The Laws of Life

Another Development and the New Biotechnologies

By Gary Fowler, Eva Lachkovics, Pat Mooney and Hope Shand

Introduction

The Socioeconomic Impact of New Biotechnologies in the Third World

Statement by Amir H. Jamal

The 1987 Dag Hammarskjöld Seminar on 'The Socioeconomic Impact of New Biotechnologies on Basic Health and Agriculture in the Third World' was divided into two parts, a workshop with about 30 participants organized in the French village of Bogève outside Geneva and a symposium at the Palais des Nations in Geneva, where the workshop participants were joined by Third World ambassadors, representatives of different UN agencies and members of third system organizations concerned with the subject. The symposium was opened on March 12, 1987, by Ambassador Amir H. Jamal, Permanent Representative of Tanzania to the UN Agencies and other International Organizations in Geneva and Vienna. Dr Jamal, who served for many years as Minister for Finance and in other ministerial capacities in the Government of Tanzania, has been a Trustee of the Dag Hammarskjöld Foundation since 1977. His statement highlights some of the crucial problems confronting the Third World as a result of the new biotechnologies—problems of such a magnitude that they may well come to dominate the development discussion for the rest of this century.

I am privileged to have been closely associated with the Dag Hammarskjöld Foundation for a length of time. The Foundation has over the years initiated, organized, stimulated and encouraged basic work and thinking in fields of human endeavour at the heart of which has been a concern for global development. That it found itself, in the process, paying sustained attention to the needs of the Third World as a matter of high priority is not surprising at all. The very name it bears, that of Dag Hammarskjöld, has made the concern for the Third World its categorical imperative. Hammarskjöld dedicated his life to strengthening peace and through it development, because he believed that both peace and development were indivisible. In everything—and I say everything with deliberate emphasis—that the Foundation has undertaken either in its home in Uppsala or in Asia, Africa and Latin America, it has worked with countless committed men and women in promoting peaceful development and, in so doing, strengthening the United Nations system.

To mention only a few examples of the Foundation's activities, I would like to draw your attention to the 1975 Dag Hammarskjöld Report, *What Now: Another Development,* which as an independent contribution to the discussion, was presented to the Seventh Special Session of the United Nations General Assembly in September 1975. In this report development alternatives—need-oriented, self-reliant, endogenous, environmentally sound and based on structural transformation—are presented in the form of an integrated concept of 'Another Development'. The Report which has been

distributed in 100, 000 copies is used all over the world. Other important endeavours to be mentioned are 'The South-North Conference on the International Monetary System and the New International Order' in 1980, presenting important contributions to the work on monetary reform, the whole range of seminars on alternatives in education focusing in the first place on development in Southern Africa, and the seminars on alternatives in health leading up to the 1985 seminar on 'Another Development in Pharmaceuticals', which also has relevance to our discussions here. All this is documented in the Foundation's journal *Development Dialogue*.

This symposium on 'The Socioeconomic Impact of New Biotechnologies on Basic Health and Agriculture in the Third World' is yet another initiative of the Foundation to ensure international concern for a matter of immense potential significance for the peaceful development of human society. Those of us who may have had an occasion to read the special issue of *Development Dialogue* published by the Foundation in 1983—entitled 'The Law of the Seed: Another Development and Plant Genetic Resources' —would already understand why the Foundation has given such a priority to organizing the present symposium.

Science and technology permeates the daily life of the industrialized countries and increasingly determines the options for development in the Third World. It has brought benefits as well as setbacks in the evolution of man. With each passing day, its potential for bringing about swift and widespread amelioration of man is only matched by its potential for even swifter and more widespread damage and destruction of man and his environment. With all the achievements of science and technology, it is as true today as it has always been—it takes a lifetime to build and only an instant to destroy. It still takes nine months for the infant to be nourished in the womb before it enters the world outside, and it still takes 16 to 18 years to reach adulthood, and another decade to reach maturity. Unlike instant death, there is no such thing as instant mature adulthood. It is unbelievable that genetic engineering will make that possible.

Capital combined with science and technology when given free play in the market may succeed in developing the most efficient techniques to short-cut evolution and natural selection. It may, however, at the same time create social and economic consequences for the disfranchised vulnerable sections of humanity with little countervailing power to safeguard their short-term as well as long-term interests.

Biotechnology offers the potential to displace traditional agricultural com-

modifies on a massive scale. Several significant agricultural exports of the South are already threatened. Let me give just a few examples from my continent, drawn from the valuable research undertaken by the Rural Advancement Fund International, which has made such a significant contribution to this seminar.

A number of companies in the United States are now using biotechnology to produce natural vanilla flavour in the laboratory—a process which could eliminate the need for traditional cultivation of the vanilla bean. This technology can result in the loss of over US $50 million in annual export earnings for Madagascar, where three-quarters of the world's vanilla beans are produced. Approximately 70, 000 small farmers on this island nation are engaged in the production of vanilla beans. Vanilla is just one example of the many high-value flavourings and spices which are the target of biotechnology research.

Cacao is the second most important agricultural commodity produced in the Third World, and Africa accounts for 57 per cent of world production. Research now underway in Europe, the United States and Japan is focusing on a means to produce cocoa butter in the laboratory using biotechnology. At least two companies have already received patents on a microbial process to produce cocoa butter. This research is still in the early stages, but if it is commercialized, it will be devastating for major producers of cacao beans throughout the world.

Alternative sweeteners to be used as sugar substitutes are another target of biotechnology research. Corporations in the United States and Europe are now using genetic engineering to produce thaumatin protein, a protein which is derived from the fruit of a West African plant. Thaumatin is the sweetest substance in the world, several thousand times sweeter than sugar. If commercially successful, sugar substitutes like thaumatin will result in the erosion of traditional sugar markets. The livelihood of an estimated 8 to 10 million people in the Third World is threatened by the loss of traditional sugar markets and a drop in world sugar prices.

These are just three examples which illustrate the potentially devastating impact which new products of biotechnology may have on the economies of Third World nations. Beyond this looms large the whole future of seeds, its development, its preservation, and its equitable propagation.

The affluent society and the scientific community in particular will need to be altogether vigilant as we stand on the threshold of epoch-making tech-

nological developments. Their expanding comprehension of the behaviour of the most basic of nature's living organism, and the inexorable drive of research and development through the interaction between the physical and the genetic components of creation itself, propelled by historically accumulated capital, imposes on them a global obligation towards those societies whose options for their own social and economic development are also historically conditioned by their dependence on primary production. Any violation of the integrity of human life, of the promise of a peacefully developing future for all, will be increasingly placed at the feet of the world's scientists. They must increasingly share actively in the policy-making of nations, so as not to subvert the law of life itself. No longer will it be possible for them to leave it to the politicians who only take a short-term and parochial view of their responsibilities.

The seminar has had, as its core, an intensive four-day workshop of specialists meeting until yesterday at Bogève and will continue in the form of a symposium until tomorrow. I very much hope it will make a significant contribution towards what has to be a sustained, deliberate process of building disciplines in the literally vital field of the new biotechnologies, for safeguarding health and the basic means of sustaining life in all its splendour—that is agriculture.

On behalf of the Dag Hammarskjöld Foundation, I express deep gratitude to your excellencies and distinguished guests for honouring us with your presence here. You have given us immense encouragement. We thank you for it.

Editorial

From Linnaeus's Garden to Leeuwenhoek's Looking Glass

If history is to have its due and we must offer up a time and a place and a person—a beginning—then the time must be the 17th century and the place and person the Caretaker of Delft—Anton van Leeuwenhoek. Crusty, cranky and an unlearned genius, Leeuwenhoek stole time from his menial chores to grind glass and fashion the world's first microscopes.

The invention became a journey of discovery beyond the widest horizons of a Magellan. Leeuwenhoek studied everything—from butterflies to leaf mold to his own urine. He discovered the beginnings of life, saw cells divide and divide again. The theory of spontaneous generation fell away and science was left to struggle for a new understanding of the fabric of existence. Still, just beyond our vision lay another world. Somehow, in ways Leeuwenhoek could only vaguely imagine, this other world controlled our own.

It was more than a century later that the Hungarian Abbot, Gregor Mendel, made the second journey and offered the world the laws of genetic inheritance based upon his study of the propagation of peas. For the first time—in an organized way—it seemed possible for humankind to guide and predict the outcome of breeding. For the first time, Life—the marvelous mystery—became Life—the manageable tool.

The third journey began with the turn of this century when German scientists discovered the practical application of Mendel's laws in plant breeding and, in 1902, that it was possible to regenerate cells in a laboratory environment.

Another half century of research on both sides of the Atlantic led, in the mid-fifties, to the discovery of DNA. The progress of life could not only be guided, the parts of life—the parts that smell and think and bend and bloom—could be mapped. By 1972, scientists in the San Francisco Bay area were turning the map into a department store—taking a gene from one organism and inserting it successfully into another. By the end of the seventies, the world began to hear about 'biotechnology' and 'genetic engineering' on an almost daily basis. Newspaper headlines began to prophesy the end of illness, the end of hunger, the end of pollution, the end of resource shortages and even the end of death.

In 1983, *Development Dialogue* published 'The Law of the Seed: Another Development and Plant Genetic Resources'. With that issue, the Dag Hammarskjöld Foundation set forth on a journey that began in Linnaeus's Garden—a short walk from our offices in Uppsala—where the botanist showed humanity the wonder and diversity of nature. Linnaeus celebrated

diversity. His world was made of Kingdoms and Genera and Species and Families. Linnaeus did not so much count Life as count our blessings. In this issue of *Development Dialogue,* we move from the awe and wonder of Linnaeus and Leeuwenhoek to the practical implications of the management of life.

In 'The Law of the Seed', Pat Mooney succeeded in clarifying the problems posed by the rapid erosion of the world's plant genetic resources in a way that caught the imagination of thousands of our readers, many without much previous knowledge of the subject. In 'The Laws of Life', the authors have accomplished a similar feat by making intelligible to the interested layman and development worker a complicated subject matter of great social and economic importance, until recently the exclusive preserve of technical specialists. In order to guide the reader, a detailed table of contents has been worked out. A comprehensive overview of the Socioeconomic and technical aspects of the subject is given in the three chapters on The Life Technologies' in Part One of the following presentation. Parts Two and Three go on to treat the economic and political aspects in depth.

Biotechnology will affect us all. But its most profound impact may be felt in the Third World. Before we can reach an understanding of the proper role of the new biotechnologies, we should therefore consider what the needs of the world are and what genuine development should be—development *for whom* and of *what,* by *whom* and *how.* And as readers of this journal and especially of the Dag Hammarskjöld Report *(What Now: Another Development)* are well aware, this leads up to a number of crucial questions, which are also raised in different contexts in this issue of *Development Dialogue.* If, for instance, science is truly in the service of humanity, then what do the poorest of humanity require in the form of technical tools? This asked, consideration must be given to which tools should be applied. Will traditional or conventional technologies meet a need more safely and with less disruption? If so, these technologies should be used. If these tools will not do the task, then society should consider biotechnology. And even then, great caution should be applied. As is becoming increasingly clear and as is well illustrated by many telling examples in this issue of our journal, both the physical and social risks may be considerable.

Thus, it seems certain that the use of the new techniques in agriculture will lead to the overproduction of some commodities, cheaper substitutions for others, and the development of plant and animal breeds that may require ever greater quantities of chemicals for their protection. Small holders in the Third World—in the midst of a new 'Gene Revolution'—will once again

lose out to larger farms and plantations. New and often incredibly costly pharmaceutical products will once again take centre stage and draw support away from the basic health requirements of the Third World. The new biosciences have the potential to help humanity with many problems. Unfortunately, in the current economic and political environment, these techniques are much more likely to be used to concentrate political and corporate power. What is urgently required today is therefore a global debate about how the biotech industry should be used, developed, regulated and controlled. An examination of the data already available proves beyond doubt that strong and concerted action is needed to turn present trends towards Another Development.

In attempting to analyse the new and exceedingly difficult problems posed by biotechnology, the Dag Hammarskjöld Foundation—with the assistance of the Rural Advancement Fund International (RAFI)—and with the cooperation of the International Organization of Consumers Unions (IOCU), the International Coalition for Development Action (ICDA) through its seeds campaign, and the Non-Governmental Liaison Service (NGLS-Geneva) of the United Nations—convened a seminar at Bogève, France and at the Palais des Nations, Geneva, March 7-14, 1987. Titled 'The 1987 Dag Hammarskjöld Seminar on the Socioeconomic Impact of New Biotechnologies on Basic Health and Agriculture in the Third World', it was divided into two parts, a workshop at Bogève, March 7—11, and a symposium in Geneva, March 12-14. For the workshop at Bogève, 31 participants from 22 countries gathered while the symposium in Geneva was attended by an additional 45 participants, mainly Third World diplomats, representatives of different UN agencies and activists in non-governmental organizations concerned with the probable impact of the new biosciences on the poor.

It was important to the success of the undertaking that the seminar could draw on the experience and expertise of RAFI and the co-sponsoring organizations mentioned above and also on the participation of persons actively involved in IBFAN (International Baby Food Action Network), HAI (Health Action International), PAN (Pesticide Action Network) and SAN (Seeds Action Network). Each was able to bring a perspective on the issues that broadened the understanding of the subject. Many important and useful papers were presented and the debate was often intense. After four days of discussion, the participants were able to agree on what has become known as the Bogève Declaration on biotechnologies, first submitted to the symposium in Geneva and widely distributed in English, French, Portuguese and Spanish. It is also reprinted in this issue (see page 289).

To allow for greater clarity for non-scientist readers of *Development Dialogue,* it was agreed that the papers should not be published *per se* but that an editorial group—consisting of Cary Fowler, Eva Lachkovics, Pat Mooney and Hope Shand—would be given a free hand in translating papers and discussions into an informative and usable document. For the confidence thus placed in the editorial group, the sponsors are especially grateful. The editorial group has also done its best to acknowledge the contributions of the seminar participants to the proceedings.

The pace of change in the new biotechnologies is such that it is simply impossible for a publication such as *Development Dialogue* to record the immediate status of either the technology or the corporations managing the technology. The data offered here is judged accurate by the editorial group as of April, 1988, but events since then could easily alter many things. What has been attempted here is to define some of the fundamental issues at stake—the broad philosophical and strategic issues.

Even here, the analytical parameters shift almost daily. Within days of the end of the seminar, UNIDO—the UN Industrial Development Organization based in Vienna—shut down its biotechnology unit and severed its connection with the International Centre on Genetic Engineering and Biotechnology (ICGEB). UNIDO was the lead UN agency working on biotechnology. ICGEB—a creation of UNIDO—is the only international body attempting to train and facilitate Third World researchers in biotechnology. The curtailment of the UNIDO initiative is attributable to pressure from the United States and Japan—the world's two leading biotech countries.

Short weeks later, the United States Patent and Trademarks Office proclaimed that higher life forms would be patentable. In making its announcement, the Office's biotechnology expert told the *New York Times* that the only thing that cannot be patented in the United States is a human being. He added, however, that it may become possible to patent certain human characteristics.

Within a month of this announcement, an anthropologist at the University of Florence reported that laboratories in the USA and elsewhere had used biotechniques to create an anthropoid embryo using the sperm of a man and an egg from a chimpanzee. Once the embryo was successfully established in the laboratory, the experiments were terminated.[1]

In 'The Law of the Seed', reference is made to Linnaeus's Plant Kingdom

and our readers were warned that the prayer 'Give us this day our daily bread' must not become a prayer to a Shell Oil or a Ciba-Geigy, two giants in the seed industry. Leeuwenhoek shows us the other Kingdoms and we are obliged to add that 'Give us this day our health, our food, our energy, and give us this day our lives' cannot become a prayer to just anyone. But then: whose will shall be done? And, more immediately, what is to be done?

We would like to offer some suggestions based on the conception of Another Development and addressed to the representatives of the first, second and third systems, i.e. to national governments and the United Nations, to business and industry and to the people's associations.* But while offering these suggestions here as priorities for political and social action, may we ask our readers to go through them rather quickly in a first reading but to return and re-examine them once the rest of the contents of the journal has been absorbed. These then are our suggestions.

To the first system

The primary responsibility for directing the new technology must rest with national governments. An unusual degree of genuine 'leadership' is required:

1. The national governments could create a constructive national discussion on the Socioeconomic and environmental consequences of the new technologies and work with others in society to determine the functions most suitable for biotechnology;

2. Clearly, national health, safety and environmental quality laws should be reviewed to take into account the new situation created by genetically-altered organisms in use in society. This review—including research standards as well as end products—is urgently required and might be conducted in cooperation with appropriate UN agencies;

3. Anti-combine, cartel or competition policies and laws could be reviewed

* The state or national government (the first system) and the market or business (the second system) are the two main sources of the power exercised over people. The third system has been defined as those associations and agents of change which endeavour to listen to people and reflect their views. The third system then is that part of the people which is reaching a critical consciousness of their role. It is not a party nor an organization; it constitutes a movement of those—free associations, citizens and militants—who perceive the essence of history as the endless struggle by which people try to master their destiny (see 'Building Blocks for Alternative Development Strategies', *Development Dialogue,* 1981: 1, pp 68—101, and 'Neither Prince nor Merchant: Citizen—An Introduction to the Third System' by Marc Nerfin, *Development Dialogue,* 1987: 1, pp 170-95).

in order to deal with the unique problem of monopolization of life technologies and processes posed by biotechnology that could lead to horizontal control over a wide range of industry segments;

4. Governments may also wish to examine their intellectual property legislation (including patents, trademarks and copyright) in order to ensure the specific exclusion of intellectual property monopoly over biological products and processes. Laws which do not directly preclude 'life' patents might otherwise be interpreted to include 'life' and lead the nation down the road of non-legislated monopolies;

5. Finally, national governments should not establish 'national centres of institutes of biotechnology' with the effect that all other forms of scientific exploration suffer. Rather, biotechnologies should be considered and, where useful, incorporated, into ongoing goal-oriented programmes.

To the UN system

For all its manifest limitations, the United Nations has a central role to play in setting the political understanding of biotechnology. Initiatives at the UN level often result in legislation at the national level. Work can be undertaken on several fronts:

6. Devise, either in New York or Geneva, a Code of Conduct on Biotechnology including research, technology transfer, intellectual property and the social consequences and priorities of the technologies;

7. At UNIDO, re-establish and expand the programme on biotechnology with particular attention to training and to social impact analysis;

8. At UNESCO, explore the inclusion of genetic materials in the Treaty on Cultural Rights and the Repatriation of Cultural Heritage. Biotechnology is interested in both the plants and animals of the poor and in the wisdom of the poor in using genetic materials;

9. At FAO, expand the Commission and Undertaking on Plant Genetic Resources to include FAO's work in forestry, aquatic and animal germplasm. Look to the Code of Conduct on Pesticides with a view to expanding its mandate to take new biotechniques into account;

10. At WHO, there is urgent need to ascertain the essential needs of the poor for drugs, sanitation and nutrition as a means of measuring the utility of new biotechniques in meeting these needs. A Code of Conduct on

Pharmaceuticals should be developed and expanded to include the impact of biotechnology;

11. At UNEP, the environmental impact of the new science should be studied in the widest possible context. The office dealing with the International Registry of Potentially Toxic Products should be greatly expanded to include the monitoring of genetically-engineered micro-organisms. UNEP should take the lead in the joint WHO/FAO/UNEP committee on safety standards for biotechnology;

12. The significance of biotechnology for children—the unborn and the newly-born—should be a special concern for us all. UNICEF should take the lead in examining the technical and social consequences of genetic engineering and work with WHO and related agencies to formulate policy recommendations;

13. The socioeconomic impact of the biosciences on workers—especially those in agriculture and food processing—should be the basis for investigction and debate within the ILO. The safety of those who work with the biotech industry should also be considered;

14. One of the central issues of the biotechnology debate will be waged at the World Intellectual Property Organization (WIPO) and its subsidiary, the Union for the Protection of New Varieties of Plants (UPOV) in Geneva. UPOV will be amending its Convention to accommodate biotechnology and WIPO should do the same. The rights of farmers and communities may be trampled as companies and governments attempt to establish monopoly patent rights over life. This must be vigorously opposed:

15. Although the UN Centre on Transnational Corporations (UNCTC) has a history of important research into the structure of industry and has done some helpful work related to biotech enterprises, much more and better work is demanded. New and bolder studies are needed. Analysis of the impact of the industry and suggestions on competition policy and the implications of horizontal and vertical integration are overdue;

16. We see the need for a much bigger role for the Advance Technology Alert System of UNCSTD in New York. Good work has already been done and more is needed to bridge the gap between socially concerned scientists and social activists and government policy makers. In particular, UNCSTD should explore the relationship between artificial intelligence technologies and biotechnology;

17. Among the specialist bodies in the United Nations System, a particularly important role can be played by the UN Conference on Trade and Development (UNCTAD) which has shown leadership in many areas of North-South relations. UNCTAD could undertake a wide overview of all the issues involved in biotechnology. In particular, however, it has strong expertise in transfer of technology issues and in commondity-by-commodity evaluation of the specific impact of the new sciences on Third World economies;

18. A highly flexible and effective forum for discussion and analysis could be provided through the UN'S important Regional Commissions. The diverse contributions of the separate agencies could be brought to a useful regional focus through multi-disciplinary Commission reports and conferences. The United Nations should take full advantage of this flexibility and provide the necessary leadership to initiate and stimulate the debate;

19. Ultimately, the work of these separate agencies must come to a focus at a major UN Conference on the Life Sciences. This conference should be held in the Third World no later than the early 1990s. It should be approached with the same care and scope as the Stockholm Conference on the Human Environment and with the same political attention given the Law of the Sea negotiations.

