiments. It is well known that every coup d'etat in Latin America resulted in the massive loss of its best scientists, but the existence or nonexistence of science did not modify the daily performances and miseries of the population in any measurable way.

Life in Argentina did not change when Cesar Milstein and his collaborators were sacked in 1963, in spite of the fact that they were trying to create the first group in molecular biology on the continent. At that time—only ten years had elapsed since the publication of the pivotal Watson and Crick papers—the hot race for the control of molecular biology in areas like immunology was barely starting. Milstein went back to Cambridge and proceeded to make fundamental contributions to protein chemistry and molecular immunology, which culminated in the momentous achievement of monoclonal antibodies.

For a central country, the departure of Milstein and his group would have been an event with tragic implications. Losing the seed of molecular biology would have meant condemnation to death for the pharmaceutical industry of the twenty-first century. However, the Argentine pharmaceutical industry—owned either by foreign corporations or dedicated to import and copy drugs developed abroad—did not care about the existence

or the absence of a group working in "esoteric" and "theoretical" subjects such as molecular biology and chemical immunology. In this everybody coincided, both in the "left" and in the right of the political spectrum: molecular biology was an intrinsically pointless activity, totally unrelated to the "real" priorities of a "developing" country.

Likewise, life in Argentina continued unruffled in 1966 when more that three hundred mathematicians, physicists, and chemists left the country after the brutal police attack against the School of Sciences of the University of Buenos Aires. The massive emigration furnished scores of distinguished professors to the universities of the First World but did not modify a bit the commercial, industrial, and political events of the country. Why should anyone care about high-quality mathematics and physics, in a country without a single real national security problem and lacking a single world-competitive industry based on original science and technology?

Periodically, Third World governments and their economic teams are criticized for not making long-range scientific plans. This criticism reflects the basic lack of understanding of the political economy of science. A meaningful science planning can emerge only if a country needs original technology to survive. Technological needs imply a commitment to a struggle for industrial preeminence, global competitiveness, and military independence. This is something that has yet to happen in the Third World. Our science may be good or bad, but is not perceived as a real need by our political and industrial leaders. Accordingly, when budgets need to be cut, the moneys for science are the unwanted fat. This completes the trap, because even the barest intellectual activity is dimmed, and new waves of expatriations are triggered.

The International Organizations and Third World Biotechnology

Huge foreign debts, hyperinflation, depressed economies, and falling commodity prices induce the trimming of science budgets in many Third World countries. Consequently, scientists and scientific administrators are forced to look for new sources of funding. The international organizations are such a source, because they provide much-welcomed loans for research programs.

Many of the officers of the international organizations involved in the financing of scientific projects and programs are not scientists, and their approach to problems of science and technology is highly theoretical. They lack experience in actual research and are alien to the complexities created by the intertwining of scientific, technological, and commercial interests that make the picture of contemporary science so difficult to manage. This profile, coupled with the lack of any real social demand for a functioning and useful scientific establishment, puts them in a very difficult position.

Although the officers of the international organizations deal with underdeveloped countries, they live and work in the central countries. Not being scientists and unable to understand the technicalities of the projects they manage, they look for scientific and technological advisors among the top scientists and technologists of the First World. With the best of intentions, they select the best experts, who may be masters of their subjects but who are wholly unfamiliar with and often uninterested in the realities of underdevelopment. Their advice might be technically correct, but often is politically, socially, and economically unwise.

Yet expertise in molecular biology nowadays means commercial interests, a fact of life that the officers of international organizations seem not to take into account, or delib-

erately ignore. The better the expert, the more likely is the existence of connections with biotechnological firms and great corporations. Political leaders of the Third World in general do not pay a lot of attention to problems related to science and scientists. The result is that the political and commercial implications of the recommendations of the experts and the programs approved seldom receive much attention. Contributions for scientific development are considered, by definition, to be untouched by worldly interests and hence politically benign.

This fundamental misconception leads to the adoption of all sorts of programs colored by a gentle scientism, mostly unrelated to the real problems of underdevelopment. Money is spent by the millions in the acquisition of equipment which inexorably ends up reinforcing the pundits of the scientific establishments or rots in its cases for years. Something similar happens with the programs of scientific cooperation with developed countries. The perspective of having some money for equipment and the possibility of traveling opens all doors.

Accordingly, the international organizations and the developed countries become important elements in the formulation of science policies in the Third World. Nobody asks the key question: who really benefits from all this?

After a relatively slow start, the international organizations became interested in biotechnology, and—willingly or unwillingly—they joined the biotech propaganda blitz.

Their first move was making censuses of scientists and technologists in Latin America. It is hart to find a single international organization that has not yet made at least one of these head counts by enumerating the people listed as professors and scientists in the payrolls of universities and other research institutes. Body counting has become a popular activity among the sociologists and administrative officers of the national research councils of the Third World. Several of these catalogues have already been made in Latin America, and they are all useless.

Body counts certainly are not the way to evaluate the scientific capabilities of any country, and especially those in the underdeveloped world, where many administratively recorded professors or scientists would not qualify as such in the First World.

In the central countries, evaluations are necessarily serious, because they are intended to gauge the development of a discipline and to correct possible mistakes and weakness. The David Report on the state of the U.S. mathematical sciences, made by the U.S. National Science Council, was a landmark analysis elaborated by a team of distinguished American mathematicians. The report dissected the great accomplishments and exposed the grave problems besetting contemporary American mathematics. It was based on the estimation of the relevance of the work of departments, schools, and programs, as measured by the usefulness of results and theories in the context of the advancement of mathematics and its applications. The importance of these critical reviews lay precisely in the fact that they were value judgments made by top experts, technical evaluations of performance, and as such, outspoken, explicit, and brutal.

This type of evaluation contrasts with the uncritical body counts produced by the international organizations and the scientific administrators of peripheral countries. The listings reflect only the political history of the region, i.e., the instability, the exclusions, and the massive expatriations.

In many countries, the scientific establishments are made up of scientists who remained during periods of repression and civil disaster. They are not the best, but they still control the money, the university positions, the scientific councils, and the international scientific relations. The empty numerology of the body counts contributes to the perpetuation of the hoax and amounts to an implicit endorsement of the status quo.

The Consolidation of "Priorities"

By uncritically financing national and multinational programs covering the usual array of biomedical "priorities" of underdevelopment, the international organizations actively contribute to the direction of people and efforts toward trivialities.

Instead of helping to create the conditions needed for the emergence of good science and educating the politicians, economists, administrators, and industrialists in the realities and problems of high technology, this policy perpetuates the disaster and accentuates the ever-increasing gap between the North and the South.

Diagnostic kits, the brainless screening of antiparasitic drugs, the field testing of new vaccines, the micropropagation of plants, and the establishment of open gene banks are all diversionary moves that bring out of focus the real strategic problem that the Third World must face for its survival: the lack of scientific excellence.

The international organizations are strong proponents and backers of international courses on topics related to molecular biology and biotechnology. These courses increase the contact between biomedical researchers in Latin America, who can visit each other in different countries and learn about new technologies and experimental systems. Foreign experts can meet their Latin American friends and their graduate students and establish good personal links.

All this is very important indeed, but unfortunately, learning "modern" techniques and confraternization do not remove the main educational obstacle that hinders the development of Third World biotechnology: its decaying universities.

The cost/benefit ratio of most of the courses is rather high. It is not easy to pinpoint concrete new biotech developments and/or products originated in them. It may also be worthwhile to examine critically the urgency and the political meaning of these types of courses.

New techniques soon become routine. Ten years ago a DNA sequence was a scientific feat, yet nowadays it is a trivial protocol done by a low-level technician (who is difficult to find and retain because of the tedious nature of the job), and tomorrow will be done automatically by a machine. The heroic accomplishments of the past suddenly are a triviality. Moreover, if the techniques are not used, learning them is a useless exercise of style. How many gene sequences have been made in Latin America by alumni of the international courses of DNA sequencing?