Beyond the work of the various UN agencies, the South Commission under the chairmanship of Mwalimu Julius Nyerere has an important role to play. For this Commission not to make biotechnology a prominent element in its considerations might render part of its analytical work irrelevant before the ink is dry. A study of both the science and the social context of the new techniques should, therefore, be a priority for the Commission.

To the second system

The biotech industry must be aware that it is entering into a venture filled with social, political and economic uncertainty. The potential for the commercial development of biotechnology is enormous. But the new technologies call for new approaches to public responsibility:

20. It is the medium and long-term interest of the biotechnology industry to participate actively in a broad public discussion of the implications and uses of the new techniques at the outset. A superficial, unrealistic or one-sided interpretation of the technology will quickly lead to public distrust and reaction when the first problems arise. An informed public will be able to assess the costs and gains.i of biotech and accept some of the

inevitable problems. Industry should recognize that society is not anti-science and be willing to work with society in the orderly introduction of beneficial products and processes;

21. Given the broad social opposition to the patenting of life forms, the industry should consider its realistic requirements and, if necessary, be prepared to negotiate with society (through its governments) for non-monopolistic subsidies or incentives in exchange for social control over the direction of the implementation of the technologies;

22. The biotech industry should recognize that it is itself entering a phase of rapid consolidation and consider legislative and regulatory initiatives that might serve to encourage the viability of small enterprises in the face of transnational concentration. Such initiatives could include anti-combines, cartel or competition laws and also those incentives which could be designed to exclusively stimulate the development of small firms.

To the third system

The third system, i.e. those associations and agents of change who represent the struggle of the people to master their own destiny, is by its very nature a highly heterogeneous system, this being both its strength and its weakness. But however this may express itself in different situations, there is no doubt about the growing influence of the third system as a global reality and its increasing capacity to act as a countervailing force to the first and second systems. In some industrialized countries— especially the United States and Canada—and in some parts of the Third World, the faith community plays a paramount role. But in other industrialized countries as well as in other parts of the Third World, political movements, peace movements and women's movements play an equally important role together with issue-linked organizations like HAI, IBFAN, PAN and SAN.

The faith community

In 1979, the World Council of Churches' Conference on Faith, Science and the Future[2] launched an important discussion on the impact of the new biology on human life. Nevertheless, almost the entire discussion as well as the final recommendations focused on genetic screening and human reproduction. Although aspects of wider agricultural and biological warfare concerns were raised, the conference took place in advance of the major expansion of the science and the industry.[3] It is time for the faith community to renew the discussion it began almost a decade ago and to broaden the debate to include all aspects of biotechnology. The recent development of the World Council of Churches' programme 'Peace, Justice and the Integrity of Creation' could be an excellent forum for this discussion. Once again

leaders of all faiths are called upon to take a stand. It is not too late to broaden public understanding of the new sciences and technologies. This can be done by:

23. Preparing discussion papers and educational packages to help religious workers and congregations understand the science and the issues, adressing both their theological and social implications;

24. Organizing regional conferences on the impact of the new technology with special consideration for its regional significance for Asia, Africa, Latin America, Australasia, Europe and North America;

25. Holding a Global Conference on Humanity, Science and Power, inviting scientists, political and business leaders and social activists to discuss the implications of biotechnology;

26. Gathering and strengthening those who oppose corporate or governmental efforts to monopolize and control life and engaging those who contemplate and plan for biological warfare.

The voluntary community

The World's rapidly increasing voluntary organizations may still be small in number but have an enormous potential in energy and creativity. This energy and this creativity can be used to put pressure both on national governments, on the United Nations and on the corporate world. Although the various issue action networks already have heavy and important agendas and insufficient support, they may be able to stimulate some action in the following areas:

27. The specific short- and long-term impact of biotechnology on basic health in the Third World could be studied and acted upon by HAI (Health Action International) and this work could influence WHO, national governments and others;

28. A specific understanding and strategy for the dairy industry in particular and food processing in general is urgently needed. IBFAN (International Baby Food Action Network) could assume the lead in this work and take its case to a number of UN bodies and fora;

29. The concentration in agricultural input industries and the potentially harmful consequences for the environment, farmers and consumers need careful analysis. PAN (Pesticide Action Network) is well-positioned to do the studies and carry the message;

30. The wide-ranging issues surrounding the use and control of genetic raw materials including intellectual property rights have long been an area of interest for SAN (Seeds Action Network) and SAN could play a leading role in opposing the new developments at FAO, UPOV and WIPO.

In the final sessions in Geneva, the seminar created a Joint Action Committee on Biotechnology (JACOB) to continue the cooperation. Together with the Dag Hammarskjöld Foundation, RAFI, IOCU, ICDA Seeds Campaign and ELCI (Environment Liaison Centre International) are taking a facilitating role. It is clear that the immobilizing contemplation of the impact of biotechnology must be converted to actions and strategies. At a follow-up meeting of JACOB in Batu Malang, Indonesia, in early December, 1987, the need for detailed planning was recognized and participants set to work on a full Code of Conduct on Biotechnology. For its part, RAFI—in cooperation with counterparts in the South—will undertake a series of sectoral studies in each of the major areas of agriculture, food processing, health care and biological warfare. The objective of these studies will be to formulate policy options and action programmes for those who will be adversely affected by the new science.

Traditional development NGOs are faced with a new challenge. The complexity and scope of the issue we face is such that traditional boundaries between governmental and non-governmental agencies are a barrier to harnessing the policies and scientific capabilities needed to deal with biotechnology. NGOs must bridge the gap and be willing to formulate new kinds of cooperative relationships with governments. NGOs must take the initiative in seeing their considerable financial potential as a means of catalysing both NGO and governmental action in the South and North.

In addition, traditional development NGOs must dig in for the long haul. They must be willing to explore new South North and South-South structures for cooperative analysis and action. These structures and strategies must be multi-year in length and much more diverse in scope than normal. The Socioeconomic scope of the technology demands this.

As we write, the Ethiopian Plant Genetic Resources Centre has placed a portion of its gene bank under the auspices of the FAO Commission on Plant Genetic Resources. The first to take advantage of this remarkable Ethiopian Government facility are agricultural NGOs in Zimbabwe looking for a safe haven for their traditional seeds. Together the Ethiopian scientists and the Zimbabwe farmers are cooperating with RAFI and the Unitarian Service Committee (USC), Canada—a traditional NGO—in

developing a one million dollar strategy for coping with and developing agricultural biotechnology and biological diversity in Africa. This is the kind of creative cooperation NGOs need to forge.

New forms of cooperation are urgently needed. Time is running out. The final industrialization of Linnaeus's garden is at hand.

Notes

1. Schmetzer, Uli, 'Ape-Human Possibility Comes of Age', *Chicago Tribune,* reprinted in *The Charlotte Observer,* 14 May, 1987, p. 1A.
2. Shim, Roger L. (ed.), *Faith and Science in an Unjust World,* Vol. 1 & 2, World Council of Churches, Report of the WCC Conference on Faith, Science and the Future 12-24 July, 1979, M.I.T., Cambridge, Mass., USA.
3. Note, *Faith and Science in an Unjust World* (op.cit), Vol. 1, p. 269-70, discussion by Jonathan King and Vol. 2, p. 66, containing recommendations.

Authors' Note

It is more than a year since the Dag Hammarskjöld Seminar at Bogève and in Geneva. We have tried our best to retain the spirit of those important discussions while updating the information. The pace of technical, political and corporate change makes both the data and the analysis something of a moving target. No doubt we have sometimes missed our mark.

In the swirl of enthusiastic and uncritical media 'hype', we have found it most appropriate to present mainly the negative Socioeconomic implications of the new biotechniques. Readers are exposed to enough of the other side already. This leaves us open to the criticism that we are 'Luddites'. This is not true. We see many wonderful possibilities in the science—most especially in the area of human health care—but we are very doubtful that the positive potential will be realized.

The new technology is 'arriving'—it is not really 'here' yet. We are sending out a warning signal. This means that we have had to talk most about the places where the technology is being developed—North America and Europe—the United States most of all. We regret what might appear to be an ethnocentric view of the technology. Future writers will be able to talk much more about the impact in the South, that is where the most serious consequences are likely to be felt.

Explaining biotechnologies to lay people is not an easy task. (Explaining it to ourselves has been painful!) Although we have tried to be technically accurate, we have opted for what are sometimes oversimplifications in order not to bury policy-makers in technical detail. We have also noticed that the industry sometimes appears to deliberately obscure or mystify the issues in their own news releases and journals. The biotech industry should not be the ones to define our terms for us. To the scientists we apologize for our simplifications. To the majority of our readers, we apologize for our 'technolingualism'.

We also apologize for all that is missing. Both in what people said at Bogève and what is happening with the issue. In every field, we are painfully aware of the topics we have not even discussed—and, of course, the changes and experiences in the areas we have discussed. This is particularly so in the case of the feminist perspective on biotech and human reproduction, which has been the subject of several excellent studies and a number of conferences (Frankfurt, Basel, Berlin, to name a few). At some point, however, we had to stop researching and start writing! We also had to keep the text a manageable size.

We owe a great deal to all the participants at Bogève who trusted us with this task and who have kept in touch with us and passed on important information ever since. We must also express our gratitude to Jeremy Rifkin and Andy Kimbrell of the Foundation for Economic Trends for their information and ideas over the past year. We also have to single out Martin Abraham of IOCU and Henk Hobbelink of the Seeds Campaign for their constant flow of information and inspiration.

Most of all, we express overwhelming gratitude to Sven Hamrell, Olle Nordberg and Gerd Ryman-Ericson and their hardworking colleagues at the Dag Hammarskjöld Foundation. We soared months past several deadlines and they have borne our drafts, data and confusion with superhuman forebearance. No doubt they have often thought fondly of our genetic manipulation. The Dag Hammarskjöld Foundation is a remarkable group of people—and we have tested them to their limits! We thank them very much.

As the authors of this compilation, we must also offer our most sincere thanks to Beverley Cross and Tracy Strowd who have had to bear the burden of all our drafts, redrafts and data searches. They have both been terrific! During the course of this writing, three of the four of us have had babies (we take genetic diversity seriously) and Cary has had a puppy. Our gratitude to all our friends and families for bearing with us!

Cary Fowler, Eva Lachkovics, Pat Mooney, Hope Shand

Part One

The Life Technologies

Some Facts of Life

Towards Understanding the Biosciences

Now you guard the sciences' light,
Use it and do not misuse it,
So that it does not as a fire fall
In times to come engulf us all...
Bertolt Brecht, Galileo Galilei

Traditionally, policy makers and social activists are confounded by the complexity of technology. They suspect—and rightly so—that the technical detail obscures the fundamental human issues at stake. It is understandable, therefore, that scientists are left to cringe in horror as politicians and activists bandy about technical terms and concepts that even Nobel Laureates use with trepidation.

We are asking that biotechnology be the exception to this tradition. No mere tinkering with the machinery, no new wrinkle in an old cloth, biotechnology is a revolution as profound as any the world has ever known. The world's economic engines fueled by hydrocarbons and non-renewable minerals are shifting, we are told, to an engine driven by biology—renewable (sometimes) genes or proteins. The very unit of power is changing. We are moving from the Gold Standard onto the Gene Standard. If ever you needed to understand at least the rudiments of a new technology, that time has come.

The breadth of the new biosciences almost defies intelligent analysis. The mind reels from one new discovery to the next—from one new implication to another. Therefore, it is crucial to keep a few basic precepts or facts in mind. During our discussions at Bogève, some of these became clear:

1. **Any new technology introduced into a society which is not fundamentally just will exacerbate the disparities between rich and poor.**

If the problem is injustice, the solution is not technology. It never has been, though most major technological breakthroughs have been accompanied by claims that they solve society's problems. It sometimes seems that humanity's woes have been surrendered to the care of an assembly-line of Sorcerer's Apprentices—each trying to correct the calamities created by the other while still claiming to provide a technological answer to injustice. Technology is a tool not a recipe.

This leaves us in a quandary. The most powerful technology the world has ever seen is being inserted into a world rife with injustice. That the technology will be abused and work against the poor, we have little doubt. But to meet it with blanket opposition seems impractical and irrational. We cannot turn our backs on hope, on something so essential to the human adventure. Despite our basic concerns about the final contribution of biotechnology, many of us at Bogève could see the opportunities. (Could we turn our backs on a cure for AIDS?) Our other 'facts' flow from this basic contradiction.

2. Some aspects of this technology are high-risk and should only be used after more conventional options have been explored.

   Though we can map the human genome, we still may know little about life. Altering life forms may have unthinkable consequences. Society must monitor biotech developments with the same—or greater—intensity with which we monitor nuclear research. Where safer, known technologies are available, they should be used.

   The impact of biotechnology is two-pronged. Research and products obviously alter our physical world and our society. But the debate over the importance of the impact can be confusing. Biotechnology is not a single entity, it is a grouping of new techniques. People must learn to distinguish between those methods which, by their nature, carry major risks for the human environment (such as those involving genetic manipulation) and other instruments which are, for all we know, benign (cell biology, for example). Regardless of the technique, however, the social consequences of any biomethod can be profound. Whether scientists are using simple tissue culture techniques to speed up the pace of plant breeding or engineering human genes into sheep, society has the need and the right to demand wide-ranging impact studies.

   Remember history. Remember the Sorcerer's Apprentice. The world has witnessed a long procession of new technologies each of which has created. along with certain benefits, some irreversible damage. The chemical industry which promised us a vast new repertoire of cheap consumer products is destroying the ozone layer and bringing about Waldsterben in Europe's forests. The Green Revolution which was to feed the world's hungry is destroying the genetic base of the food supply. The agrochemical industry which promised more and cheaper food has, in fact, polluted the water table, eroded our soils and given us Bhopal. The nuclear industry which offered us cheap energy has, instead, given us expensive energy and Chernobyl. The same technology that gives us computer games and compact disks also portends the Police State and Star Wars.

   It is not our particular role to weigh the benefits of biotechnology against the liabilities and declare a winner. Industry groups and even some scientists are already doing this, with the result that all critiques are deemed suspect, unnecessary or wrong. At this early stage no expert could pretend to forecast the future of biotechnology. Thus, it is important that society engage in dialogue. This requires that some attention be devoted to the possible negative consequences—something industry and government rarely, if ever, do.

The high-risk aspect of biotechnology has special implications for policy makers. Whenever new issues are raised there comes the cry to establish special secretariats, new institutes or even whole new ministerial portfolios to deal with the new circumstance. The cry for 'National Centres for Biotechnology' and 'Biotechnology Development Boards' is almost deafening. We would argue that this revolution is too important to be allowed to function or develop out of context. Biotechnology will touch all ministries, all institutions, all people.

Unfortunately, delegating authority over biotechnology to one institution may relieve others of their responsibility to grapple with the implications of the new technologies.

Governments cannot afford to turn the bioscience tool into an end product. Although new laws and regulations will be required in order to deal with the complex implications of biotech research and releases, the biosciences should otherwise always be judged and used in the context of more conventional tools, with the end goal still that of meeting human needs. The temptation for over-enthusiastic governments to distort their development strategies and to waste money is very real.

3. There will be accidents. There may not be a 'genetic Chernobyl' ... but we might not know if there were.

Rachel Carson once wrote that agricultural chemicals were a stick hurled against the fabric of life. Biotechnology may give us life hurled at the fabric of life. Unlike the chain reaction in a nuclear power plant—where the elements are contained and controlled—the release of genetically-manipulated organisms could launch a chain reaction which we can neither understand nor control. This chain reaction will not be in the laboratory but in our world.

The chances of a genetically-engineered organism 'taking over' are quite, quite slim. The world will probably never wake to a report that a green slime has crossed the Potomac and is now munching on Moscow. Don't look for a genetic Chernobyl or Bhopal. It is much more likely that the genetic Chernobyls—if there are any—will spread slowly, perhaps undetected. The media will focus on the potential for slave species and brain-transfers but even these theoretical choices will have a minor impact on the great majority of humanity. The real choice is not between Einstein and Frankenstein but between research to combat diseases in plants and people, for

example, and research on the same diseases for biological warfare. How will society identify the difference?

Blinded by the brilliance of the new Sorcerer's techniques, are we looking to biotechnology as an escape from the economic and environmental crisis that engulfs us? Desperate for solutions, politicians are uncritically embracing a science they do not even comprehend. But never before has science offered products so capable of fundamentally altering the human equation. The need for caution and constructive criticism is urgent.

4. **The Gene Revolution is occuring both quickly and slowly. The period of transition may prove more risky than the outcome.**

The co-evolution of artificial intelligence technologies with the new biotechniques make the pace of change faster than any preceding 'revolution'. The neolithic revolution that launched agriculture and the industrial revolution that inaugurated the era now being eclipsed both evolved over millennia or centuries. By comparison, biotechnology is coming quickly. Products unimaginable ten years ago are now on their way to the marketplace. New products will appear in the 1990's at breathtaking exponential rates.

At least two factors will slow the transition. The first is that many of the new products will not work, will not work adequately, or will create new problems for which there is still no biotech response. Venture capitalists in particular and society in general are demanding the new products and pressurizing the scientists to get things on the shelves. Tremendous mistakes will be made in this atmosphere.

Secondly, there is still money to be made in the old technologies. As long as the patents and the markets last, the transnational enterprises that really control the new techniques are not anxious to cut their profits by prematurely releasing competitive products.

The combination of these two factors means that we will wander for some time to come in a world of competing technologies reaping the benefits and dangers of both. We will not have only biological pest controls. We will have all the old chemicals and crop varieties that have been adapted to tolerate even more chemicals. We will have both microbes that gobble up oil spills and we will have biological 'spills' that will gobble up other life forms.

5. The heart of the matter is not safety but control.

Despite our own expressed concerns, perhaps too much media attention has been focused on the questions of regulation and safety. By contrast, there has been almost no media comment on the actual structure of the industry and the control of the techniques.

Let us state the problem unequivocally: the greatest threat in the new biosciences is that life will become the monopoly property of a few giant companies. In the key countries, the products and processes of biotechnology either are, or are becoming, patentable. Beyond the wildest dreams of the industrial barons of the past, the whole gene revolution is on the verge of becoming private property. Of all technologies, this life-derived technology must remain in the hands of the people.

Aside from opposing the patenting of life forms, we must impose tough controls on the genetics supply industry. We must work to make sure that the new techniques are in the service of the poor. We must control the transfer of technology. Most especially, we must strengthen the capacity of universities and other public sector institutes—South and North—to analyse and develop their own science.

The first casualty of the new biosciences may be human culture. Special care must be taken to ensure that the fabric of society is not torn apart. The companies now searching the Indonesian archipelago and combing the Caribbean beaches for flora and fungi are not only looking for micro-organisms. They are after the knowledge of the people who have used these resources for millennia. These people must be protected. They must not have their wisdom 'stolen' to be misused.

At Bogève, we were fortunate to have the active participation of a number of highly qualified scientists. They made it clear that responsibility for the safety and control of the new technology must be shared. Scientists must not divorce themselves from the social consequences of their research. Not surprisingly, Bertolt Brecht said it best ...