On the other hand, courses are not offered on the design of machines for the automatic sequencing of polynucleotides, covering their open problems in chemistry, cybernetics, electronics, and micromechanics. But would anyone involved in the design of frontier technologies in molecular biology come to Latin America of any other region of the world to discuss candidly its research? We know perfectly well that the answer is no! These subjects have a huge profit value, because they are strategic pieces in the battle for competitive advantage in the international marketplace. We will be drowned by a deluge of courses to sell us the expensive machinery once it is ready. The Third World is a target for these machines, because they will be bought with glee, and many will join the fate of so many other dream instruments that can be detected, unused and forgotten, in run-down labs.

It is much cheaper to send people to learn the new techniques in the First World and later organize local courses for those interested in learning it from scratch, at home, and without frills. The money wasted in air tickets and hotel rooms could be better spent bringing top experts in strategic areas to teach complete courses of various lengths to undergraduate students and research workers, in order to compensate the gross deffi-ciencies of the local faculties in most of the strategic topics of modern biology.

The International Centers of Biotechnology

To speed up the building of biotech capability of the underdeveloped countries, a group of international organizations have created two institutes of biotechnology for the Third World.

Centers of this nature pose new and baffling questions. Their pros and cons should be seriously discussed by the countries concerned, to establish their political and economic risks and to evaluate their technological and technical usefulness.

One of the most important factors in the molecular biology of the biotech era is the stiff secrecy and patenting that protects most projects and results, which are often funded by industrial grants. In the powerful research universities of the central countries, one of the main tasks of the doctoral thesis advisors is to train their graduate students in the art of not releasing information because of its proprietary value.

But here we are confronted with an amazing situation: underdeveloped countries are encouraged to send their scientists to research institutions to create new biotech products in an international setting where secrecy is by definition excluded. These centers will attract top Third World scientists and graduate students who will produce interesting results in an unprotected setting. Since the research subjects of these institutions will necessarily be related to biomedical, veterinary, and agricultural problems that affect a huge number of people, valuable animals, and crops, any useful result could mean a product for a huge marketplace.

What is at risk is the germplasm. The agrochemical and pharmaceutical corporations will be able to tap freely this reservoir of genetic information and knowledge, obtaining data and genetic information pertaining to many interesting and potentially profitable organisms. If something important is ever discovered, they will be free to appropriate the results. Drugs and procedures could then be developed in the protected environment of the corporate laboratories. Any successful product will generate money for the corporations, and the country that financed the initial research will not profit at all.

This scenario elicits a disturbing sensation of déjà vu. It has a strong family resemblance to the International Centers of Plant Breeding, the most efficient machines ever invented by the First World for the subtraction of germplasm from the Third World.

We have all the reasons, then, to be worried about the creation of the international centers of biotechnology, designed and implemented by international organizations. There are many reasons to reject the inherent sanctity of these organizations. Although in many instances their work has been useful, and some of their former officials have played historical roles in the defense of the Third World, it is also true that they have been used as umbrella organizations for the international corporations. This institutionalization of germplasm robbery was organized in the offices of an international organization, and the most recent clandestine experiment of environmental release of a recombinant vaccinia-rabies virus in Argentina was performed under the auspices of another international organization. Moreover, many of the highly qualified scientists that they use as consultants are connected with the biotech industry.

We do not need international technological institutes to shape our biotechnology. We need to develop our local capability in molecular biology and modern biomedical and agricultural sciences and then build up our own biotech institutes—in the Third World and in the First World—to design and produce new drugs. Third World countries contribute their share to the international organizations and are entitled to discuss their objectives, check their policies, publicly debate their strategies, and review with utmost

care the financial, political, and economical implications of these and other similar projects of international cooperation.

The underdeveloped countries must act to turn the international organizations into important instruments of progress and correct those traits that make them powerful enhancers of underdevelopment.