> When scientists, intimidated by selfish rulers, content themselves with accumulating knowledge for knowledge's sake, Science can be turned into a cripple, and your new machines may only mean new oppression.
>
> *Bertolt Brecht,* Galileo Galilei

The Hard Technology Path

A Brief History of the March of Progress of New Technologies

> The academic or industrial chemist cannot assess the public health effects of chemicals leaking from waste-disposal sites. The agricultural scientist endeavouring to control pests is usually unaware of the ecological issues or approaches needed to evaluate the impact of pesticides on non-target populations. The nuclear physicist and the managers of nuclear facilities are not competent to assess the medical consequences of radiation. The scientist in a given field or the industrial manager hoping to exploit that field is often in no better a position to evaluate the consequences of the endeavour than a hen to comment on the edibility of her egg.
>
> *M. Alexander*[1]

During the 1980s, the world has been stunned by a succession of high-tech disasters: Union Carbide's Bhopal pesticides tragedy, the Chernobyl nuclear power plant catastrophe, the Sandoz and Ciba-Geigy Rhine River chemicals spills, the radiation disaster at the medical clinic in Goiania, Brazil[2] and the Ashland Oil tank collapse near Pittsburgh. Such incidents occupy a common niche in what seems to be a predictable pattern taken by many new technologies.

1. Early and basic discoveries are made by rank amateurs with little or no standing in the profession.

2. Universities and other public bodies undertake the basic research needed to make the discovery workable.

3. Private companies mushroom up around the university proposing collaborative R&D, Professors begin to work for both. Eventually, key scientists pull out of the campuses for the companies, dismayed by the university's failure to provide adequate research support and compensation. Stories spread on Wall Street that the new technology may be the solution to either hunger, disease, poverty or all of the above.

4. The new technology is guaranteed to be innately safe and intrinsically beneficial. Advertising executives assure us of this on television.

5. Company scientists speculate that contrary to the statements of detractors, the new technology will be inexpensive and universally available.

6. Some of the biggest companies from traditional but related industries enter the field. The public sector is advised not to waste taxpayer

dollars by competing with the private sector. Companies ask governments to fulfil their human rights obligations and broaden the patent system to protect the new technology.

7. The technology proves to be (initially) expensive and available only to the wealthiest buyers. The companies explain that this situation is only temporary and condemn government regulators and left-wingers for the problem. Journalists are warned that the Japanese may be winning.

8. It is discovered that unforeseen factors in the science mean that the new product is not entirely safe and new regulations have to be developed. The corporations applaud the new scientific breakthroughs that have exposed the problem and proclaim that the 'system' is working.

9. The previously 'excessive' regulations prove inadequate.

10. Unexpected social side effects are also discovered and society is challenged to retain its faith in the future and to share the burden of these effects. Executives urge taxpayers not to falter on the threshold of a brave new world.

11. In the spirit of social responsibility, the major companies admit that the complexity of the new technology requires stiffer regulation. They point out the costly nature of adequate research and regret that smaller firms can neither afford the regulations nor meet the investment demands. 'Long overdue' changes in competition laws allow the small start-up companies to be absorbed into the larger companies.

12. The new technology is placed in the responsible hands of major corporations. Somewhere, someone makes a discovery. The cycle begins anew.

/Votes

1. Alexander, M., 'Ecological Consequences: Reducing the Uncertainties', *Issues in Science and Technology,* 1985, 1 (3), pp. 57-60.
2. Dawnay, Ivo, 'Foreign Experts Aid Brazil Over Radiation Leak', *Financial Times,* 8 October, 1987, International, p. 4. This reference is cited because the Brazilian disaster is, sadly, less well-known.

Journey to the Centre of Life

Introduction to the New Biotechnologies

More and more people are beginning to hear about biotechnology, but few know what it means. Workshop participants at Bogeve discussed the need to de-mystify and popularize our understanding of biotechnology. In order to discuss either the potential or pitfalls of these new technologies, it is essential to have a basic understanding of a variety of scientific techniques which are collectively known as biotechnology.

Austrian biochemist Eva Lachkovics, a member of the RAFI staff, prepared an important background paper, 'Introduction to Modern Developments of Biotechnology', for participants at the Bogeve meeting. Eva's presentation gave workshop participants a thorough introduction to various techniques of biotechnology. She also discussed current and potential applications of these techniques in the fields of agriculture, medicine, food processing, pharmaceuticals, energy, mining and military warfare.

What is biotechnology?

Modern biotechnology is a wide range of techniques which involve the use and manipulation of living organisms and which can be commercially exploited. Many people mistakenly assume that biotechnology means 'genetic engineering'. Actually, it is much more than that. It is important to keep in mind that biotechnology is a very general term. It refers to a variety of techniques involving living organisms as a means of production. Some of the most common techniques are tissue or cell culture, cloning and fermentation methods; cell fusion; embryo transfer; and recombinant DNA technology ('genetic engineering').

Biotechnology is not new. It dates back several thousand years when people inadvertently came across the usefulness of one-celled organisms such as yeasts and bacteria. The ancient Egyptians used brewer's yeast to brew beer, and baker's yeast to bake bread. Some 7, 000 years ago in Mesopotamia people used bacteria to convert wine into vinegar.

In recent years, discoveries in biochemistry and microbiology have led to radical changes in the field of biotechnology. Exciting breakthroughs are reported weekly, and the frontiers of this new technology are being extended every day. The commercialization of modern biotechnology has spawned a giant new industry which will have enormous impact on all major sectors of the economy.

In the following pages we offer a brief introduction to some of the major techniques of biotechnology. It is not meant to be a comprehensive review

of all aspects of biotechnology—but rather a simple and basic introduction to several of the techniques which are commonly referred to as biotechnology.

Tissue or cell culture, cloning and fermentation

Tissue or cell culture technology is one of the most commonly used techniques of biotechnology. It involves growing isolated cells (or tiny pieces of tissue) from plants, animals or even humans in an artificial medium that will nourish them and keep them viable. Under such conditions the cells will multiply and produce many different substances—depending on their metabolism.

New techniques to cultivate plant, animal, and human cells in vitro are being developed at a rapid rate. Some types of cells are much easier to cultivate than others. Most normal human cells, for example, will not survive in culture at the present state of knowledge, whereas a wide variety of plant cells adapt relatively easily to growth in culture.

To better understand the use and application of tissue or cell culture, it is important to become familiar with other related techniques: cloning and fermentation.

What is cloning?

A cell culture started from a single, multiplying cell is called a clone. It contains genetically identical copies of the single starting cell. (In fact, random mutation prevents all cells from being absolutely identical.) The copying process is called cloning. This method is applied whenever scientists want to obtain a large number of cells or organisms with the same characteristics. Cloning is a standard method in biotechnology. As we shall see, it is used in combination with many other techniques. Without the possibility of multiplying a genetically engineered cell, for example, genetic engineering would be meaningless for production purposes.

What is fermentation?

Cells have been grown in culture for thousands of years. Single-celled organisms such as yeast and bacteria, for example, have been used to make bread, wine and other foods. The term 'fermentation' generally refers to a natural process in which the biological activity of micro-organisms plays a critical role. Today, the definition of fermentation includes processing methods carried out by any kinds of cells in culture, not only micro-organisms. Cells can be isolated under specific conditions in the presence of nutrients in large tanks called 'fermentors' for large-scale production of various substances, such as chemical or pharmaceutical compounds. Since commercial biotechnology depends on large-scale production, modern fer-

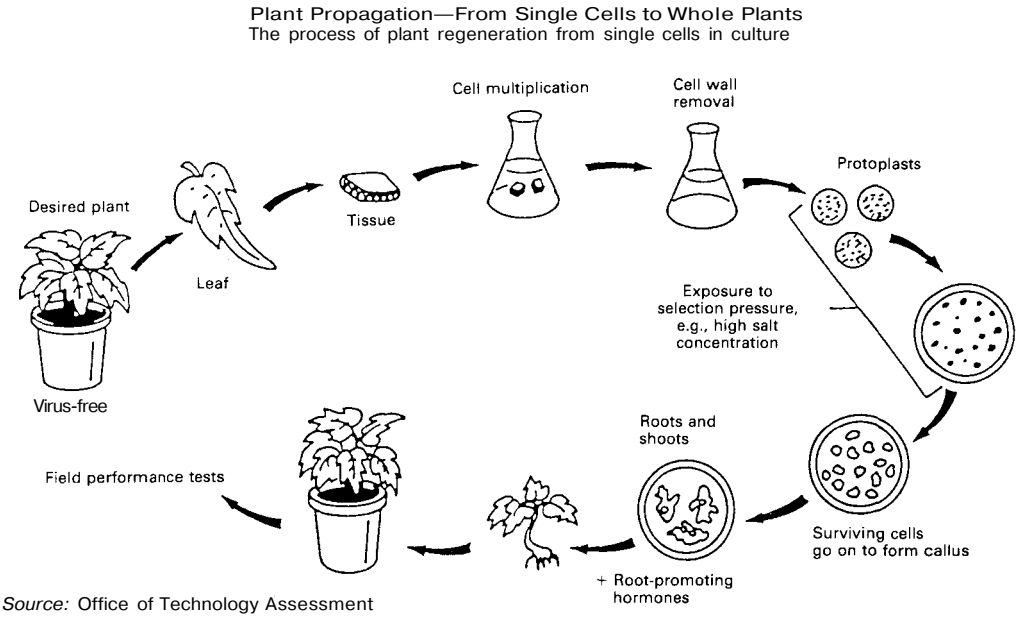


Figure 1 The process of plant regeneration from single cells in culture

mentation techniques are considered one of the most important methods used in biotechnology today. It will gain increasing significance as the production of more and more commodities will be transferred from the fields of the South into industry's fermentors in the North.

Applications

There are numerous applications of tissue or cell culture in modern biotechnology. In the following section we describe several applications of plant tissue culture. It is important to keep in mind, however, that this technique is not confined to plant cells.

1. *Mass propagation of plants.* Tissue culture techniques are commonly used for mass propagation of plants. In some cases, entire plants can be regenerated from a single cell because each cell contains all the genetic information it needs to become a whole plant.

The tissue culture process involves placing plant cells—or tiny plant parts—on solidified media containing special hormones and nutrients which encourage the formation of a clump of cells known as 'callus'. This is undifferentiated tissue. Once callus has formed, the addition of different nutrients and hormones encourages the formation of leaves and roots in certain types of plants. In these cases, plantlets develop which can be potted in soil and grown to maturity. This is a cloning process. It is not uncommon to produce (copy) as many as a thousand plants from each gram of starting cells.

Tissue culture technology thus permits production of plants on a far more massive scale, in a far shorter period and with a far narrower genetic base than is possible by conventional plant breeding methods. However, it is important to note that many plants—including many economically important crops—cannot yet be regenerated in this way.

Tissue culture techniques often represent a tremendous shortcut over traditional plant breeding. After selecting a high-yielding, disease-free plant, for example, scientists can mass-produce copies that are virtually genetically identical. Using this technique for multiplication of plants, fields can be reduced to petri dishes, and the time required for breeding experiments can be reduced from months and years to weeks or even days. Using selection and cloning techniques, crop yields can be increased enormously.

Using tissue culture techniques, disease resistant plant varieties can be identified more rapidly. Millions of plant cells, rather than the whole plants, can be exposed to the causative agents in vitro. The surviving cells are the resistant ones. If the species can be regenerated from a single cell, the resulting clones can be used for the production of resistant plants.

Today, plant tissue culture is routinely used for the production of many crops in large numbers. Clonally propagated oil palm plantations in Malaysia offer a particularly dramatic example of the use of tissue culture in tropical agriculture. Unilever, one of the world's largest transnational corporations, has propagated oil palms from cloned plant cells for its Malaysian oil palm plantations. They have reportedly increased oil yields by 30 per cent with new, high-yielding oil palm clones.[1]

Tissue culture technology is also being applied in traditional crop production. One US-based company recently announced that they are developing new soybean varieties 20 to 40 per cent faster through tissue culture techniques.[2]

Obviously, one of the greatest virtues of this new technology is also one of its most serious problems. The reproduction of thousands of genetically identical plants through cloning results in an extremely narrow genetic base. While there are many commercial advantages to producing entire plantations of uniform, high-yielding crops, clonally propagated crops are six times more vulnerable to pests and diseases than their seed-bred counterparts.[3]

2. Germplasm preservation. A very beneficial aspect of plant tissue culture technology is that it offers an alternative method of preserving germplasm, particularly for vegetatively propagated crops. Seeds of some species which are difficult or impractical to keep in storage (like coconut), are much easier to preserve using tissue culture. Tissue culture technology also offers a convenient and speedy method of reproducing rare or endangered plants which might be difficult to reproduce by seed.

3. *Production of natural substances in plant tissue culture.* The use of tissue culture technology to obtain plant-derived products (flavours, fragrances, colours, pharmaceuticals, dyes, enzymes, etc.) from cell culture on a commercial scale is called 'phytoproduction'.

In phytoproduction, the goal is not to regenerate an entire plant from tissue culture but for the plant cells to produce a desired chemical, known as a 'secondary metabolite'. Examples of secondary metabolites include vanilla flavouring derived from the vanilla orchid; cocoa butter from the cacao plant; capsaicin (a hot, spicy flavouring) found in chili peppers; saffron derived from crocuses.

The basic technique used to produce natural substances via tissue culture involves the selection of cells from the desired plant. The cells are then propagated in suspended cultures. Careful regulation of culture conditions, nutrients and metabolic regulators are used to induce the production of the desired chemical compound. Commercial production of natural, plant-derived substances will one day take place in industrial scale fermentation vats, closely resembling a modern brewery.[4]

Scientists have been experimenting with the production of natural substances via plant tissue culture for many decades, but the technology is still relatively expensive and inefficient. The first tissue culture product was commercialized in 1983. Shikonin, a dye and pharmaceutical manufactured by Mitsui Petrochemical Industries, Ltd. (Tokyo, Japan) sells for $4000 per kilogram.

Although phytoproduction is still in the very early stages of commercial development, research is being conducted on a wide range of high-value tissue culture products. An estimated 25 per cent of all pharmaceuticals are derived from plants, and the global market for plant-derived products is an estimated US $10.5 billion at the consumer level.[5] Needless to say, there is tremendous incentive for commercializing tissue culture technology. A

US-based food industry magazine describes the advantages of producing natural substances in plant cell culture:

> What makes plant tissue culture so attractive? The reasons for its attractiveness may be summarized in the words 'quality', 'supply' and 'cost'. Quality and supply can be improved and controlled by the use of production processes based on plant cells. Many of our flavours and other products come from remote parts of the world, where the political instability of governments or the vagaries of weather yield inconsistent supply, cost, and product quality from season to season. In a plant tissue culture process... all parameters ...can be controlled.'

Cell fusion

Using electric shocks or chemicals that 'melt' cell surfaces, scientists are able to fuse two different cell types to create hybrid cells that have the properties of both parents. One of the most important products of induced cell fusion in modern biotechnology are cells which produce monoclonal antibodies.

Monoclonal antibodies

An important example of cell fusion is the fusion of cancer cells, which have the property of constantly dividing, with cells that produce antibodies (antibodies are proteins produced by white blood cells that provide natural defences against viruses, disease-causing bacteria or other infectious agents that are foreign to the body). The product, a 'hybridoma' cell, combines the desired qualities of the two different types of cells: the ability to replicate endlessly, and the ability to produce one specific type of pure antibody.

The hybridoma cell thus provides a source of highly specific diagnostic and therapeutic agents, called monoclonal antibodies. Because the hybridoma cells produce only one specific antibody, they are more concentrated than the antibodies produced by conventional techniques—and thus potentially more effective in fighting or detecting disease.

The following illustration depicts, very simply, how monoclonal antibodies are produced.

Application of monoclonal antibodies

The technique of producing monoclonal antibodies has become a standard procedure in medical and research laboratories, both for human health care and veterinary medicine. Worldwide, the projected market for monoclonal antibody-based products in 1991 is US $1.7 billion.[7] Monoclonal antibodies are produced in large amounts for diagnostic tests and specific screening methods, for purification processes in research and industrial production, and to some extent as therapeutic agents.

1. A mouse is injected with a specific 'antigen'—a substance foreign to the mouse such as a virus, disease-causing bacteria, or a foreign molecule such as human insulin—depending on what the antibodies are wanted for. The presence of the antigen causes the mouse's immune system to respond by creating antibodies—proteins that seek out the antigens and help to destroy them.

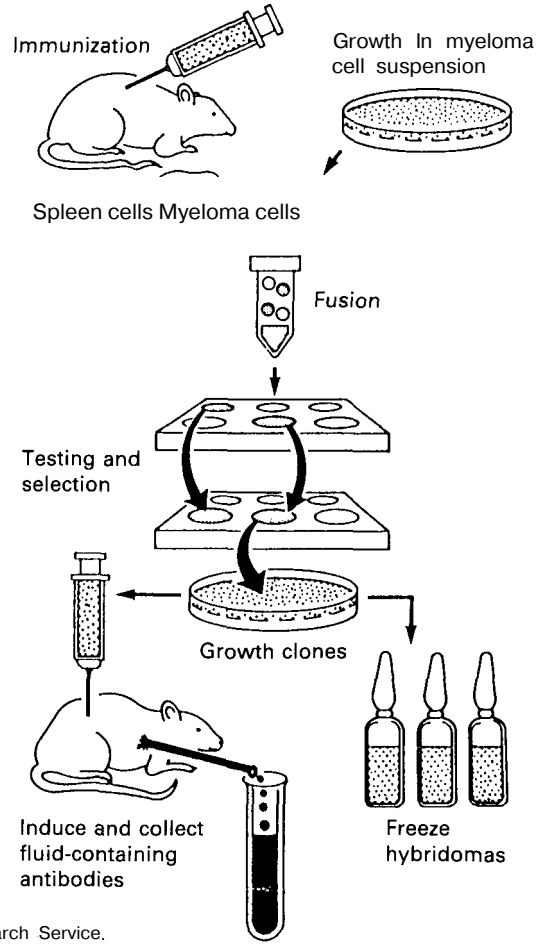
2. Since antibodies are produced in the spleen (among other places), cells from the mouse's spleen are removed to recover the selected antibody-forming cells.

3. Myeloma cells, cells of a malignant tumor of the immune system (cells which have the property of replicating endlessly), are retrieved from cancerous mouse bone marrow and grown in tissue culture.

4. The myeloma (cancerous) cells and antibody-producing cells are fused to form hybridoma cells.

5. The resulting hybridoma cells are separated from each other. Each single viable hybridoma cell multiplies and starts a clone.

6. The clones are laboriously screened for antibody production. Each antibody producing clone makes only one specific type of antibodies—monoclonal antibodies.



Source: US Department of Agriculture, Agricultural Research Service.

Figure 2 Monoclonal antibody production

An important field of application for monoclonal antibodies is diagnostic medicine. Specific diagnostic assays and kits for quick and simple diagnosis are already being used in human and veterinary medicine, and others are being developed. Monoclonal antibodies are routinely used to detect the presence of hormones, drugs and viral or bacterial products in the blood or urine. This new field of diagnostics is particularly attractive to the pharmaceutical industry because expensive clinical tests are not required for the registration and marketing of such products.

Monoclonal antibodies can also be used to purify a substance (e.g. interferon). This technique is of great importance to the purification of cloned products, which must be extracted from a complex mixture of other cell products. An extremely high degree of purity can be obtained with the help of monoclonal antibodies.

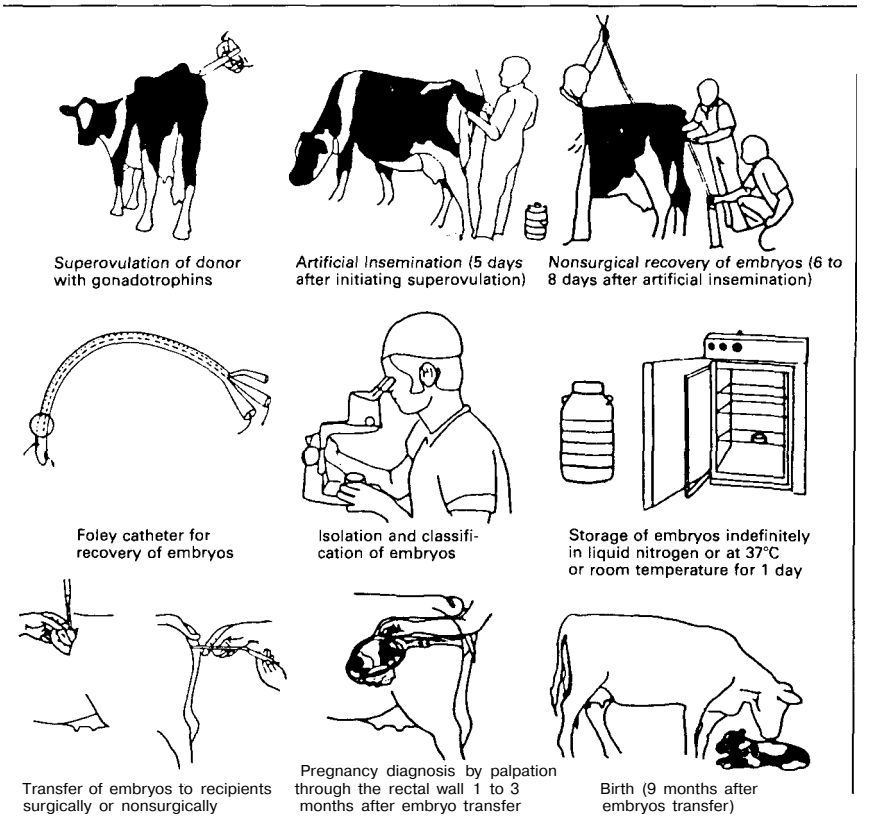
Monoclonal antibodies can also be used therapeutically, to protect or fight against disease. In cancer therapy, for example, monoclonal antibodies which specifically attack cancer cells are already being used to some extent. In addition, monoclonal antibodies can be used as targetting vectors for drugs, a process which has the potential to make drugs more precise and effective in treating diseases.

The following are just a few examples of the current and potential applications of monoclonal antibody technology:

- A product marketed by Molecular Genetics is used to treat scours (diarrhoea) in beef and dairy cattle.
- A small biotechnology company, Agri-Diagnostics, is jointly developing a diagnostic kit with Ciba-Geigy Corporation which will allow farmers to detect fungus infections in crops. The kit will presumably boost sales of Ciba-Geigy's leading fungicide, worth an estimated US $50 million per year.
- A diagnostic kit has been developed to test contaminated foods for the presence of a specific bacterial toxin which causes food poisoning.
- Several companies have developed diagnostic kits to detect early pregnancy and predict ovulation in both humans and animals. Monoclonal antibodies recognize the respective hormones and help determine their concentration.
- Monoclonal antibodies can also be used to determine the sex of livestock embryos.
- A specific type of monoclonal antibodies directed against another type of immune cells (T-lymphocytes) is used to help the human body accept organ transplants.
- Monoclonal antibodies are used to determine AIDS infection.
- Research is underway to use monoclonal antibodies for both detecting and killing cancer cells in humans.

Embryo transfer

The embryo transfer technology is a technique used for upgrading the quality and production efficiency of livestock, most commonly in cattle. It involves the removal of embryos from the reproductive tract of a valuable donor cow and transfer to the reproductive tracts of less valuable cows for gestation to term. With embryo transfer, a valuable cow can be the biological mother of up to 20-30 calves per year (instead of the normal one) without actually giving birth to any. As the technique becomes more sophisticated and less costly, the number of successful embryo transfers is expected to increase. It may someday be as commonplace as artificial insemination in



Source: Adapted from G.E. Seidel, Jr., 'Super Ovulation and Embryo Transfer in Cattle', Science, vol. 211, Jan. 23, 1981, p. 353.

Figure 3 Cow embryo transfer procedures

animal breeding. According to one livestock specialist in the United States, 'By the end of this century, cattle breeding will be a completely controlled procedure'.[8]

The embryo transfer procedure

The embryo transfer procedure is depicted step-by-step in the illustration above. Successful embryo transfer depends on the utilization of several other compatible techniques such as superovulation and artificial insemination.

1. *Superovulation.* Superovulation occurs when an animal is injected with hormones which stimulate the production of more than the normal number of eggs per ovulation. For example, when superovulated, some dairy cows can produce as many as 14 eggs at a time instead of the normal one. Scientists predict that, by the end of the century, it will be possible to produce 100 or more eggs at a time as a result of superovulation.[9]

2. *Artificial insemination.* About 5 days after initiating superovulation, the cow can be artificially inseminated with sperm from outstanding bulls.

3. *Embryo recovery.* Six to eight days after artificial insemination, embryos can be recovered from cattle. Most embryo recoveries from cattle are now performed by nonsurgical methods, but recoveries from ewes (sheep) and sows (swine) require surgical intervention.

4. *Special embryo treatment in the laboratory.* After embryos are recovered from the mother, and before they are implanted in the surrogate mother, they can be frozen in liquid nitrogen and stored, or further manipulated. For example, the sex of the embryo can be determined to enable the deliberate breeding of male or female offspring. Embryos can also be split to multiply the number of offspring. These methods are still in early stages of experimentation. Scientists are also experimenting with the fusion of embryo cells from different animals. In the US, for example, researchers have produced a 'geep'—a cross between a sheep and a goat which resulted from fusion of embryo cells. Scientists are also experimenting with genetic engineering techniques which will allow scientists to some day insert specific genetic information (genes) into fertilized egg cells.

5. *Embryo transfer to surrogate mother.* The surrogate mother can be impregnated with embryos either surgically or non-surgically. In cattle, the birth will take place nine months after embryo transfer.

Embryo transfer technology was first commercialized in the US and Canada in 1972. Annual gross sales of the embryo transfer industry in North America now approaches US $50 million. Because of the high costs of embryo transfer services—and the sluggish growth of the US dairy and cattle sectors—the industry is growing slowly and less than one per cent of US cattle are now involved in embryo transfers. In 1987, an estimated 200,000 cattle embryos were collected in North America, resulting in about 100,000 pregnancies.[10] Virtually all commercial embryo transfers involve dairy cattle and beef cattle.

Since embryo transfer technology facilitates the sale and export of breeding stock over long distances, the industry will likely have a significant impact on livestock breeding and herd composition in the Third World. Despite the high cost of embryo transfer services, it is much easier to export a small cannister full of embryos on an airplane than it is to ship a herd of cattle across the ocean. In 1987, an estimated 10, 000 cattle embryos were exported from North America, half of which went to Europe-11 China, India,

Indonesia and several Latin American nations are among those who are most actively importing cattle embryos in the Third World.

Many countries that do not permit importation of livestock from areas with endemic diseases not found in the importing country do permit importation of frozen embryos. As a result, the embryo transfer industry is reportedly 'reconnoitering potential markets in all corners of the globe'.[12]

The commercialization of embryo transfer services raises many important concerns about the future of livestock breeding and the impact on genetic erosion in animals—particularly in the Third World. The introduction of new breeds of livestock via embryo transfer could drastically reduce indigenous herds and result in the loss of valuable genetic diversity.

Embryo transfer technology can also be used to rescue rare animal breeds by increasing the number of offspring. The London Zoo, for example, transferred the embryo of a wild Indian bison called a guar into the womb of a Friesian cow in an attempt to save the guar from extinction. The Cincinnati Zoo has bred rare antelopes called bongos by transferring bongo embryos into eland antelope.[13]

Recombinant DNA technology

Among the variety of techniques that fall under the general heading of biotechnology, recombinant DNA technology is the most sensational. It enables scientists to manipulate genetic information, which is responsible for features, characteristics and abilities of all living things. Deoxyribonucleic acid (DNA) contained in every reproducible cell of an organism is the carrier of this genetic information. Genes, segments of DNA, carry units of specific genetic information, e.g. the instruction for the production of a protein, such as insulin. The principle of genetic engineering involves the transfer of genes from one cell to another. As the technology advances, transfer between cells of different species further and further apart in terms of evolution becomes possible. The results are organisms with modified genetic make-ups.

New breakthroughs and exciting discoveries in genetic engineering are being reported at a phenomenal rate. Scientists now have the potential to manipulate inherited characteristics in microbes, plants, animals and humans on a scale previously unimaginable.

Current research on recombinant DNA technology runs the gamut—from valuable pharmaceutical products to animals with human genes to blue-

coloured roses. The following are just a few examples, all of which are in the experimental stages:

- Australian scientists are attempting to isolate the gene for blue-colouring in petunias and transfer it to a rose. The goal is to create the world's first blue-coloured roses.
- A long list of corporations are using recombinant DNA technology to develop herbicide resistant crop varieties.
- Researchers at the University of Kentucky (USA) have successfully transferred genes from a fish found in the Arctic Ocean to soybean plants. The goal is to create soybean varieties with increased tolerance to cold weather.
- Genetically-engineered microbes are being designed to degrade or consume toxic waste products.
- US scientists have introduced a gene for the human growth hormone into pigs. The manipulated pigs grow faster, but suffer from arthritis due to their disproportionate size.

Despite all the hype and speculation, however, products of recombinant DNA technology are just beginning to move from the laboratory to the marketplace. As of September 1, 1987, only four genetically-engineered pharmaceutical products were available for commercial sale in the United States, with combined annual sales of approximately $150 million in 1986.[14] The products are human insulin, human growth hormone, alpha interferon and a hepatitis-B vaccine.

In November, 1987, a fifth genetically-engineered product was approved for commercial sale in the US. Genentech's tissue plasminogen activator (t-PA) is a genetically-engineered protein which helps to dissolve blood clots and will be used to treat heart attacks. (t-PA has also been approved for commercial sale in W. Germany, Austria, France, Brazil, New Zealand, the Philippines and South Korea.) It is estimated that the annual market for t-PA is US $500 million.

An estimated 400 companies worldwide are conducting research and development on genetically-engineered products, and the industry predicts that by the year 2000, over one thousand new products will be on the market.[15] According to some estimates, the worldwide market for recombinant DNA products will be more than $50 billion by the year 2000.[16]

Introduction to DNA

Genetic engineering became possible only after several decades of research on the functions of a living cell, in particular, how genetic information is stored in cells, how it is duplicated, and how it is passed from cell to cell, generation to generation. The main focus of this research has been on deoxyribonucleic acid, or DNA, the molecule that codes the instructions for the growth, maintenance and reproduction of all living things.

Around 1919, the chemical structure of DNA was analysed for the first time. Its crucial components are four related chemical compounds called organic bases which are lined up in specific sequences and linked together like beads. In the 1960s it was discovered that particular combinations of three bases make up 'words' of the genetic code. These are called codons. Specific sequences of codons—segments of DNA molecules—make up instructions for the production of proteins. Such units of information are called structural genes.

The famous discovery of the three-dimensional structure of DNA in 1953 by James Watson and Francis Crick became crucial in understanding how DNA makes available information for the processes of life. The three-dimensional structure is a double helix, two intertwined strands of DNA. When a gene on the DNA is used, the double helix is opened up. This mechanism is part of the complex regulation of the genetic system.

The structure, function and composition of DNA is virtually identical in all living organisms—from a blade of grass to a redwood tree, from a butterfly to an elephant. But the DNA molecule is made specific and meaningful through the very precise ordering of the chemical bases. DNA embedded in the chromosomes carries many thousands of genes. The number of genes correlates with the complexity of the organism. It is their number and the enormous variation of information they contain—due to the sequences of the organic bases of the DNA—that result in the variety of living beings. The enormous challenge of the past few decades was to decipher this genetic code to translate the language of DNA. How does DNA give instructions for making, maintaining and reproducing living organisms?

The answer, to a great extent, is found in genes. Each gene carries instructions for the production of a specific protein, which in turn has a specific function in the cell. Proteins are often called 'the building blocks of life' because they are the basic biochemical units that drive all biological processes. Some proteins, called structural proteins, help to build cells and tissues. Other proteins have regulatory functions such as hormones. The

entirety of the genes of an organism, structural and regulatory ones, contain a 'blueprint' for the creation of this particular organism.

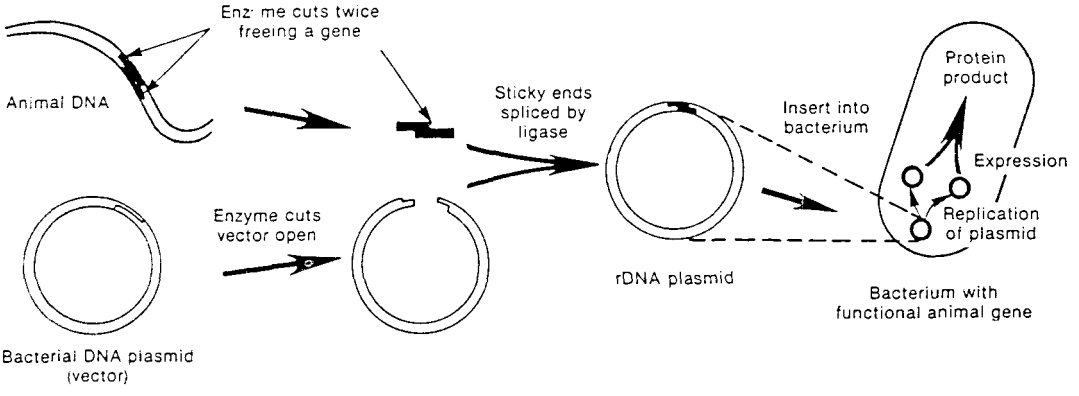
By 1966, the genetic code had been completely deciphered. This means that the parts of DNA that directly encode proteins can be read in such a way that the resulting protein can be predicted.

Theoretically, if we can identify what kind of instructions a specific gene contains, we have the potential to manipulate inherited characteristics in microbes, plants, animals or humans. And that is precisely the goal of recombinant DNA technology. DNA modification and transfer allows desired traits to be precisely transmitted from donor to recipient, not just within species but between species.

Considering that a single plant may contain 100, 000 genes and humans may contain up to 300, 000 genes, the process of first identifying and then transferring DNA from one organism to another is no simple task. It is complicated by the fact that not all genes govern some outwardly manifested trait or characteristic. Some genes control the activity of other genes—acting as switches to turn them on and off. The enormous complexity of the technology is illustrated by the fact that the most completely 'mapped' crop species—meaning that individual genes are located and their functions identified—is the tomato, and the location of only 247 genes are known for the tomato plant.

The actual process used to transfer genes from one organism to another is often compared to the process of editing a written text—using 'scissors' and 'glue' to cut and paste. The primary tools of genetic engineering—the scissors and paste—are special enzymes that enable biologists to snip genes out of DNA molecules and stick them into the DNA of microbes (usually bacteria or yeast cells). The following description explains, in very simple terms, the actual process used to prepare recombinant DNA to produce human insulin.

The protein insulin is a hormone that is an essential therapeutic agent for diabetics. Commercial insulin is derived from animal pancreas tissue, and differs slightly from human insulin. Through recombinant DNA technology, scientists have successfully isolated the gene for human insulin and transferred it into a micro-organism—E. coli (a harmless intestinal bacterium). When these genetically-engineered bacteria are cloned and produced in large quantities they serve as 'mini-factories' producing large amounts of



An animal gene is spliced into a carrier DNA (called a vector) for insertion into a micro-organism (a bacterium is shown) or alternate animal host cell, and is made to replicate and express its protein product.

Source: Office of Technology Assessment.

Figure 4 Recombinant DNA procedure

an otherwise scarce and valuable protein—insulin. A genetically-engineered insulin, marketed by Eli Lilly under the brand name 'Humulin' was one of the first commercial products of recombinant DNA technology.

Once the appropriate gene for insulin production is identified, restriction enzymes are used like chemical scissors to cut it out of the human DNA and paste it into 'plasmid DNA'. Plasmid DNA is a special kind of DNA that takes a circular form and can be used as a vehicle for transferring new genetic information into bacteria or other cells. The result is an edited, or recombinant DNA molecule. When this recombinant plasmid DNA is inserted into E. coli, the cell will be able to process the instructions for insulin production. When the bacteria cells are cloned, each cell inherits the instructions to produce insulin. On a much larger scale, this process is used to produce valuable pharmaceuticals (like insulin) and other economically important proteins.

The transfer of genes into bacteria, yeast or other simple micro-organisms is now a relatively straightforward procedure. Molecules of rDNA can now be inserted into a variety of bacteria, yeast and animal cells where they replicate and produce many useful proteins such as insulin, growth hormones, prolactin, enzymes, toxins, blood proteins, immunity enhancers (such as interferons and interleukins), and nutrients like amino acids and single-cell protein feed supplements.

Scientists are now exploring more complex procedures to introduce novel genetic material into cells of higher plants and animals. Genetic engineering of many plants, for instance, is made possible with a naturally-occurring bacterium called Agrobacterium tumefaciens—a bacterial plasmid which

carries new genetic information into plant cells. Since the *Agrobacterium* system only works in broadleaf plants (such as tomato, tobacco, soybeans) a different technique must be found to facilitate genetic engineering of cereal plants—corn, wheat, rice, etc. Scientists are experimenting with a variety of new methods (chemical induction, micro-injection, electric shock) to introduce genes into cells of higher organisms.

Our review of genetic engineering has only touched the surface of the many potential applications of this powerful new technology. In addition to agricultural and pharmaceutical applications, for example, a great deal of research is underway in gene diagnostics and gene therapy in the field of human medicine. Scientists are now developing techniques to diagnose and treat genetic aberrations in humans—especially inherited diseases and cancer.

1. Unilever's work was set back when it was discovered that cloned trees planted in 1983 began to produce abnormal flowers and fruits. The cause of the abnormalities has not yet been determined.
2. *Agricultural Biotechnology News,* Vol. 3, No. 1, 1986, p. 8.
3. *Pesticide Resistance and World Food Production,* Imperial College Centre for Environmental Technology, London, 1982, p. 64, cited in *ATAS Bulletin.* 'Impact on the Farm' by Pat Mooney, Nov., 1984, p. 46.
4. 'Plant Tissue Culture Germinates in the Marketplace'. *Prepared Foods,* November, 1986, p. 92.
5. *Biotechnology Progress,* Vol. 1, No. 1, March, 1985, p. 1.
6. *Food Technology,* April, 1986, p. 122.
7. 'Mammalian Cell Culture: Worldwide Activities and Markets', *Bio/Technology,* July, 1987, p. 692.
8. Hansel, William, 'A New Era is Dawning for Animal Agriculture', New York's *Food and Life Sciences Quarterly,* 1987, p. 23.
9. Ibid.
10. Personal communication with Dr. George Seidel, Embryo Transfer Laboratory, Colorado State University, Ft. Collins, CO, 25 February. 1988.
11. Ibid.
12. Seidel, George E., 'The Embryo Transfer Industry: Is It Viable?', *Agricultural Biotechnology News,* May/June, 1985, p. 8.
13. *The Economist,* August 15, 1987, p. 67.
14. Pollack, Andrew, 'Gene-Splicing Payoff is Near', *New York Times,* June 10. 1987.
15. *Genetic Engineering News,* June, 1987, p. 14.
16. Dibner, Mark **D.,** 'Biotechnology in Europe', *Science,* June 13, 1986, p. 1367.

Chronology of the Commercialization of Recombinant DNA Technology

1944 Oswald T. Avery, Colin MacLeod and Maclyn McCarty of Rockefeller University in New York determined that deoxyribonucleic acid carries the hereditary blueprint for all living things.

1953 James D. Watson and Francis H. Crick discover the structure of DNA, a three dimensional, double helix. Their findings enabled researchers to understand how DNA worked.

1962 The first codon—a 'word' of the genetic code—was deciphered.

1966 The genetic code of DNA had been completely deciphered; scientists knew the meaning of all the three-base combinations used for protein coding in the DNA.

1970 The Swiss scientist Werner Arber and his colleagues discovered restriction enzymes that cut DNA strands in precise location.

1973 First gene cloned.

1973 Stanley N. Cohen of Stanford University and Herbert W. Boyer of the University of California at San Francisco used restriction enzymes to isolate fragments of DNA in one bacterium and insert it into another.

1976 Genentech (South San Francisco, California, USA) became the first company established to commercialize recombinant DNA technology.

1980 The US Supreme Court ruled that genetically-engineered microorganisms could be patented under existing law—thus propelling the commercialization of modern biotechnology in the US and around the world.

1981 Scientists at Ohio University in Athens (USA) transferred genes from other species into mice, creating the first transgenic animal.

1982 First recombinant DNA animal vaccine approved for use in Europe.

1982 First recombinant DNA pharmaceutical product (human insulin) approved for use in the United States and United Kingdom.

1983 First plant gene expressed in a plant of a different species.

1986 Disclosure of illegal testing of genetically-engineered rabies vaccine in Argentina by Wistar Institute of Pennsylvania (USA).

1987 April. US Patent and Trademark Office ruled that genetically-engineered animals could be patented.

1987 April. After three years of delay because of legal challenges and environmental concerns a California-based company conducted the first legal release of genetically-engineered organisms into the environment.

The Homogenization of Life

A Summary of the Problem/Potential

Before society can reach a working hypothesis about the proper role of the new biotechnologies, we must determine what the world needs. If science is truly in the service of humanity, then what do the poorest of humanity require in the form of technical tools? This asked, we must then consider which tools should be employed. Will conventional technologies meet the need more safely and with less disruption? If so, then these technologies should be used. If standard tools will not do the task, then society should consider biotechnology. Even then, we should not abandon caution. As we have already stated, both the physical and the social risks may be considerable.

It is instructive to ask yet another question. What are the practitioners of the new technology doing already? More than anything else, this may offer society a perspective on the need to regulate and control the biotech industry.

At Bogève, seminar participants exchanged information on the focus of biobusiness in the basic areas of health and agriculture. The data was not encouraging.