Yet dependency and underdevelopment are political issues, not scientific problems. Science and technology obey their political and economic masters, and not vice versa. Without real policies toward development, the science and technology of the Third World will remain as they are now.

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References

Abelson, P.H. 1988a. World competition in biotechnology. *Science* 240:701.

———. 1988b. Competitiveness: Along-enduring problem. *Science* 241:865.

———. 1988c. Improving U.S. capabilities in technology. *Science* 242:493.

———. 1987a. Export controls of high-technology goods. *Science* 235:1297.

———. 1987b. World food. *Science* 236:9.

Alberts, B., D. Bray, J. Lewis, M. Raff, K. Roberts, and J.D. Watson. 1989. *Molecular biology of the cell.* New York: Garland Publishing.

Antia, N.H. 1988. Indo-U.S. Vaccine Action Program. *Nature* 335:584.

Antonarakis, S.E. 1989. Diagnosis of genetic disorders at the DNA level. *New England Journal of Medicine* 320:153–63.

Arroyo, G., R. Rama, and F. Rello. 1985. *Agricultura y alimentos en America Latina.* Mexico D.F.: Universidad Nacional Autonoma de Mexico.

Barber, E.G. and R.P. Morgan. 1987. The impact of foreign graduate students on engineering education in the United States. *Science* 236:33–37.

Barton, J.H. 1982. The International Breeder's Right System and crop plant innovation. *Science* 216:1071–75.

Baxter, J.P., III. 1968. *Scientists against time.* Cambridge: M.I.T. Press.

Bernal, J.D. 1971. *Science in history.* Cambridge: M.I.T. Press.

Bloch, E. 1986. Basic research and economic health: The coming challenge. *Science* 232:595–99.

Bloomberg, C.A., S.J. Marylander, and P.M. Yaeger. 1987. *New England Journal of Medicine* 317:565–67.

Blumenthal, D., M. Gluck, K.S. Louis, M.A. Stoto, and D. Wise. 1986a. University-industry research relationships in biotechnology: Implications for the university. *Science* 232:1361–66.

Blumenthal, D., M. Gluck, K.S. Louis, and D. Wise. 1986b. Industry support of university research in biotechnology. *Science* 231:242–46.

Borst, P. 1983. Antigenic variation in trypanosomes. In *Mobile genetic elements,* J.A. Shapiro. New York: Academic Press.

Bourke, J. 1988. The new classified research: Corporate sponsored research and the reign of secrecy at Harvard University. *Harvard Watch.*

Bouton, K. 1983. Academic research and big business: A delicate balance. *New York Times Magazine,* 11 September.

Braben, B.W. 1985. Innovation and academic research. *Nature* 316:401.

Brady, N.C. 1985. Agricultural research and U.S. trade. *Science* 230:499.

Brattsen, L. B., C.W. Holyoke, Jr, J.R. Leeper, and K.F. Raffa. 1986. Insecticide resistance: Challenge to pest management and basic research. *Science* 231:1255–60.

Browne, M.H. 1987. Bringing up scientists. *New York Times,* 1 September.

Bull, A.T., G. Holton, and M.D. Lilly. 1982. *Biotechnology: International trends and perspectives.* Paris: OCDE.

Chang, H-p. 1964. *Commissioner Lin and the Opium War.* New York: W.W. Norton & Co.

Comroe, J.H., Jr. 1977a. The evolution of biomedical science: Past, present and future perspectives. *Journal of Medical Education* 52:3–10.

———. 1977b. Roast pig and scientific discovery. Part I. *American Review of Respiratory Disease* 115:853–60.

———. 1977c. Roast pig and scientific discovery. Part II. *American Review of Respiratory Disease* 115:1035–44.

Comroe J.H., Jr., and R.D. Dripps. 1974. Ben Franklin and open heart surgery. *Circulation Research* 35:661–69.