For the poor, struggling to keep their young alive and reduce the fertility of those who feel they have enough children, biotechnology is helping the rich keep the old alive and make the infertile fertile. A world which needs clean water and tropical vaccines is being offered new cosmetics and organ transplants. While the poor search for solutions to malaria and diarrhoea, biobusiness plumbs the Yuppie[1] market for genetic screening and human growth hormones so that every girl can be a Barbie Doll and every boy can look like Ken.[2]

In crop production, where farmers are seeking lower input costs and hardier, pest-resistant plants, biotech is promising encapsulated embryos and pesticide-resistant plants. Where farmers look for market security, biotech offers low-priced commodity substitution and the factory farm.

In animal husbandry, biotechnology is transferring embryos to increase the genetic uniformity of herds while the world asks for embryo transfers to protect genetic diversity. The need is for hardier, foraging animals and biotech's answer is 'vet packs' and growth hormones to increase the dependence and vulnerability of livestock.

In food processing, where the poor seek self-reliance through nutritional diversity and local commodities, and look for high-calorie, high-protein

foods, biobusiness delivers proprietary products with enhanced 'mouth feel' and low-cal 'Vegisnax'[3] for the 'DINK'[4] consumer.

The world looks for diverse, renewable and environmentally sensitive sources of industry and energy. Biotechnology appears to be responding with at least some of the solutions. But we are left to marvel that the oil and chemical companies that have so profitably polluted our earth are now demanding patents and profits from the biotech products that may clean up the mess they have made.

Although it seems an absurd contradiction, the tragedy of biotechnology —as it is enacted—is that it will deny the diversity of life and bring about the homogenization of life instead.

The following table summarizes the situation in biotechnology by sector. All three columns are important. Biotechnology is not an automatic solution. It may have a role to play but that role should be determined carefully.

Notes

1. Young UPwardly-mobile Professional.
2. Barbie and Ken dolls have been with us since the 1950s and epitomize the brainless consumer.
3. Vegisnax are a consumer food product under development by DNA Plant Technology, Inc. in the USA.
4. Double Income No Kids.

Table 1 Third World needs and the new biotechnologies

Basic need	Potential contribution of new biotechnologies	Dominant research of biotech industry
	Crop production	
Conservation and improvement of diverse poor people's crops emphasizing hardiness, nutrition, and yield.	Tissue culture technology could support conservation and breeding objectives.	Rather than pest resistance the focus is on gene transfer for pesticide resistance, encapsulated embryos and yield improvement for major crops only.
	Food processing	
Key concerns are durability, nutrition, and cost. Product and production should be culturally and environmentally sensitive making the best use of local resources.	Improvement of traditional fermentation methods and development of new possibilities.	Focus is on reducing or substituting raw materials and the factory production of agricultural products.
	Animal husbandry	
Conserve diversity and broaden breeding efforts for foraging animals to develop healthier, more efficient livestock. Develop multipurpose domesticats.	Vaccines and diagnostics can support these efforts and embryo transfer can help preserve diversity.	Attention is on complete control over fertility and reproduction to develop high yielding uniform, but highly vulnerable breeds and also on veterinarial packages and on use of livestock as bio-reactors for drugs.
	Health Care	
Best way to improve health is to eliminate poverty. Following that preventive health care focusing on improved sanitation, nutrition and drinking water. Next, new vaccines for tropical diseases and AIDS.	Biotechnologies could help with monoclonal antibodies for water testing and gene technology for vaccine research and production.	Emphasis is on diagnostics and clinical assays, help against infertility, production of hormones and drugs related to aging, cancer, AIDS, heart disease and organ transplants and gene therapy.

Part Two

The Economic Laws of Life

The Gene Revolution

Food and Agriculture: A Short Overview

The link between food and health was stressed several times during the Bogève discussions. Annelies Allain of IBFAN and IOCU, Jiraporn Limpananont of the Drug Action Group in Thailand and Mira Shiva of the Voluntary Health Association of India all expressed concern that the impact of biotechnology on the two industries had to be looked at together. This section moves us from a study of various aspects of the food sector to human health and the role of pharmaceuticals. First, we look at the new plant genetics and the transformation of the food processing industry. This is followed by a discussion of animal husbandry in the 1990s leading up to an examination of likely developments in the human health sector in the next decades.

> You're going to see food products that we can't even conceive of today. You're going to see important breakthroughs in the relationship between food and disease, in which food becomes an important element in disease prevention. Biotechnology will enable us to design food to almost any specifications we want.
>
> *R. Gordon McGovern, President, Campbell Soup*[1]

When scientists transferred the luminous gene from a firefly into a tobacco plant, the event captured the public's imagination if not their understanding.[2] For a flagging tobacco industry, the advance heralded a whole new dimension to the phrase 'lighting up'.

Our appreciation of biotechnology has been thwarted by the extent of the biotech 'hype' and the lack of actual products. As hi-tech companies struggled with the incredible complexities of the science, they were forced to tout every technical advance to the rooftops. Hence, the scientists at Novagene—in all other respects grown women and men of presumed maturity—devoted enormous time and money to write the company logo into a cell, the world's first living trademark.

Where functionally useful breakthroughs have been made, they have been of a kind hard to make credible to the non-scientist. Farmers have been regaled with stories of a method to synchronize the ovulation of alligators. The technique would allow the artificial insemination of the big snappers 'en masse' and reduce the required swamp area. For farmers who still find sidling up behind their cow a cautious proposition, the thought of wading willfully into a swamp full of alligators is seen as something less than 'user-friendly' technology.

Then there is the host of veterinary diagnostic kits designed to test if your cat has leukemia or your chicken has cancer. The immediate social relevance escapes most of us. (Tell a broiler it has six months to live and there'll be a big party in the hen house!)

But the oft-heralded, much-applauded, long-awaited science is now disgorging the first fruits of its interminable incubation into the fields. Producers and consumers are already having to face a technology destined to re-shape both food and farmers.

The conglomeration of techniques that add up to biotechnology are 'life in the fast lane'. Like computers, they let us do more, faster. Unlike the old number crunchers, they also let us do new things. No matter how many monkeys work for however many centuries, the little primates will never squeeze firefly genes into tobacco. Only biotech aspires to such lofty goals.

At the most exotic level, biotech can extract a group of useful genes from one species and stuff them into another species. The biological properties differentiating bovines, broccoli and bugs are breaking down. In theory (but a little closer to reality), a cell from the leaf, stem, root or shoot of a cabbage can be split and split again and turned into a cabbage patch. Rather than grow the whole plant, biotechniques can allow industry to grow only the economically important part of the plant—strawberries without leaves or roots, tomatoes without vines, cocoa butter without cacao beans perhaps?

Beyond multiplying and combining, biotechniques can be used in selecting and diagnosing. Useful inheritable qualities can be detected without having to wait for a tree to bear seed. Disease or susceptibility to disease can be predicted. Normal biological processes can be shortened. Time and money can be saved. The economic risks for some groups can be reduced. It becomes possible to project the outcome of life by staring into a petri dish at the beginning of life.

Various biotech industry segments overlap. What is contemplated today in animal husbandry may be tried in human health care tomorrow. Work in livestock improvement must take into account other initiatives in plant genetics that will influence animal feeds and both fields must monitor developments in the food processing industry that might significantly alter the demand for plant and animal raw materials.

The segments of agriculture are introduced below and then addressed in more detail in subsequent chapters.

Plant genetics

Biotech's biggest economic impact (in terms of dollar value at the retail level) will be in the field of agricultural plant genetics. Through cloning and tissue culture techniques, the pace of plant breeding is already increasing dramatically. Biotechnology can increase yield and disease resistance and help farmers adapt to (or even arrest) declining soil conditions and adverse air pollution effects. Biological pest controls could, in theory, (there's that phrase again!) replace standard crop chemicals with a new generation of environmentally sensitive and accurately targeted 'natural' agents that will keep our water, soils, food and farmers safe. All of these techniques should reduce the cost of production and, therefore, the cost of food.

For the first time, biotechnology makes it financially feasible to work on wild plants and bring whole new species into production. Using the selection techniques in biotechnology, breeders can work with a much wider range of germplasm and offer farmers greater genetic diversity in the field.

Although the promise is there, the present reality is that most of the big money in biotechnology is focusing on the adaptation of plant varieties to traditional crop chemicals. Chemical companies recognize that there is a bonanza awaiting manufacturers who can create seeds that like herbicides.

Other techniques include the creation of male sterility in cereal crops leading to easier hybridization. The final result: farmers will be faced with more crops for which they cannot save seed, meaning higher seed prices and more genetic uniformity.

Food processing

In the latter half of this century, Third World economies have been rocked by the substitution of petrochemical synthetics for natural products. In the seventies, it was widely assumed that this form of substitution had reached its zenith. It had not. Prime targets are the pharmaceuticals and food-processing industries. Flavours, fragrances and medicinal plants together amounting to approximately $20 billion in world retail market value are at risk. Some major export crops are also endangered.

New work by Hershey's, Cadbury-Schweppes and Nestlés, for example, will allow for the substitution of lower-quality cocoa for higher-value cocoa. With this new flexibility in the 'mix' of cocoas, companies will be able to

play one country off against another. World prices will be reduced accordingly. Cacao stands as one of the world's most important agricultural trade products. At stake is the financial solvency of a dozen nations.

It is theoretically possible to move almost any natural product from the field into factory production. The actual economics of such a transfer generally make this feasible for only the most exotic goods. Laboratory production of flavours, fragrances and medicinal plants has become an attractive alternative to traditional sources. Major companies are currently exploring the possibility of factory production of such important plants as cinchona (Boehringer-Mannheim for malaria drugs), vanilla (the entire industry is involved and commercial production is expected shortly) and gum arabic (US companies).

A struggle for the control of the food system is now being waged. At one end are the agricultural input companies—chemical and petrochemical concerns often with pharmaceutical connections. At the other end are the giant food processors—the Unilevers and Nestlés of the world. In the middle are the poor and powerless. Traditionally, they have been the ones who have felt the squeeze.

Animal husbandry

Animal husbandry benefits from both work on plant genetics and human health care. Biotechnology is already making a major contribution to animal husbandry through new research on diagnostic kits that could reduce the need for veterinary visits and, possibly, the use of drugs. Some of the kits can be used by the farmer directly and others at least avoid the costly services of a laboratory. Beyond kits, the industry is also coming out with a number of new drugs and vaccines. A vaccine to combat shipping fever—a disease which afflicts about 12 million US cows a year and kills half a million—could save farmers $500 million annually. Work on new drugs for hoof and mouth disease, blue tongue and rabies also show promise.

Major research is targeted on the bovine reproductive system. Embryo transfer—combined with an awesome array of other techniques—can increase the calf yield and quality to almost incalculable levels in amazingly short time periods.

But there are questions of cost and availability. At current beef and dairy prices, the techniques are too expensive for all but the wealthiest farmers. In the US beef industry, the estimated value added by embryo transfer to the final price of an animal is only $50. Hardly worth the trouble. The

potential for overproduction is also severe. Techniques such as the Bovine Growth Hormone (bGH) can massively boost milk yields, and consequently wipe out many dairy farmers.

The embryo transfer method, which could be used to multiply endangered species and breeds, is much more likely to be used to create unprecedented genetic uniformity with a handful of super cows mated (in a test-tube) to a handful of super bulls. Such genetic uniformity breeds genetic vulnerability. This could bring us back—full circle—to greater disease problems, more drugs, lower yields, production collapses and the market instability we now seek to avoid.

Notes

1. Campbell Soup Company, 1987 Annual Report, p. 13.
2. Schmeck Jr., Harold M., 'Tobacco with Firefly Gene Implant Glows', New York Times, 11 July, 1986.

Biofarms: The End of the End

Third World Farmers and the New Plant Genetics

The public sector's Green Revolution has been superseded by the private sector's Gene Revolution—with little recollection on anyone's part of the socioeconomic lessons learned during the Green Revolution. Further, the new revolution has created an atmosphere of confusion and uncertainty about the future of agriculture. As the new age of biotechnology unfolds, two forces are competing for control of agriculture—the suppliers of agricultural inputs and the food processors. At Bogève, we discussed their strategies and the implications for the Third World.

> In little more than a century, we could move from a world where industry depends on agriculture to one where agriculture is totally dependent on industry.
>
> *William B. Lacy and Laura R. Lacy, 1986*[1]

If you are a farmer, it has been a bad century. Agricultural productivity has gone through the economic ceiling and your children have gone to the city. Somewhere in the early eighties, as the human population catapulted toward five billion, we became a predominantly urban people. It has been thousands of years since more of us were non-farmers than farmers—and then the majority of us were gatherers and hunters. Everywhere the trend is the same—Africa or Europe. There were more than 6.4 million farms in the United States before the First World War and fewer than 2.8 million at the century's three-quarter mark.[2] By the year 2000, 50, 000 American farms will account for 75 per cent of that nation's agricultural productivity.[3]

Northern industrialized agriculture now proudly boasts that one farmer produces enough food for 69 consumers—boasting, in effect, about the efficiency of its own demise. Could we not devise an agricultural system that allows more people to live on the land, providing a life and employment for themselves as well as food for others? Must we be so efficient at producing unemployment, high-priced food, and hunger?

Biotechnology is expected to increase the individual farmers' productivity ratio, indirectly increasing the urban tide. In the course of our research into the agricultural implications of biotechnology, no one at Bogève was able to report a single study in any country that predicted a reprieve for the 'family' farm or any improvement in the conditions of small farmers due to the new biosciences.

The new techniques could (and should) lower production costs by reducing the plant or animal's requirements for external inputs—fertilizers, pesti-

cides, veterinarial medicines, growth hormones, etc. More than this, biotech could 'domesticate' new species and allow farmers to diversify into new crops. Biotech has the capacity to be the Green Revolution that never was. A Gene Revolution for the poor.

Combining biotechniques with specialized computer software and electricity technologies, Bill Reid of Sungene claims that as many as two million plant cells can be rapidly scanned in a petri dish. Using conventional methods for the same work, breeders would need a 33 hectare field and an entire season.[4]

A technique known as electroporation is also speeding up the pace of hybrid development. Where it currently takes six years or more of crossing and back-crossing to develop a new maize hybrid, the time frame using electroporation can be dropped to two years or even less.[5] Electroporation also allows breeders to use exotic genes from other species. Equipment designed by Japan's Nihon Bunko Kogyo produces hybrids between protoplast-derived tobacco leaves and carrot roots at a rate of 100, 000 cells per minute.[6] The functional relevance may not be obvious but the research proves that gene transfer—once a tedious process—can become an assembly-line operation.

It is doubtful that biotech's potential will be used to aid the family farm—-much less the rural poor of the Third World. Unlike the Green Revolution which was led by the public sector (pushed by the heavy influences of East/West politics and the petrochemical industry), the new Gene Revolution is almost exclusively a private affair with little 'corporate memory' of the Socioeconomic problems that tend to accompany rapid technological transformations.

The Green Revolution was tightly concentrated in the hands of eight semi-public international centres. Though hundreds of companies are involved, the gene revolution is tightly concentrated in a handful of countries—all in the North. Despite this concentration, the focus of the new revolution is much wider. Not merely wheat, rice and maize, but all crops are up for research and development. Furthermore, it is not possible to isolate the biotech work on plant genetics entirely from the work on people or poultry. The table below might more correctly compare the green revolution of Norman Borlaug with the wider gene revolution of Watson and Crick simply because—especially in this early stage—it is unwise to separate the sub-sectors.[7] In this event, we would match CGIAR's $108 million for agricultural research to at least $280 million by US biotech firms

Comparing the Revolutions

Green Revolution	Gene Revolution
Summary	
Based in public sector Humanitarian intent Centralized R & D Focus on yield Relatively gradual Emphasis on major cereals	Based in private sector Profit motive Centralized R & D Focus on inputs/processing Relatively immediate Affects all species
Objective	
To feed the hungry and cool Third World political tensions by increasing food yields with fertilizers and seeds	To contribute to profit by increasing input and/or processor efficiencies
For Whom	
The poor	The shareholder and management
By Whom	
CGIAR has 830 scientists working in 8 institutes reporting to US foundations Industrialized countries Quasi-UN bodies	In the USA alone, 1,127[8] scientists working for 30 agbiotech companies
How	
Plant breeding in wheat, maize, rice	Genetic manipulation of all plants, all animals, microorganisms
Primary Targets	
Semi-dwarf capacity in cereals Response to fertilizers	- Herbicide tolerance - Natural substitution - Factory production
Investment	
$108 million for agricultural R&D through CGIAR system (1988)[9]	Agbiotech R&D investment of $144 million in USA (1988) by 30 companies
General Impact	
Substantial but gradual 52.9 per cent of Third World wheat and rice in HRV's (123 million hectares) '500 million would not otherwise be fed'	Enormous—sometimes immediate $20 billion in medicinal and flavour/fragrance crops at risk Multi-billion dollar beverage, confectionery, sugar and vegetable oils trade could be lost

Green Revolution	**Gene Revolution**
Impact on Farmers	
- Access to seeds and inputs uneven	- Increased production costs
- Small farmers lose land to larger farmers	- Loss of some crops to factory farms
- New varieties improve yield but increase risk	- Input/processing efficiencies increase farmer risk
- Reduced prices	- Overproduction and materials diversification
Impact on Farms	
- Soil erosion due to heavy use of crop chemicals	- Continuation and possible acceleration of Green Revolution effects plus
- Genetic erosion due to replacement of traditional varieties	- Release of potentially uncontrollable new organisms into the environment
- Species loss due to overplanting of traditional crops with maize, wheat or rice	- Genetic erosion of animals and micro-organisms
- Pressure on water resources due to irrigation	- Biological warfare on economically important crops
- Deforestation	
Impact on Consumption	
- Decline in use of high-value 'poor people's' foods	- Emphasis on feeding the rich 'Yuppie' market
- Export of food out of region	- Increased use of chemical and biological toxins
Economic Implications	
- Direct contribution of $10 billion p/a to Third World food production	- Contribution to seed production of $12.1 billion p/a by year 2000
- Indirect contribution of $50-60 billion Gene flow to US alone contribute to farms sails of $2 billion p/a for wheat, rice and maize	- Contribution to agriculture of $50 billion p/a by year 2000
	- Absorb benefit of gene flow from the Third World
Political Implications	
National breeding programmes curtailed	- CGIAR system subverted to corporate interests
Third World agriculture 'westernized'	- Genetic raw materials and technologies controlled by genetics supply industry through patents
Germplasm benefits usurped	
Dependency	

with some agriculturally-related activity. CGIAR's 830 scientists would be set against private biotech's 4,000 researchers in the United States.

Commodity roulette

In the late eighties, what the gene revolution appears to do best for farmers is to create confusion. No one knows which crops or conditions will prevail. The genetics supply industry and the food processors are influencing every aspect of the system. Some examples:

Feed, food or factory?

Farmers are faced with both new opportunities and new competitors in the important animal feeds market. For West African growers, it is good news that lignin-degrading microbes have been designed to make groundnut hulls marketable as a feed supplement.[10] However, microbial proteins derived from yeast can now be used to supplement the same feeds. The developer, Provesta, believes its product will reduce the need for high-protein cereals.[11] Bad news for grain-growers.

Still looking at animal feeds, Ralston Purina is developing a process that eliminates off-flavours in soy protein. This could boost the market for Brazilian and US soybeans.[12] But, on the other side of soy, Ajimoto of Japan and LaFarge of France are betting that higher soybean prices will encourage greater use of their biotech-developed lysine supplements.[13]

Even the farmers who buy feeds are not always winners. In conjunction with Dow Chemical, Collaborative Research (a biotech company) has created a recombinant calf rennin that could replace the traditional supply with a high quality, stable product for cheese-makers. The near-term market could reach $75 million.[14] That's a gain for Dow but a loss for ranchers and abattoirs. But, what mighty Dow wins in cheese, it could lose in petrochemicals... A new biotech process allows digestible maize starch to encapsulate both foods and pharmaceuticals. The technique is said to be safer than currently used chemicals and might even reduce the 137 million ton US maize surplus.[15] That's one for farmers.

Proctor and Gamble has devised a process that could replace 35 per cent of the home-use of natural fats and more than 70 per cent of commercial cooking fats with its new sucrose polyesters.[16] A blow to ranchers.

Flavours out of favour?

A great deal of biotech research is looking into the replacement or reduced use of high-value flavour and fragrance plants with laboratory processes. In Europe, the University of Munich, in concert with an unnamed company, is studying 29 compounds in the hope of eliminating industry dependence on the crop production of food flavours.[17]

Also in Europe, DNA Plant Technology has a joint venture with Firmenich to explore fermentation processes that would end company dependence on Third World plants.[18]

Meanwhile, a major American concern, International Flavors and Fragrances, is working on a number of aroma/taste enhancing esters that would reduce its need for Third World farmers and gatherers.[19] Didi Soetomo and his colleagues in Indonesia advise us that IFF is exploring the botanical diversity of his country in search of commercially viable herbs.[20]

Sometimes the biotech news is all bad. In the human foods sector, DNA Plant Technology has developed a high-solids processing tomato. By reducing the water content by 20 per cent, Campbell Soup expects to achieve huge energy savings and slash its crop requirement.[21] Similarly, the US Department of Agriculture has succeeded in extracting a gene from wheat that—when added to yeast—enhances the baking quality of wheat in bread.[22] Such a discovery could affect the world requirement for hard red spring wheats—a particular specialty of Canadian grain farmers.

Not all the problems and opportunities are on land. Chitin, a previously discarded by-product of shrimp and crab processing, when converted to chitosan, may have diverse uses in food processing and other industrial activities. The market value could run to hundreds of millions of dollars for processors.[23] Green Nori seaweed, traditionally grown in Asia, can now be produced on nylon mats on the American east coast thanks to a newly discovered cloning process. The market for seaweed in both Asia and the US is in the range of $600 million.[24]

Other developments could hurt fisherfolk in Europe. Batalle and Union Camp are working on a product called Nocardia which would eliminate the need for castor oil—a fast-growing market provided almost exclusively by Iceland and Norway.[25] In the field of protein adhesives, it used to cost US $15,000 and 3 million mussels to yield a single gram of adhesive protein. Chemical synthetics reduced this cost to US $10,000. Biotechniques have now reduced the cost for a new natural mussel adhesive to $2.10 per gram. Great news for mussels—bad news for mussel harvestors in Europe.

Other important changes may be coming to semi-arid and desert crops. One US concern, Desert King, has developed a process that allows extraction of 99 per cent of the oil found in Jojoba—enabling this unusual crop to become a potential competitor in the already overcrowded vegetable oils market.[26] A hard fibre crop grown in Asia and Central America known as kenaf could

replace wood pulp in the newsprint business. The research work is being supported by Canadian International Paper (a giant exporter of Canadian newsprint to the United States), the USDA, and Kenaf International.[27]

Third World fruit exporters could be deeply affected by a new California initiative. The US Department of Agriculture (USDA) has developed a plant hormone (auxim) which appears to eliminate extreme bitterness from squeezed navel oranges making them competitive with canned and frozen varieties from Florida and Brazil.[28] While this helps growers in California, it will also lower commodity prices for citrus world wide. Similar work may also be underway with the help of one of the world's largest tropical fruit buyers. RJR Nabisco and Biotechnica International have joined forces, they say, to improve the flavour and nutritional qualities of fruits and cereals.[29] RJR also owns Del Monte. Tropical producers beware.

Twinkies in the twilight zone

Back in the sixties, consumers were either horrified or titillated by the creation of an artificial cupcake known as a 'Twinkie'—purported at the time to have no known natural ingredients. Ah! The good old days! Agouron, a pharmaceutical firm, and General Foods (now owned by tobacco giant Phillip Morris), have developed a process that changes and stabilizes the texture of foods—opening the way to much broader forms of farm product substitution.[30] This research follows on the heels of university research that appears to allow processors to alter the taste of chicken to replicate beef[31]—and other research which permits the processing of low-quality meats to match the taste and texture of high-quality cuts.[32] On the other side, University Genetics has developed Belgian Blue—a bovine whose product is healthier than chicken and closer to seafood in terms of cholesterol, fat and calories.[33]

If you are a farmer, do you bet on the future of chickens or of cows? If biotech portends the 'human dawn', it also threatens the twilight of farmers. Its awfully hard to see ahead in the gathering gloom.

Other factors

Aside from the sense of commodity roulette created by the diverse range of biotechniques, it is possible to identify a number of other market factors that are particularly influenced by the new technology. Some of the key factors are summarized here. All of them are also influenced by changes in the processing industry and further comment will follow in that chapter.

Overproduction

The opportunity to increase the yield of natural products with new bio-sciences is quite spectacular. Logically, the greatest potential rests with

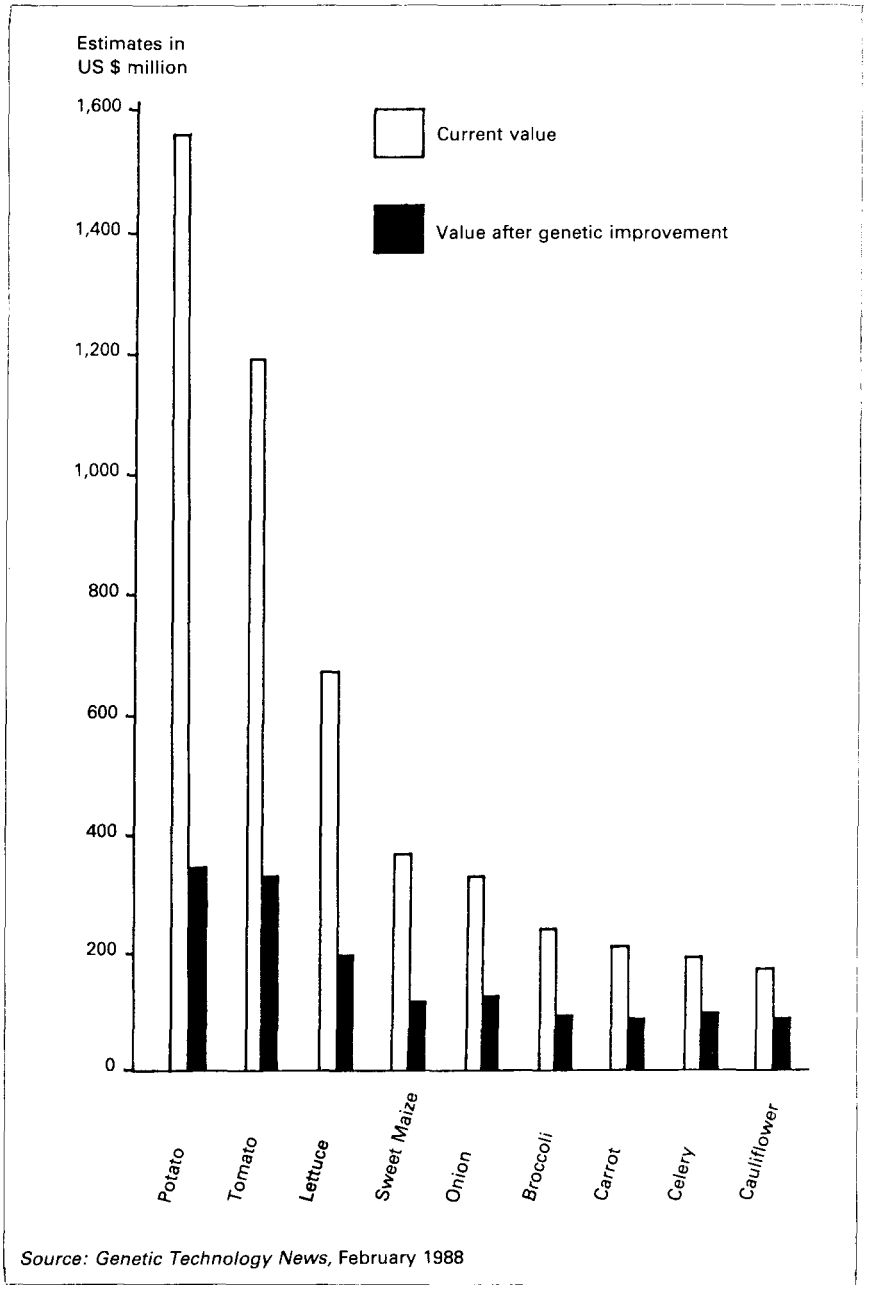


Figure 5 US market estimates for genetically-altered vegetables

under-exploited plants. Biotech may, however, push goods from underproduction to overproduction at great risk to national economies. Vegetable oils are a prime example.

Table 2 Biotechnology and major crops production increase by year 2000 (1986 =100)

Year of probable commercialization	1992 Alfalfa	1992 Maize	1992 Barley	1992 Wheat	1992 Soya	1991 Rape	1991 Rice	1991 Sunflower
USA	144	144	146	145	144	167	150	500
Canada	145	171	133	145	300	150		
Europe	200	148	140	144	200	200	300	250
Asia	200	200	200	200	200	200	200	200
Latin America	200	200	300	200	200	200	200	200
Africa	233	200	217	200	200	300	222	200
Average	162	166	166	174	176	189	200	278

Source: Based upon basic data from Manny Ratafia and Terry Purinton, Technology Management Group, 'World Agricultural Markets', *Bio/Technology,* March, 1988, p. 281.

A tissue culture technique developed by Unilever is currently producing half a million new palms a year in a market where 60 to 80 million trees might be replaced. Cloned palms can increase yield 500 per cent merely by ensuring that all the planted trees are the highest yielders. In addition, Unilever estimates that genetics work will increase the yield of the cloned trees another 30 per cent. The result will be a glut on the vegetable oils market and reduced prices for the producers of all oils (groundnuts and soyabean included). Because of the management skills required and cost/risk involved, large estates will benefit from the new technology at the expense of smallholders. Hundreds of thousands of smallholders in South-east Asia could be affected.

Further, the tissue culture process is experimental and the guinea pig is the Third World. By late 1986, Malaysian scientists discovered 'bunch failure' in 51 to 95 per cent of the clones in test fields.[34]

Despite the potential for the exotic, however, most biotech companies are concentrating on traditional commodities—the old green revolution favourites of wheat, rice and maize. New plant varieties benefiting from the new technologies are expected to be on the market by 1991 or 1992. The yield improvement over their brethren of 1986 is predicted to be a whopping 62 per cent with crops like sunflowers and rice more than doubling. The slowest growth is expected from crops like lucerne (alfalfa), maize and barley but even they will do well.

Africa will benefit the most, the companies say, but Asia, Europe and Latin America will all experience a doubling of yield in the eight crops studied.

North America will not do nearly so well. Whether Third World countries will have affordable access to the new varieties—or whether their consumers will be able to buy the end product—are questions beyond the ken of companies.

Transferred production

Biotechnology can extend the habitat of plant and animal organisms making it practical for temperate zone countries to adapt tropical or subtropical species for domestic production. Kenaf is a prime example. With support from the US Government, Agrifuture has established a subsidiary firm, Kenaf International, to collect germplasm in Thailand, Taiwan and Guatemala. The company hopes to plant 45,000 acres in Texas by the end of the decade and is developing pulp and paper plants in Texas and Costa Rica. Agrifuture now 'monopolizes by default' the world's storehouse of kenaf seed. Kenaf paper could replace pine trees in newsprint production. This could offer some relief for tropical rain forests. The crop is also used to make currency and cigarette paper.

Aside from the possible benefit for rain forests, Third World countries may not lose an export market so much as fail to benefit from the utilization of a natural raw material which would not have been a target of biotech research were it not for the pioneering work of producers and scientists in the South.

Technology packaging

The market opportunities (and dangers) presented by biosciences encourage vertical integration from raw materials to processing. Among the side-effects of this integration can be the opportunistic packaging of new technologies. For example, American Cyanamid developed a new range of herbicides and a maize gene resistant to those herbicides. The altered gene was then given—without change—to the world's largest corn breeding company. Pioneer Hi-Bred.

Multiple-sourcing

At the processing end of biotechnology, it is possible to broaden the geographic sources of raw materials through 'natural' adaptations in the production process. In this way, the few remaining barriers between various vegetable oils can now be eliminated entirely. Sunflowers, canola, soybeans and palm will compete equally with olive oil. Cheap cacao can compete with expensive cacao. The caffeine level of robusta coffee can be altered to match arabica coffee (or vice versa depending on the consumer market). Sweeteners can be drawn from an ever-wider range of economically viable species.

The bright green gene machine

The new sciences threaten to destabilize crop production and that 40 per cent of all manufactured goods dependent upon biological materials. Many

of these materials—from herbal medicines to industrial waxes—form part of the exports and foreign exchange earnings of the Third World.

Bill Reid of Sungene notes that most of the exotic gene work underway involves the movement or alteration of a single gene. The average cultivated plant expresses between 50,000 and 100,000 structural genes during its life cycle. Reid says, '...it is essential that the interaction of 49,999 genes not be overlooked in the excitement of modifying the function of one gene'.[35]

The final solution?

The danger of monoculture first became evident with the Irish Potato Famine of the 1840s and 50s. Millions died and millions more became the world's first boat people—fleeing to other parts of Europe and North America. Monoculture, in turn, created a market for crop chemicals. Now, BASF has finally put it all together. It has discovered a fungus called Penicillium cyclopium. No run-of-the-mill fungus, this one yields two compounds that are structurally identical save for one hydroxyl group. One compound is 95 per cent effective against the original Irish Potato Blight (still a factor in European farming) and the other acts as a tranquillizer —structurally very close to Valium.[36] One for the field—one for the farmer. All set for the 21st century!

Notes

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2. Ibid.
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5. Schneider, Keith, 'Researchers See Gain in Efforts to Design Crops', *New York Times,* March 16, 1986, p. 26.
6. Plotkin, Hal and Coleman, Ken, 'Japan Round-up', *BiolTechnology,* January, 1988, Vol. 6, p. 19.
7. According to *BiolTechnology,* March, 1988, p. 243, US Ag Biotech firms spend US $47 million a year on R&D of a biotech (R&D) total of US $400 million for the USA.
8. Data drawn from a study by Marc Dibner made for the North Carolina Biotechnology Center, 1988.
9. All data used in this column—including statements in quotes—comes from CGIAR information office in Washington DC and was obtained in telephone conversations in 1988 by Pat Mooney, RAFI.

10. *Bio Processing Technology,* 6/87.
11. Ibid. 7/87.
12. Ibid. 5/87.
13. *Agricultural Genetics Report,* 3-4/82.
14. Ibid. 2/87.
15. *Bio Processing Technology,* 10/87.
16. Ibid. 6/87.
17. Ibid. 11/87.
18. *Agricultural Genetics Report,* 1-3/85.
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24. *AgBiotechnology News,* 5-6/87.
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28. UNIDO, *Genetic Engineering and Biotechnology Monitor,* 7-9/86.
29. *AgBiotechnology News,* 11-12/87, p. 10.
30. *Bio Processing Technology,* 7/87.
31. *AgBiotechnology News,* Vol. 4, No. 3, May-June, 1987, p. 19.
32. 'Restructuring Cheap Meat into Prime Cut', *AgBiotechnology News,* January-February, 1987, p. 22.
33. 'New Beef Animal Said to be Nutritionally Better than Chicken', *AgBiotechnology News,* July-August, 1987, p. 1.
34. *South Magazine,* January 1987, p. 109, and *Agricell Report,* November 1988, p. 34.
35. Reid, William J., President, Sungene Tech., 'Biotechnology and Breeding Team Up in Agriculture', *Bio/Technology,* September, 1987, p. 900.
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Pharm-ecology

The Corporate Approach to Organic Agriculture

Nowhere is the bio-babble of the new technology more full of double talk and double think than it is in relation to agricultural inputs. For the first time in this century, agricultural scientists, the companies and governments who employ them and the farmers who are their market targets are, all of them, uncertain and confused about the state and future of food production. All agree that there is a crisis. All… or most… admit that the current system has failed.

In two decades we won't be spraying crap on plants anymore.
Sam Dryden, then President, Agrigenetics[1]

... the craziest thing since Looney Tunes!
Roger Salquist of Calgene on nitrogen-fixation[2]

The struggle of people[3] against power is the struggle of memory against forgetting.
Milan Kundera[4] *as quoted by Martin Abraham at Bogève*

Erosion

The agricultural apocalypse that many foresee has new horsemen. Each horseman is a form of erosion. Most prominent of all is the environmental erosion. Not only are the final days of the twentieth century witnessing the genetic erosion of crop resources—a loss of more than half of the diversity of major food plants in a scarce three decades—we are also observing soil erosion—perhaps half a billion hectares of tropical farm land driven from production early in the next century. Further, we are beginning to experience a kind of atmospheric erosion. The ozone holes over the polar icecaps have profoundly shocked the scientific community and substantial losses in food production (among many other kinds of losses) are predicted.

The environmental horseman has been joined by a political horseman. The political power of farmers—South and North—has been eroding all of this century. Now faced with new trade wars and economic crisis on a broad scale, agriculturalists lack the political numbers to defend themselves. Commodity prices are dropping and international trade in food has become an all-out war between North America and Europe and between North and South. No one dares to predict with any semblance of certainty where prices will go and who will survive. What is clear is that farmers have little influence over the final outcome. What is questioned—for the first time in the history of agriculture—is the validity of increased production.

The third horseman is corporate. The number of major players in agricul-

tural inputs, food processing, and retailing has dropped phenomenally in the industrialized countries. Corporate erosion in the past ten years may have swept away as many as one-third of the transnational enterprises that dominated the field in the mid-seventies. Not that the corporate power has been eroded. Rather the power has been concentrated into fewer and fewer hands. Farmers—who have never had many buyers to bargain with—have far fewer today.

Organic agriculture

With these three horsemen dominating the rural skyline, even the most arrogant scientists are doubting their own basic concepts. Intellectual space has been created for farmers and agronomists alike to contemplate radical alternatives. The combination of low commodity prices and high input costs has cast particular doubt over farming systems that emphasize the use of synthetic fertilizers and pesticides. Suddenly, organic agriculture—historically regarded by the scientist as the preserve of kooks and quacks—has achieved a modicum of acceptability.

Here and there, universities are beginning to teach 'sustainable' agriculture. Now and again, corporations are offering grants for work in biological pest control. Those who have been preaching in the wilderness for decades can be found wandering the corporate or government halls in glassy-eyed euphoria convincing themselves that the kingdom has finally come.

If the crisis has stimulated intellectual ferment—and it has—it has also given the major corporate players space in which to manoeuver. The new biotechnologies make it possible for biotech companies to adopt the language of organic farming and don the mantle of agricultural sustainability while actually pursuing products that may increase risks to the food system.

At Bogève, Kwaku Haligah of Togo, José Lutzenberger of Brazil and Martin Abraham of Malaysia discussed the potential for sustainable agriculture. Lutzenberger—a former BASF senior executive (and a 1988 winner of the Right Livelihood Award) who has almost single-handedly made Latin Americans conscious of the problems of agro-toxins and the potential for sustainability—argued that farmers and consumers were becoming aware of the need for sustainability and that the emphasis had to be on practical training, research and public education. Abraham, on the other hand, pointed to the threat that the new technologies would pervert the organic movement by offering a whole new range of so-called natural products that might prove more dangerous than the old chemicals or might actually increase the market for these chemicals.

Table 3 Research focus: agricultural biotechnology and the private sector: company activity by region.

	Number of Enterprises					
Type of Product	USA	Canada	Europe	Latin America	Japan	Total
Seeds	137	14	38	3	11	203
Disease resistance	40	4	15	2	8	69
Herbicide resistance	26	3	8	0	1	38
Nitrogen-fixation	20	1	6	1	0	28
Pest resistance	18	2	4	0	0	24
Stress resistance	15	3	4	0	1	23
Protein improvement	18	1	1	0	1	21
Plant diagnostics	54	3	19	4	1	81
Plant food/feed	75	8	56	5	3	147
Other related products	10	2	12	25	1	50
Grand Total	276	27	125	37	16	481

Source: Manny Ratafia and Terry Purinton, Technology Management Group, 'World Agricultural Markets', *Bio/Technology,* March 1988, p. 281.

Sustaining the input companies

Of the 405 enterprises in 19 countries engaged in the commercialization of new biotechnologies, 103 are working in agriculture. Fifty-one of these are concentrating on agricultural inputs research.[7] Estimates of the market impact of biotechnology on agriculture vary from a low of US $12.6 billion[8] to a high of $67 billion[9] on or about the year 2000. Analysts suggest that, shortly after the year 2000, about US $12.1 billion of an estimated $28 billion world commercial seed market will contain contributions from biotechnology.[10]

Media attention has focused on the potential to develop super plants that would require little or no chemicals. In fact, the short and medium-term strategy of the genetics supply industry is to maximize the use of chemicals and use new biotechniques to broaden the applicability of pesticides. The longer-term strategy foresees a shift away from synthetic inputs toward a new era of biopesticides and biofertilizers. However, the living, 'Natural' inputs may be even more dangerous to society than the artificial products they replace.