Crespi, R.S. 1989. Claims on tissue plasminogen activator. *Nature* 337:317–18.

Crick, F.H.C. 1988. *What mad pursuit.* New York: Basic Books.

———. 1966. *Of molecules and men.* Seattle: The University of Washington Press.

Djerassi, C. 1984. Making drugs (and soaking the poor?) *Nature* 310:517.

Dahlberg, K.A. 1987. Redefining developmental priorities: Genetic diversity and agrodevelopment. Paper presented at Annual Meeting of the American Association for the Advancement of Science.

Dickson, D. 1987. America's seductive charms. *Science* 237:1107.

Di Prisco, M.C. and Y. Texera, eds. 1986. *Biotecnologia: Oportunidades para Venezuela.* Caracas: Fondo Editorial Acta Cientifica Venezolana.

Dixon, B. 1976. *What is science for?* Harmondsworth: Pelikan Books.

Evans, P. 1979. *Dependent development: The alliance of multinational, state, and local capital in Brazil.* Princeton: Princeton University Press.

Finkielman S., C.L. Fischer-Ferraro, A. Diaz, D.J. Goldstein, and V.E. Nahmod. 1972. A pressor substance in the cerebrospinal fluid of normotensive and hypertensive patients. *Proceedings of the National Academy of Sciences U.S.A.* 69:3341–43.

Fischer-Ferraro, C.L., V.E. Nahmod, D.J. Goldstein, and S. Finkielman. 1971. Angiotensin and renin in rat and dog brain. *Journal of Experimental Medicine* 133:353–63.

Frank, A.G. 1979. *Dependent accumulation and underdevelopment.* New York: Monthly Review Press.

Galeano, E. 1984. *Las venas abiertas de America Latina.* 3d ed. Mexico D.F.: Siglo Veintiuno Editores.

Garcia, R.V. 1982. *Drought and man: The 1972 case history.* Vol. I, *Nature pleads not guilty.* Oxford: Pergamon Press.

The genetic alternative. 1988. *The Economist,* 30 April.

Gereffi, G. 1983. *The pharmaceutical industry and dependency in the Third World.* Princeton: Princeton University Press.

Giovanni, G. 1980. *A questao dos remedios no Brasil: Producao e consuma.* Sao Paulo: Polis.

Gladwell, M. 1988. Scientist warns of U.S. reliance on foreigners. *Washington Post,* 6 September.

Goldberg, R.B. 1988. Plants: Novel developmental processes. *Science* 240:1460–67.

Goldstein, D.J. 1988. Molecular biology and the protection of germplasm: A matter of national security. In *Seeds and sovereignty,* ed. J. Kloppenburg, Jr., Durham and London: Duke University Press.

———. 1987a. Crystallography, protein engineering, and industry. Paper presented at Annual Meeting of the American Association for the Advancement of Science.

———. 1987b. Un comentario sobre "Biotecnologia: oportunidades para Venezuela." *Interciencia* 12:254–55.

———. 1986a. Biotechnology in underdevelopment. *Bio/Technology* 4:672.

———. 1986b. Molecular tagging of plants and the protection of germplasm. Paper presented at Annual Meeting of the American Association for the Advancement of Science.

———. 1985a. Biotecnologia, agricultura y paises en desarrollo. In *Biotechnology in the Americas II: Applications in tropical agriculture*. San Jose de Costa Rica: CONICET/Interciencia.

———. 1985b. New patents in biotechnology: Their impact in Latin America. In *Biotechnology and food systems in Latin America*. San Diego: Center for U.S.-Mexican Studies, University of California at San Diego.

———. 1984a. Las Prioridades cientificas y politicas latinoamericanas en biotecnologia. Interciencia 9:242.

———. 1984b. Latin America: three case studies. *Advance Technology Alert System Bulletin* 1:36–39.

———. 1984c. The biotechnological challenge: To be or not to be like Eduardo S. Bradford. *Interciencia* 9:188–89.

———. 1983. *Problemas para et desarrollo de una biotecnologia autonoma en America Latina* Washington, D.C.: Pan American Health Organization.

Goldstein, D.J., C.L. Fischer-Ferraro, V.E. Nahmod, and S. Finkielman. 1970. Angiotensin I in renal and extra-renal tissues. *Medicina (Buenos Aires)* 30:81–83.

Goodman, R.M. 1986. New technology and its role in enhancing global food production. *FASEB Journal* 45:2432–37.

Goodman, R.M., H. Haupti, A. Crossway, and V.C. Knauf. 1987. Gene transfer in crop improvement. *Science* 236:48–54.

Gladwell, M. 1988. AIDS vaccine dilemma: Who pays if there are lawsuits? *Washington Post,* 25 November.

Halstead S.B. 1988. Pathogenesis of dengue: Challenges to molecular biology. *Science* 239:476–81.

Hatsopoulos, G.N., P.R. Krugman, and L.H. Summers. 1988. U.S. competitiveness: Beyond the trade deficit. *Science* 241:299–307.

Hobsbawm, E.J. 1968. *Industry and empire*. Vol. 3. Harmonsworth: Penguin Books.

Horowitz, Z.P. 1981. *Angiotensin-converting enzyme inhibitors: Mechanism of action and clinical implications*. Baltimore and Munich: Urban & Schwarzenberg.

Investments with an eye on the future. 1988. *Nature* 336:323–24.

Jaenisch, R. 1988. Transgenic animals. *Science* 240:1468–74.

Jaffe, A.M. 1985. Ordering the universe: The role of mathematics. *Notices of the American Mathematical Society*.

Katz, J.M. 1974. *Oligopolio, firmas nacionales y empresas multinacionales: La industria farmaceutica Argentina*. Buenos Aires: Siglo Veintiuno Editores.

Kenney, M. 1986. *Biotechnology: The university-industry complex*. New Haven: Yale University Press.

Klein, L.R. 1988. Components of competitiveness. *Science* 241:308–13.

Kloppenburg, J.R., Jr. 1988. *First the seed. The political economy of plant biotechnology 1492–2000*. New York: Cambridge University Press.

Knight, P. 1989. The carbohydrate frontier. *Bio/Technology* 7:35–40.

Koshland, D.E., Jr. 1988. Economic arteriosclerosis and competitiveness. *Science* 240:701.

———. 1986. *Biotechnology: The renewable frontier*. Washington D.C.: American Association for the Advancement of Science.

Krimsky, S. 1986. The new corporate identity of the American University. *Alternatives* 12:20–29.

Lamming, G.E. 1988. Farming biotechnology. Regulating growth of animals. *Nature* 336:19–20.

Lattes, A.E., and E. Oteiza. 1986. *Dinamica migratoria argentina (1955–1984): Democratizacion y retorno de expatriados* Geneve: United Nations Institute for Social Development.

Lederberg, J. 1986. A fortieth anniversary reminiscence. *Nature* 324:627–28.

Leloir, L.F. 1981. Cycles in polysaccharide biosynthesis. *Current Topics in Cellular Regulation* 18:211–20.