A report by a private consulting firm made public in 1988 optimistically suggests that biotech houses are working hard at pest and disease resis-

tance. Often, however, 'pest' resistance becomes pesticides resistance and 'stress' resistance amounts to the plant's ability to withstand pesticides. Over 80 enterprises are working on plant diagnostic kits as well—but, like their cousins in the human health care field, the result could lead to greater input costs and added work rather than the 'as advertised' input cost reductions.

New biotechniques

The modern era of new biotechnologies began in the late seventies with promises of a world agricultural system without chemicals. The President of Agrigenetics, a biotech conglomeration of 12 smaller seed companies, predicted that new biological pest controls and hardier plant varieties would turn farm chemical pails into museum pieces within a few decades. So far, his own company has been absorbed by Lubrizol—a major chemical concern—and he has moved on to other things.[11]

The techniques of gene transfer and of somatic embryogenesis make possible a major revolution in farm inputs. Herbicide resistant genes found in exotic species may be transferred into crop varieties. Somatic embryogenesis can be used to grow a plant from parts other than its seed. Scientists can actually sow encapsulated embryos rather than seed. Bacteria that are toxic to insect pests for one crop can be transferred to other crops. New strains of rhizobia can theoretically (and with some risk) be developed to enhance the nitrogen-fixing capacity of plants.

By the mid-eighties, however, the Chief Executive Officer of one of the largest biotech companies, Calgene, was claiming that the notion of a fertilizer-free agriculture should be stricken from the language[12] and Donald Duvick of Pioneer Hi-Bred (the world's largest seed company) was advising that screening for genetic resistance to herbicides was 'becoming as important as screening the same cultivars for genetic resistance to prevalent diseases and insect pests'.

Changes in the industry

The development of these techniques comes at a time of major restructuring in the farm inputs industry. Where 30 manufacturers were engaged in pesticides development in the mid-seventies in the United States, there are only a dozen today. Industry sources suggest that only half of these will survive to see the next century. The United Kingdom claimed sixty manufacturers and formulators in the early eighties but only six were important to the market. Even this number is expected to decrease.[13] Worldwide, the US

Table 4 The global pesticides industry: the top seven enterprises in 1986 (US $ million)

Enterprise	State	Sales	Percentage of global sales	Herbicide tolerance
Bayer	FR Germany	2,344	13	Yes
Ciba-Geigy	Switzerland	2,070	12	Yes
ICI	UK	1,900	11	Yes
Rhone-Poulenc	France	1,500	9	Yes
Monsanto	USA	1,152	7	Yes
Hoechst	FR Germany	1,022	6	Yes
Du Pont	USA	1,000	6	Yes
Top Seven		10,988	63	

$17.4 billion[14] pesticides industry is dominated by seven transnationals (each with sales of one billion dollars or more) that share 63 per cent of global sales.[15]

Of the lead seven pesticides firms, five are also ranked among the world's largest 20-25 seed companies. Only Bayer and Du Pont have marginal seed interests.

The seed industry has also been massively transformed. Estimates of the number of take-overs in recent years vary from a low of 120 companies[16] to a high of more than 500 acquisitions and an equal number of other equity arrangements giving international firms a dominant position in world seed sales.[17] Total world retail sales in seeds per annum approximates US $13.6 billion—of which $6 billion is 'proprietary' (patented or hybrid seed). The top ten companies have close to 20 per cent of the world's commercial seed market.[18]

Of the top ten only Pioneer and Limagrain are traditional to the industry and only these two have no significant interest in crop chemicals.

Short- to medium-term strategies

The immediate strategies employed concentrate on the extension of the market for registered crop chemicals through the promotion of herbicide tolerance and through the development of encapsulated embryos to replace traditional seed. Both tactics are described below.

Chemical adaptation

The overwhelming majority of the work associating plant breeding with chemicals has been in the sphere of herbicide tolerance ('HT') research. Some companies (notably Shell Oil and Ohm and Baas) have also worked

Table 5 The global genetics supply industry: the top ten enterprises in 1987 (US $ million)

Enterprise	State	Seed sales	Percentage of global sales	Herbicide tolerance
Pioneer	USA	891,0	6,55	Yes
Shell	UK/Netherlands	350,0	2,57	Yes
Sandoz	Switzerland	289,8	2,13	Yes
Dekalb/Pfizer	USA	201,4	1,48	Yes
Upjohn	USA	200,0	1,47	Unknown
Limagrain	France	171,5	1,26	No
ICI	UK	160,0	1,19	Yes
Ciba-Geigy	Switzerland	152,0	1,12	Yes
Lafarge	France	150,0	1.10	Unknown
Volvo	Sweden	140,0	1,03	Unknown
Top Ten		2,705,7	19,89%	6 of 10

with chemical hybridization agents ('CHA') or with fungicides. In addition, Shell and Ciba-Geigy, at least, have produced chemical packages linking the use of specific chemicals with specific plant varieties.

At least 27 enterprises have launched 63 research programmes directed toward the development of herbicide tolerant (or resistant) crop varieties. Fifteen major world crops are involved including cotton, maize, potato, rice, sorghum, soy bean, and wheat[19] as well as some forest species and vegetables. The market value is expected to exceed US $3.1 billion by the mid-nineties and touch $6 billion by the turn of the century.[20]

Incentive. After years of growth, the world pesticides industry is falling upon harder times. Faced with lower crop prices, farmers are looking to cut input costs and are especially critical of high chemicals costs. Sales have been declining in the mid-eighties. At the same time, environmentalists have increased pressure on government regulatory agencies and on the industry. Society has begun to identify important inefficiencies in the performance of the industry. Although more than a billion pounds of toxic active ingredients are poured onto American crops every year, only 1 per cent hits its target. Since the rise of pesticides, 30 species of weeds and 447 species of insects have become tolerant of the chemicals designed to thwart them. The industry itself now estimates that errors in applying herbicides on the US maize, wheat, and soybean crops alone cost farmers US $4 billion per annum.[21]

Given these factors, the focus of research has not been on pest resistant

plant varieties but on pesticide resistant (or tolerant) varieties. The orientation is commercially if not environmentally—logical.

First, the cost of developing a new crop variety rarely reaches US $2 million whereas the cost of a new herbicide exceeds $40 million. Thus, it is cheaper to adapt the plant to the chemical than to adapt the chemical to the plant.

Second, the profitability of an existing herbicide is greatly extended if varieties are bred that survive spraying. Adapting plants to chemicals has numerous other advantages. Plant breeding is faster and less subject to government regulation, for example. On the other hand, a herbicide that has survived the regulatory maze will have a long market life. Adding new crops to the chemical's repertoire extends product life expectancy.

The additional economic returns are considerable. If soybeans could be made tolerant of Ciba-Geigy's atrazine herbicides, annual sales could rise an additional US $120 million.[22] Monsanto's Roundup is the world's largest selling herbicide but tends to kill anything green making its use on crop fields limited. If tolerant seeds are developed, annual sales could increase by US $150 million. According to Plant Genetic Systems (a Belgian biotech company), tolerant strains to Hoechst's Basta herbicide would boost global sales by US $200 million a year. When American Cyanamid developed a new family of imidizolinone herbicides, it contracted to Molecular Genetics to find a gene that would give crops tolerance to the chemical. Once found, Cyanamid gave the gene, gratis, to Pioneer Hi-Bred—the world's largest maize breeding company. Pioneer has agreed to insert the gene into its hybrids much to the benefit of Cyanamid.[23]

Benefits. Herbicide manufacturers like Austrian Chemie Linz argue that the use of herbicide-tolerant seeds will be a major saving to farmers since they will have access to more effective chemicals than before and these chemicals will reduce crop losses. As already noted, chemical firms now state that losses from mistakes in crop spraying in the past (including chemical residues in the soil affecting the yield of the following season's crop) cost at least US $4 billion per annum. Previously, companies insisted that such damage was minimal.

Concerns. Although the first genetically-engineered, herbicide tolerant seeds are not expected on the market until the end of this decade or the beginning of the next, Bogève participants were concerned that the strategy will lead to: (1) increased use of more toxic chemicals; (2) greater risks for farm workers; (3) increased environmental damage including a threat to the

water supply; (4) more chemical residues in the food system; (5) increased production costs; (6) and danger of crop loss.

Rather than encouraging the use of more environmentally sympathetic chemicals, herbicide tolerance strategies make it possible for manufacturers to employ more toxic products since the crop itself may not be harmed. These chemicals may be used under conditions and in environments where they have not been used in the past. According to one industry source, 'The theory is that farmers would be willing to use even more of the weed-killers, safe in the knowledge that their crop won't be damaged'." Herbicide tolerant seeds may find widest acceptance on estate crops in the Third World where regulation is more difficult and where the bottom line concern is crop production.

Despite statements by the biotech industry that herbicide tolerance should be able to reduce production costs by increasing yield, Bogeve participants were concerned that the 'packaged' technologies of seeds and chemicals together could mean an unnecessary increase in farm costs. In addition, to be assured that the seed is 'guaranteed' to survive the chemical, farmers may feel obliged to return to the market each season rather than to save their own seed. Even non-hybrid seeds offering herbicide tolerance may demonstrate the same market characteristics as a hybrid.

The risk of crop loss is difficult to ascertain. The scientific strategies pursued in developing genetically-engineered tolerance may invite some of the same problems discovered with single-gene resistance breeding against crop diseases. The gene mutates, or is overcome by other pressures, leaving the crop suddenly vulnerable. Unlike single-gene resistant breeding where the crop may or may not be attacked by disease, genetically-engineered herbicide tolerant seed is always used in conjunction with the herbicide. If the genetic protection is lost, the crop is lost. Further, the residue left by some chemicals will make it dangerous for farmers to observe the same crop rotation pattern they followed when they avoided the herbicide. An altered rotation could prove economically disadvantageous. Worse, farmers with little access to information may misunderstand and assume that all crops will tolerate the herbicide. The new crop could be damaged by the residue from the old application or with new spraying.

Other observers are concerned that it is only a matter of time before the crop's herbicide resistant gene is transferred to the crop's weedy competitors. When this happens, the chemicals versus pests conflict will escalate once again and farmers will be driven to yet more toxic weapons.

Many of the Bogève delegates were convinced that the move from pest resistance breeding to pesticide resistant breeding is intellectually absurd. The beneficiaries will be the genetics supply industry. 'As the plant protection companies concentrate their interests', a French industry journal noted, 'As they supply both the seed and the chemical product adapted to it, they extend their commercial influence over the farmer'.[25]

Feasibility. Some observers are skeptical that herbicide tolerance is an workable strategy. They point out that many of the pesticides for which new varieties are being adapted will be at the end of their patent protection about the time the new seeds are ready for market. Plant breeders are also concerned that the time involved in fixing genetic resistance to a herbicide is time lost for yield and other improvements. Farmers, they reason, will not pay a premium for HT seed that yields below other varieties.

These are sound arguments. HT strategies can only be profitable if (1) all the dominant companies adopt the same strategy; and (2) farmers are persuaded that HT seeds are worth the price.

This appears to be the case for the world's most important seed market, maize. Pioneer, Dekalb-Pfizer, Ciba-Geigy, and Sandoz (the dominant four firms) as well as ICI, American Cyanamid, Rhone-Poulenc, and Shell all have HT breeding programmes. Can farmers be 'advertised' into buying HT varieties? Maybe. Fifty years ago, some of the same companies persuaded US farmers to throw away their seed and buy hybrid maize from the store every year. The hybrids took longer to develop—yield development was delayed—and seed costs were high. Yet, despite a shocking lack of evidence, the image of the 'hybrid' is now sacrosanct.[26]

Artificial seed

'The delivery of somatic embryos directly to the greenhouse or field as an artificial seed will require an encapsulation matrix pliable enough to cushion and protect the embryos and allow germination, and yet be sufficiently rigid to allow for rough handling of the capsules during manufacture, transportation, and planting. The matrix should be able to contain and deliver sufficient nutrients, growth, and developmental control agents, and other chemical or biological components necessary for embryo-to-plant development. Ideally, the capsules could contain plant growth promoting micro-organisms and agricultural chemicals specifically chosen for cultivar and environmental conditions. The encapsulation process should also allow for the formation of single-embryo capsules. Furthermore, the encapsulated somatic embryo should be handled and planted using existing seed planting equipment to facilitate acceptance at the farm level.[27]

A seed is an embryo containing the plant's instructions for reproduction

surrounded by starch providing the embryo with food. Through somatic embryogenesis, this reproductive information can be isolated from any of several parts of a plant and stimulated to grow into a whole plant. The need for seed is eliminated. An 'artificial' seed consisting of a dried or encapsulated embryo is possible. The encapsulated embryo may also be wrapped in nutrients and pesticides making it the perfect market vehicle for fertilizer and pesticide manufacturers.

Artificial seeds are being developed for 13 crops by 9 enterprises working in 17 research programmes.

Benefits. Current research concentrates on high-value horticultural crops such as celery, carrot, green peppers, and tomatoes but work is also in progress on barley, maize, rice, sorghum, and wheat. In theory, the development of artificial seeds could allow the more rapid breeding and distribution of crops which are normally propagated vegetatively (i.e. potatoes) since growers would have access to a reliable 'seed' whose genetic properties were not in doubt.

Farmers could also reduce their chemicals dependence and save money. Encapsulated embryos of tomatoes or peppers, for example, could reduce their use of a fungicide like Apron to one-tenth of one per cent if the fungicide was inserted in the capsule directly. There would also be savings for the environment. Also, in theory, the germination rates of artificial seeds could come close to 100 per cent offering some genuine savings in seed costs and through increased yields per hectare.

Artificial seeds also offer new savings and profits to the genetics supply industry. By producing embryos *en masse* in laboratories, companies can cut out the 'middleman'—the commercial seed grower. Since, occasionally, seed crops are lost in the field through disease or other adverse conditions, this risk is eliminated and the company's need to stockpile seed (and those costs) are also eliminated. Further, companies can reduce their financial risk and inventories by delaying embryo multiplication until just before the growing season.

Concerns. On the other hand, the genetics supply industry can increase its profitability in at least two ways: First, by exploiting the capsule as a chemicals package and giving farmers no choice but to use more toxins. Secondly, artificial seed technology extends an approach to agriculture which weighs against both the use of farmer-saved seed and farmer decision-making.

Countries such as Argentina, Chile, Mexico, Morocco, New Zealand, Tanzania, and Tunisia, that have specialized in seed multiplication, will also suffer. In Arusha, Tanzania, for example, 11 international companies have seed growing stations and make a marked financial impact on the region.[28] Direct flights connecting Arusha to Amsterdam tie the industry to the Dutch seed trade. This could all end with encapsulated embryos.

Participants at Bogève believed that artificial seeds will not become a significant factor in the vegetable seed industry until well into the next decade. Cereal seed production will not be affected until sometime after that. Farmers save and seed growers produce cereal seed with comparative ease and little cost and it will be difficult for the genetics supply industry to break into this market. Nevertheless, the micro-encapsulation of embryos in agriculture is the fastest growing of all the controlled release technologies being developed.[29] Ultimately, encapsulated embryos are the logical industry goal for all crops.

Long-term strategies

Longer-term industry strategies by no means preclude the use of herbicide tolerant genes or encapsulated embryos. But they do assume a shift away from synthetic crop protection toward biological pest controls and fertilizers. Work is underway in biofungicides, bioherbicides, bioinsecticides and in nitrogen-fixation. Almost all of this work is in the public sector but it can be assumed that at an appropriate time, the genetics supply industry will step in to co-opt this research and develop marketable products. Work in each product area is examined below.

> I think if you're trying to eliminate things that are peripheral, then eliminate talking about genetically engineering nitrogen fixation. It is the most absurd example that has ever been raised in agricultural biotech and it should be permanently stricken from the vocabulary.
>
> *Roger Salquist, chief executive officer, Calgene*[30]

Biofertilizers

Although many genetics supply enterprises are scornful of the potential to enhance the nitrogen-fixing capacities of crop plants, several universities and a few commercial concerns are engaged in this work. Progress has been made in substantially increasing the capacity of some leguminous plants already. Biotechnica International (Canada) has developed a bacterium that may increase the yield of alfalfa by 17 per cent.[31] Scientists in three US universities have shown that nitrogen fixing genes can be successfully transferred to non-nitrogen fixing crops opening up the possibility for self-fertilizing cereals.[32] Should nitrogen-fixing genes prove commercially

transferable to other crops, the potential reduction in the use of nitrogen fertilizers would be substantial.

While most fertilizer research focuses on nitrogen fixing Rhizobium bacteria, some important work is also underway using algae as a cover crop. Soil Technologies Corporation, for example, has created a dry spray of dormant green algae and blue-green algae to reduce soil compaction enhancing both aeration and water retention in the field. The spray costs about US $8 an acre and has increased cotton lint production by 200 pounds per acre. Test plot work with soybeans shows an increase of 9.4 bushels per acre. The estimated US market for algae cover crops is about US $40 million.[33]

We are concerned that the improvement of nitrogen-fixing qualities in plants could actually exacerbate groundwater pollution depending on the soil husbandry practices employed by farmers. Sown in areas where nitrogen levels are already adequate, for example, nitrogen-fixing plants would create a problem rather than solve one.[34] Recent studies indicate that fertilizers are the leading source of nitrate pollution in groundwater.[35]

It is possible, however, that the research related to nitrogen fixation will lead to the development of plant varieties capable of utilizing synthetic fertilizers more effectively—or absorbing greater quantities of fertilizers. In this event, farmers may ultimately use more fertilizers than at present. Production costs and environmental damage would increase.

Biopesticides

No fewer than 34 significant research programmes related to biological pest control for fungus, insects or weeds are currently underway. The companies engaged in this work are fighting to break into a global pesticides market of more than US $17 billion. The short-term prospects are not especially attractive. One analyst estimates that the market for biological pest control in the United States will not exceed US $175 million in the mid-1990s.[36]

Although the targets differ, all of these biocides offer a common promise and a common risk.

At least seven enterprises are presently engaged in the development of biofungicides through ten research programmes. Current world spending on fungicides alone is in the order of US $2.3 billion.[37] The work varies from the development of diagnostic kits to detect fungal diseases in lawn grass and golf courses (a US $65-75 million fungicide market in the US alone)[38] to the development of highly-specific bacteria intended to combat fungus in stone fruit or wheat.

The precision of the biopesticides is both their attraction and their problem. Biological pest controls can be much more environmentally sympathetic than their chemical counterparts and target only a very specific pest. However, with many successful broad-spectrum chemical agents on the market, the niches available for biopesticides are limited. For commercial success, companies engaged in this work have two choices: they can either link their product with a standard chemical or they can opt to broaden the range of pests attacked.

Pennwalt, for example, has licensed USDA developed technology to employ the first strategy in developing strains of *B. subtillus* to be applied along with Benomyl to combat pests in stone fruit. The strategy means no reduction in the use of chemicals but an actual increase in the use of toxins. The potential market is approximately US $50 million in the USA.[39]

That companies may opt to broaden the target range of biopesticides is a matter for greater concern. The wider the range, the more potent the genetically altered bacterium and, with extended applications, the greater the danger of uncontrolled mutation. The fact that the toxin is 'natural' rather than 'synthetic' (a selling point stressed by those working in this field) is of little comfort. Synthetics do not multiply themselves and mutate in the environment, natural products may.

Despite the number of initiatives underway on biopesticides (although this number is barely half that of programmes for herbicide tolerance) the scope of the work is surprisingly narrow. Ninety-five per cent of the commercial research into bioinsecticides has concentrated on the adaptation of *Bacillus thuringiensis* to diverse crops.[40] This work was originally developed at a number of US universities and is now being exploited by private firms at some risk to the environment. There is already some evidence that more potent Bt strains are creating mutations in insect pests and that a resistance to all Bt is developing.[41]

This does not mean that Bt products would not be useful. European and US farmers now spend $330 million fighting the European Corn Borer with only half success. Crop losses still amount to more than US $400 million a year.[42] Effective Bt control would be a great relief.

Many researchers believe that the proper tone of caution and concern is set in the statement by Robert Goodman, the vice president of Calgene, one of the leading companies engaged in agricultural biotechnology:

You hear people suggesting, for example, that if we understood more about allopathy, we could make plants that produced their own herbicides. Well, that's all fine and dandy, but we know that some of the allopathic chemicals are, for example, arsenic and cyanide. Just because it's 'natural' doesn't mean it's safe.[43]

In the final analysis, it should be understood that companies do not have a long-term vested interest in the promotion of chemicals in agriculture. The new technology might be expected to move farmers, in the short run, to a greater use of existing chemicals; in the medium range, to a mixture of synthetic and natural toxins; and, in the long-term, toward biological pest controls which may or may not be safer.