Levins, R. 1974. Genetics and hunger. *Genetics* 78:67–73.
Lewin, R. 1988. Costa Rican diversity. *Science* 242:1637.
Lock, S. 1988. *Nature* 336:278.
Lwoff, A., and A. Ullman. 1979. *Origins of molecular biology: A tribute to Jacques Monod.* New York: Academic Press.
Mansfield, E. 1988. Industrial innovation in Japan and in the United States. *Science* 241:1769–74.
Mares, M.A. 1986. Conservation in Latin America: Problems, consequences, and solutions. *Science* 233:734–39.
Mac Leod, R., and P.F. Rehbock. 1988. *Nature in its great extent. Western science in the Pacific.* Honolulu: University of Hawaii Press.
Marx, J.L. 1988. Gene watchers' feast in Toronto. *Science* 242:32–33.
———. 1984. Abzymes make the mark? *Science* 241:1164.
Mayr, E. 1982. *The growth of biological thought: Diversity, evolution, and inheritance.* Cambridge: Belknap-Harvard University Press.
McIntyre, A.R. 1972. History of curare. In *International Encyclopedia of Pharmacology and Therapeutics.* Oxford: Pergamon Press.
Miller, D.F. 1988. An internationalist focus. *Science* 242:119–20.
McGourty, C. 1988. Dangers of industrial domination of academic research. *Nature* 335:317–18.
McKeown, T. 1988. *The origins of human disease.* London: Basil-Blackwell.
Mintz, W.W. 1985. *Sweetness and power: The place of sugar in modern history.* Harmondsworth: Penguin Books.
Mooney, P.R. 1983. The law of the seed: Another development and plant genetic resources. *Developmental Dialogue* 1/2.
Munoz, J.M., E. Braun Menendez, J.C. Fasciolo, and L.F. Leloir. 1939. Hypertensin: The substance causing renal hypertension. *Nature* 144:980.
National Research Council. 1982. *Priorities in biotechnological research for international development.* 1982. Washington D.C.: National Academic Press.
Newmark, P. 1988. Horizons in molecular biology. *Nature* 331:401–2.
———. 1988. New vaccine and initiative mean end of rabies in sight in Europe? *Nature* 336:416.
Office of Technological Assessment. 1984. *Commercial biotechnology: An international analysis.* Congress of the United States, Washington, D.C.: U.S. Government Printing Office.
Olson, S. 1986. *Biotechnology: An industry comes to age.* Washington D.C.: National Academy Press.
Pearse, A. 1980. *Seeds of need, seeds of want: Social and economic implications of the Green Revolution.* Oxford: Clarendon Press.
Pena, M. 1968a. *Antes de Mayo.* Buenos Aires: Ediciones Fichas.
———. 1968b. *Alberti, Sarmiento y el 90.* Buenos Aires: Ediciones Fichas.
———. 1968c. *El paraiso terrateniente.* Buenos Aires: Ediciones Fichas.
———. 1968d. *La era de Mitre.* Buenos Aires: Ediciones Fichas.
———. 1968e. *De Mitre a Roca.* Buenos Aires: Ediciones Fichas.
———. 1968f. *Masas, caudillos y elites.* Buenos Aires: Ediciones Fichas.
Pluknett, D.L., N.J.H. Smith, J.T. Williams, and N.M. Anishetty. 1987. *Gene banks and the world's food.* Princeton: Princeton University Press.
Rappoport, E.H. 1987. *Lo bueno y lo malo tras et descubrimiento. El punto de vista ecologico y biogeografico.* Sevilla: Seminario En los umbrales delos grandes descubrimientos 1492–1992.
Reich, R.B. 1987. The raise of techno-nationalism. *Atlantic Monthly.*
Roberts, L. 1988. U.N. considers biodiversity convention. *Science* 241:1604.
Rocha e Silva, M., and H.A. Rothschild. 1974. *A bradykinin anthology.* Sao Paulo: Sociedade Bradileira de Farmacologia e Terapeutica Experimental/HUCITEC.
Rogers, E.M. 1977. *Physics for the enquiring mind.* Princeton: Princeton University Press.
Rose, H., and W. Rose. 1970. *Science and society.* Harmondsworth: Pelikan Books.

Rural Advancement Fund International Communique. 1989. *Microbial insecticides: Special focus on Bacillus Thuringiensis.*

———. 1988a. *Biotechnology and Indigo dye.*

———. 1988b. *Biotechnology and vegetable oil.*

———. 1988c. *New substitutes threaten to displace export market for water soluble gums.*

———. 1987a. *Animal patents.*

———. 1987b. *Cacao and biotechnology.*

———. 1987c. *Vanilla and biotechnology.*

———. 1987d. *Agricultural inputs in biotechnology.*

Sadosky, C., and D.J. Goldstein. 1986. Causes of emmigration of scientists from Latin America. Paper presented at Annual Meeting of the American Association for the Advancement of Science.

Schmeck H.M., Jr. 1988. Gene altered animals enter new commercial era: promise of foreign genes. *The New York Times,* 27 December.

Schmitt, R.W. 1984. Export controls: Balancing technological innovation and national security. *Issues in Science and Technology* 1:117–26.

———. 1988. Farmers to face patent fees for gene-transferred animals. *New York Times,* 6 February.

———. 1986a. Looking abroad to fill our bellies. *New York Times,* 3 August.

———. 1986b. Biotech's stalled revolution: Growing concern about genetic engineering has forced Monsanto to half a pesticide project. *New York Times Magazine,* 16 November.

———. 1986c. Argentina protests use of life vaccine by scientists of U.S. *New York Times,* 11 November.

Serre, J.-L. 1984. La genese de l'ouvre de Mendel. *La Reserche* 15:1073–79.

Shields, R. 1989. Moving in on plant genes. *Nature* 337:308.

Steen, L.A. 1989. Mathematics for a new century. *Notices of the American Mathematical Society* 36:133–38.

Straus, J. 1985. *Industrial property protection of biotechnological inventions: Analysis of certain basic issues.* Geneva: World Intellectual Property Organization.

Sun, M. 1988. U.S.-Japan science pact signed. *Science* 241:17.

———. 1986. Agricultural firms seek more patent protection. *Science* 232:151.

Swinbanks, S. 1987. What future now for Japanese biotechnology research? *Nature* 329:661.

Todorov, T. 1982. *La conquete de l'Amerique: La question de l'autre.* Paris: Seuil.

Timm, M. 1988. World Food Congress: Biotech yields better enzymes, crops, and pigs. *Bio/Technology* 6:14.

Tonn, R.J. 1988a. Review on recent publications on the ecology, biology and control of vectors of Chagas Disease. *Revista de la Sociedad Argentina de Microbiologia* 20(supp. 1): 4–24.

———. 1988b. Potential for research on vectors of Chagas Disease. *Revista de la Sociedad Argentina de Microbiologia* 20(supp. 1): 1–3.

Vaisos, C. 1972. Patents in less developed countries. *Journal of Developmental Studies* 9:76–85.

Van Brunt, J. 1988. Molecular farming: transgenic animals as bioreactors. *Bio/Technology* 6:1149–54.

Waddington, C.H. 1948. *The scientific attitude.* Harmondsworth: Pelikan Books.

Walbot, V. and G. Bruening. 1988. Plant development and ribozymes for pathogens. *Nature* 334:196–97.

Watson, J.D. 1968. *The double helix.* New York: Atheneum.

Watson, J.D., and F.H.C. Crick. 1953a. Molecular structure of nucleic acids: a structure for deoxyribose nucleic acid. *Nature* 171:737–38.

———. 1953b. Genetic implications of the structure of deoxyribonucleic acid. *Nature* 171:964–67.

Watson, J.D., N. Hopkins, J.W. Roberts, J. Argentsinger Steitz, and A.M. Weiner. 1988. *The molecular biology of the gene.* Menlo Park: Benjamin/Cummings Publishing Co., Inc.

Weiner, C. 1986. Universities, professors, and patents: A continuous controversy. *Technology Review* 1:34–43.

Weissman, R. 1988. Scholars, Inc.: Harvard academics in service of industry and government. *Harvard Watch.*

Weissman, R., and J. Bourke. 1988. Still a bad idea: A critique of Harvard University's medical science partners proposal. *Harvard Watch.*

Yanchinski, S.A. 1987. Boom and bust in the bio business. *New Scientist* 44–47 (22 January).

Young, S.A. 1988. Technology and competitiveness: A key to the economic future of the U.S. *Science* 241:314–16.

Zuckerman, H., and J. Lederberg. 1986. Postmature scientific discovery? *Nature* 234:629–31.