What is certain is that the control of the new technologies will become further concentrated in the hands of a few companies. Some major world enterprises—such as ICI and Royal Dutch/Shell—have a significant market position in seeds, herbicides and fertilizers. The interrelationship of these three agricultural inputs in light of the new biotechnologies in herbicide tolerance, encapsulated embryos, and nitrogen fixation is a cause for concern.

The following table offers a basic summary of the work underway in the biotech development of artificial seeds (encapsulated plant embryos). biofertilizers, biofungicides, biopesticides (often affiliated with the use of regular chemicals), and plant breeding (for herbicide tolerance). The list is not complete. The number of research initiatives and participating companies seems to increase almost with each month.

Table 6 The control of agricultural inputs in the biotech/genetics supply industry (by product group)

Product	Target crop (if applicable)	Brand name (if applicable)	Developer or Contractee	Comment	Source
Artificial Seed	Barley		Sungene	Patent for regeneration of immature embryos	AgriCell Report, July, 1987, p. 6
	Carrot		Kemira Oy	Encapsulated somatic embryos germinate at 45 per cent	AgriCell Report, July, 1987, p. 4
	Carrot		Purdue Univ.	Encapsulated somatic embryos	Bioprocessing Technology, March, 1987, p. 3
	Cauliflower		–	Somatic seeds encapsulated with commercial germination rates	Bio/Technology, September, 1986, p. 797
	Celery		–	Somatic seeds encapsulated with commercial germination rates	Bio/Technology, September, 1986, p. 797
	Grapes		IFAS	Dehydrated somatic embryos for artificial seeds	Agricultural Biotechnology News, Jan.-Feb., 1987, p. 22
	Loblolly pine		Univ. California (Davis)	Somatic embryo regeneration	Bio/Technology, February, 1987, p. 104
	Maize		Sungene	Patent for regeneration of immature embryos	AgriCell Report, July, 1987, p. 6
	Orchardgrass		IFAS	Dehydrated somatic embryos for artificial seeds	Agricultural Biotechnology News, Jan.-Feb., 1987, p. 22
	Rice		Sungene	Patent for regeneration of immature embryos	AgriCell Report, July, 1987, p. 6
	Rice		Univ. Florida	Dried embryos of grape, orchardgrass and rice for commercial markets	Bioprocessing Technology, March, 1987, p. 4
	Sorghum		Sungene	Patent for regeneration of immature embryos	AgriCell Report, July, 1987, p. 6
	Sunflower		Sungene	Patent for regeneration of immature embryos	AgriCell Report, July, 1987, p. 6
	Tomato		Atlantic Richfield	Protoplast regeneration system from shoots	AgriCell Report, July, 1987, p. 45
	Unspecified		Eureka	Artificial seeds in pellets with chemicals	Cultivar Seed Business, May, 1986, p. 89

Product	Target crop (if applicable)	Brand name (if applicable)	Developer or Contractee	Comment	Source
Artificial Seed	Wheat		Sungene	Patent for regeneration of immature embryos	AgriCell Report, July, 1987, p. 6
Biofertilizer	Alfalfa		Biotechnica Int'l	Rizobium meliloti bacterium increases yield by 17 per cent	Agricultural Genetics Report, August, 1987, p. 7
	Cotton	Microp	Soil Technologies	Algel cover crop increases lint yield by 200 lbs. per acre	Agricultural Genetics Report, April, 1987, p. 5
	Rosaceae		Oregon, Arizona, NC Univ.	Micrograftingof rootstocks for nitrogen-fixation	AgriCell Report, July, 1987, p. 46
	Soybean	Microp	Soil Technologies	Increasesyield by 9.4bu. peracrein tests	Agricultural Genetics Report, April, 1987, p. 5
	Soybean	Unknown	Calgene	Nitrogen absorption enhancement	Wall Street Journal, May 10, 1983
	Unspecified		Biotechnica Int'l	Develop nitrogen-fixing crop plants	Agricultural Biotechnology, May/June, 1985, p. 2
	Unspecified		Cyanotech	Blue-green algae; 1 lb. = 60 lbs. nitrogen	Agricultural Biotechnology, Jan.-Feb., 1985, p. 6
Biofungicide	Brussel sprouts	Alcide	Alcide	Biofungicidewith alcide for Black rot in brassicas	Agricultural Biotechnology News, Jan.-Feb., 1987, p. 14
	Cabbage	Alcide	Alcide	Biofungicidewith alcide for Black rot in brassicas	Agricultural Biotechnology News, Jan.-Feb., 1987, p. 14
	Cauliflower	Alcide	Alcide	Biofungicidewith alcide for Black rot in brassicas	Agricultural Biotechnology News, Jan.-Feb., 1987, p. 14
	Cotton		Advanced Genetic Sciences	Pythiumfungus target	Bioprocessing Technology, July, 1987, p. 3
	Unspecified		ICI	ICI pushing hard into biofungicides market competing partly with chemical fungicides	Bioprocessing Technology, June, 1987, p. 2
	Wheat		Ecogen		Bioprocessing Technology, March, 1987, p. 6

Product	Target crop (if applicable)	Brand name (if applicable)	Developer or Contractee	Comment	Source
Bioherbicide	Fruit	Botram (plus)	USDA	B. subtilis and Botram combined to fight fungus in stone fruit	Agricultural Genetics Report, August, 1987, p. 5
	Lawn grass		Michigan State Univ.	Bacterium attacks annual bluegrass in lawns	Bioprocessing Technology, May, 1987, p. 5
	Unspecified		Abbott	New plant to develop biological herbicides and insecticides	UNIDO, July-September, 1986, p. 41
Biopesticide	Citrus		Rohm & Haas	Bacillus thuringiensis gene against moth caterpillar—world's worst crop insect pest	UNIDO, July-September, 1986, p. 42
	Cotton		Ecogen	Heliothis Bt against budworm and bollworm	Agricultural Biotechnology, Jan.-Feb., 1986, p. 2
	Cotton		Rohm & Haas	Bacillus thuringiensis gene against moth caterpillar—world's worst crop insect pest	UNIDO, July-September, 1986, p. 42
	Maize		Crop Genetics Int'l.	Bt target on European corn borer causing $400 million damage p/a in USA alone	Bioprocessing Technology, May, 1987, p. 4
	Maize		Monsanto	P. Flourescens microbe coating maize seed	Agricultural Biotechnology, Jan.-Feb., 1985, p. 6
	Maize		Rohm & Haas	Bacillus thuringiensis gene against moth caterpillar	UNIDO, July-September, 1986, p. 42
	Soybean		Rohm & Haas	Bacillus thuringiensis gene against moth caterpillar	UNIDO, July-September, 1986, p. 42
	Tobacco		Durham Univ.	Cowpea enzyme transferred into tobacco	AgriCell Report, July, 1987, p. 2
	Tobacco		Rohm & Haas	Bacillus thuringiensis gene against moth caterpillar	UNIDO, July-September, 1986, p. 42

Product	Target crop (ifapplicable)	Brand name (ifapplicable)	Developer or Contractee	Comment	Source
Biopesticide	Tomato		Native Plant Industries		UNIDO, July-September, 1986, p.42
	Tomato		Rohm & Haas	Bacillus thuringiensis gene against moth caterpillar	UNIDO, July-September, 1986, p.42
	Unspecified		Mycogen	Bt strains 10 to 100 times more powerful	Bioprocessing Technology, March, 1987, p.5
	Unspecified		Abbott	New plant to develop biological herbicides and insecticides	UNIDO, July-September, 1986, p.41
	Unspecified		Calgene	Microbial/chemical combination for biopesticides and adhesives, etc...	Bioprocessing Technology, July, 1987, p.7
	Unspecified		Clemson Univ.	Bt system	Bioprocessing Technology, July, 1987, p.2
	Unspecified		Microbial Resources	Bttech	Bioprocessing Technology, July, 1987, p.9
	Unspecified		Plant Genetic Systems	Bacterial protein toxic to mosquitos used in blue-green algae	Bioprocessing Technology, July, 1987, p. 10
	Unspecified		Univ. of Washington	Bt system/gene licensed from University to implant in crops	Bioprocessing Technology, July, 1987, p. 10
	Unspecified	Decyde	Micro Gene System	Decyde works against codling moth in South America etc.	Agricultural Genetics Report, June, 1987, p. 5
Plant Breeding	All vegetables	Imidozolinones	George J. Ball	Ball will incorporate resistentgenein vegetables	
	Canola	Atrazine	Allelix		
	Canola	Betanal	Calgene		
	Canola	Kanamycin	Calgene		
	Canola	Roundup	Calgene		
	Canola	Unknown	Advanced Genetic Sciences		
	Canola	Unknown	Biotechnicalnt'l.		
	Canola	Unknown	Phyto-Dynamics		

Product	Target crop (ifapplicable)	Brand name (ifapplicable)	Developeror Contractee	Comment	Source
Plant Breeding	Cotton	Kanamycin	Agracetus	Resists Kanamyacin antibiotic	Agricultural Biotechnology News, Jan.-Feb., 1987, p. 9
	Cotton	Roundup	Calgene	Estimated annual market of $150 million	
	Legumes	Roundup	Biotechnica Int'l.		
	Maize		ICI	Herbicide tolerance interest behind purchase of Garst Seeds	Cultivar Seed Business, May, 1986, p. 85
	Maize	Aquinol	Shell	Aquinol/Maize advertising package in FR Germany	
	Maize	Cinch	Shell		
	Maize	Imidizolinones	Molecular Genetics	Resistent gene was licensed gratis to Pioneer	
	Maize	Prowl	Phyto-Dynamics	Herbicide-resistant varieties by 1990?	Chemical Week, Dec. 19, 1984, p. 29
	Maize	Roundup	Calgene		Agricultural Biotechnology, May/June, 1985, p. 2
	Maize	Roundup	Phyto-Dynamics	Herbicide tolerance	Chemical Week, Dec. 19, 1984, p. 29
	Maize	Treflan	Phyto-Dynamics	Herbicide-resistant varieties by 1990?	Chemical Week, Dec. 19, 1984, p. 29
	Maize	Unknown	Biotechnica Int'l.		
	Maize	Unknown	Callahan		Agricultural Biotechnology News, Jan.-Feb., 1987, p. 7
	Poplar	Roundup	Calgene		Agricultural Biotechnology, March/April, 1985, p. 13
	Potato	Altrazine	Univ. of Guelph		
	Potato	Basta	Biogen		
	Potato	Basta	Plant Genetic Systems	$200 million market for resistence to all crops	Agricultural Genetics Report, April, 1987, p. 2
	Potato	Roundup	Calgene		
	Potato	Unknown	Advance Genetic Sciences	Equipment to identify tolerant genes	
	Rice	Unknown	Rohm & Haas		
	Sorghum	Bronco	Monsanto		
	Sorghum	Dual	Ciba-Geigy	'Herbi-shield' protective coatings, etc.	
	Soybean	Atrazine	Calgene		

Product	Target crop (if applicable)	Brand name (if applicable)	Developer or Contractee	Comment	Source
Plant Breeding	Soybean	Atrazine	Ciba-Geigy	Tolerant soybean varieties could double sales	Jack Doyle, Genewatch, Vol. 2, Nos. 4–5, p. 3
	Soybean	Glean	Du Pont	Altered 'Williams' soy variety to tolerate Glean family	Agricultural Biotechnology News, Jan.-Feb., 1987, p. 3
	Soybean	Lexone/ Sencor	Mobay (Bayer)		
	Soybean	Roundup	Calgene		
	Soybean	Unknown	Callahan	Callahan adapting varieties to Rhone herbicides	Agricultural Biotechnology News, Jan.-Feb., 1987, p. 7
	Sugarbeet		Calgene	Tolerance for Ceres sugarbeets	Cultivar Seed Business, May, 1986, p. 85
	Sunflower	Buctril	Calgene	Tolerance for Seedtec varieties	Cultivar Seed Business, May, 1986, p. 85
	Sunflower	Buctril	Calgene		
	Tobacco	Atrazine	Ciba-Geigy		
	Tobacco	Atrazine	USDA	Herbicide tolerant gene	UNIDO, July-September, 1986, p. 42.
	Tobacco	Basta	Biogen		
	Tobacco	Basta	Plant Genetic Systems	$200 million market for resistence to all crops	Agricultural Genetics Report, April, 1987, p. 2
	Tobacco	Glean	Du Pont	Glean 'family' market seen to be $500 million p.a. for general crops	Agricultural Biotechnology News, Jan.-Feb., 1987, p. 3.
	Tobacco	Picloran	Cornell Univ.		
	Tobacco	Picloran	Du Pont		
	Tobacco	Roundup	Calgene		
	Tomato	Apron	Plant Genetic Systems		
	Tomato	Atrazine	Calgene		
	Tomato	Basta	Bioten		
	Tomato	Basta	Plant Genetic Systems	$200 million market for resistence to all crops	Agricultural Genetics Report, April, 1987, p. 2
	Tomato	Benlate	Plant Genetic Systems		
	Tomato	Captan	Plant Genetic Systems		
	Tomato	Roundup	Calgene		
	Turnip Rape	Betanal	Clagene	$10 million Northern European market	

Product	Target crop (if applicable)	Brand name (if applicable)	Developer or Contractee	Comment	Source
Plant Breeding	Turnip Rape	Betanal	Phytogen	European market is $10 million	
	Unspecified	Atrazine	Harvard		
	Unspecified	Atrazine	Michigan State		
	Unspecified	Diuran	USDA		
	Unspecified	Diuran	Weitzman Institute		
	Unspecified	Roundup	Monsanto		
	Unspecified	Roundup	Shell		
	Unspecified	Thiocar-banate	Stauffer		
	Unspecified	Unknown	DNA Plant Technology		
	Wheat	Hybrex CHA	Rohm & Hass	Breeding combined	Cultivar Seed Business,
	Wheat	Unknown	Biotechnica Int'l.		

Notes

1. Doyle, Jack, *Altered Harvest,* Viking Press, 1985, p. 89-90. Doyle works on biotech issues at Environmental Policy Institute in Washington, D.C.
2. As quoted by Ashley Stevens of BioTechnica Agriculture in *Agbiotechnology News,* March/April, 1988, p. 18.
3. The original quote refers to 'men' and not 'people' but we have opted for poetic license—something Milan Kundera should appreciate!
4. Czech novelist. Translation provided by Martin Abraham at Bogève.
5. George Kidd of L. Wm. Teweles & Co. estimates total seeds and agricultural chemicals market to be $50 billion but estimates on the commercial value of their global seeds market vary.
6. George Kidd, senior market analyst, L. Wm. Teweles & Co., 1986.
7. Fifth Genetic Engineering News Guide to Biotechnology Companies, 1987.
8. Estimate by Theodore Sheets of T.A. Sheets Co. reported in *Agricultural Genetics Report,* March-April, 1982, p. 6.
9. Reported by Maro R. Sondahl et al. in *ATAS Bulletin* No. 1, November, 1984, p. 14, citing 'Biotechnology in the Americas: Prospects for Developing Countries', *Interciencia* 1983.
10. George Kidd, senior consultant, L. Wm. Teweles Co. in *Bid/Technology,* February, 1987, p. 133.
11. 'The Bio/Technology Roundtable on Plant Biotech', *Bio/Technology,* Vol. 5, February, 1987, p. 128. Interview gives Sam Dryden's history with Agrigenetics and current post with Plant Biological Systems.
12. Roger Salquist in *Bio/Technology,* February, 1987, p. 130.
13. Conway, Gordon (ed.), *Pesticide Resistance and World Food Production,* Imperial College Centre for Environmental Technologies, 1982, p. 67.

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15. RAFI estimate based upon annual reports and industry investment reports.
16. George Kidd, senior market analyst, L. Wm. Teweles & Co., 1986.
17. RAFI estimates over 500 acquisitions since the late sixties with another 500 changes in the industry due to stock purchases, important contractual linkages and some newly developed subsidiaries of TNCs.
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22. Jack Doyle quoting George Kidd in *Genewatch,* Vol. 2, Nos. 4-6, p. 3.
23. *Agricultural Biotechnology,* September-October, 1985, p. 3.
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30. *Bio/Technology,* February, 1987, p. 129.
31. *Agricultural Genetics Report,* August, 1987, p. 7.
32. 'Grafts between N-fixing and non N-fixing shrubs', *Agricell Report,* July, 1987, p. 46.
33. ***Agricultural Genetics Report,*** April, 1987, p. 5.
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39. Ibid., p. 5.
40. *Genetic Engineering and Biotechnology Monitor,* UNIDO, July-September, 1986, p. 40.
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The Factory Farm

The Transformation of the Food Processing Industry

The big winners in biotechnology will probably be the food and beverage processors already familiar to most Northern consumers. The losers will be farmers—South and North—and those of us with a lingering fondness for food. At Bogève, Annelies Allain of IBFAN led us in an analysis of industry strategies. Daniel Goldstein, a native of Argentina, chaired the session and contributed substantially to our understanding of the scientific strategies. It became clear that agricultural commodities are becoming the property of food processors who are vertically integrating down the food chain to control production.

> The major thing that's going to happen in terms of biotechnology in agriculture, I believe, the single most startling thing is a strategic restructuring of the industry to vertical integration... Historically the processors of products from agriculture have purchased them on the commodity markets. What's going to happen with biotechnology is that you're creating proprietary products out of commodities.
>
> *Roger Salquist, Calgene, 1986*[1]

Biotechnology and our food have a long interlinked history. According to the historians, the Mesopotamians harnessed micro-organisms to turn wine into vinegar 7, 000 years ago. Ancient Egyptians used single-cell yeasts to brew beer and bake bread about the same time as the Chinese were using bacteria for pickling. Not much later, the Slavs put controlled fermentation to work in the service of sauerkraut.

What we think of as brewing or fermentation is actually a form of biotechnology—the genetic restructuring of a living organism. This does not mean that every time we make yoghurt we can expect a Nobel Prize. But many of the most promising techniques of super-biology are still recognizable permutations of these ancient arts.

If you are a food processor, biotechnology spells nothing but increased profit. Whatever you do in biotech, you will either cut energy costs and processing times, diversify and/or reduce raw materials requirements, lower waste disposal costs and/or develop new markets for waste materials, extend product shelf life, modify old products for new markets or design whole new products, eliminate supply instability, improve quality standards—or all of the above.

Members of the biotechnology committee of the German Dechema predict

that 80 per cent of the products on grocery shelves in 1982 will have been replaced by 1990. Many of the substitutes will be the product of some aspect of the new biotechniques.[2]

The range of estimates for the economic impact of biotech on food processors starts at a low of US $2 billion by the fabled year 2000. One early Japanese industry evaluation placed biotech's impact on food processing at US $17.2 billion in 2000—well above their estimate for pharmaceuticals (US $12.8 billion).[3] The breadth of the predictions depends, in part, on which end of the food chain you are rattling. Farmers, of course, will not rattle but be rattled. Food processors will rattle along very well indeed —and consumers will pay the whole tab at the retail end of the chain.

Any decline in the use of agricultural raw materials and/or any increase in the diversification of commodities used in processing means a drop in farm prices and a loss of farmers. These savings at the processing level may or may not be passed along to consumers.

Rather than eliminate additives, the new techniques may replace chemicals with new life forms causing even more regulatory complications than the old additives.

Nevertheless, nutrition and food choices may well improve at the 'Yuppie' end of the food market. DNAP's 'Vegisnax' of celery and carrots are still a cut above potato chips. But, the average consumer will simply face more of the same at higher prices.

The patenting of the technology will lead to yet greater market concentration and oligopolistic pricing. Increasingly, farmers will be sold patented breeding stock (plants or animals) by food processors. The same food processors will buy the harvest. In many cases, the entire relationship for both the input and the output will be contractual. (For a discussion of biotech patenting see pages 237—55.)

The corporate sandwich

Try as they will, the start-up biotech houses are given little chance of taking over markets. It is one thing, for example, for small companies to take a run at the pesticides market. The product range is limited, the advertising is product specific and the range of buyers is limited. It is quite another thing to make a play for a niche in the food processing industry. All the key players are highly diversified. Advertising sells images rather than products. The relationships between processors and retailers and customers

Table 7 Reducing costs and increasing profits on the factory farm

Objective	Example
Cutting energy costs	Campbell Soup's new tomatoes have 20 per cent less water, meaning a major saving of energy used in dehydration
Speeding up processing time	Kirin Brewery has developed a fermentation process that halves the brewing time for beer
Diversifying raw materials needs	Hershey's et al. are developing vegetable oil substitutes for cocoa butter
Reducing raw materials need	Proctor & Gamble is developing processes that would slash the need for cooking fats
Lowering waste disposal burden	Anheuser-Busch has developed uses for sludge including road building and defence to citrus canker
Extending product shelf life	DRINC has developed carbonated milk with a longer shelf life than regular milk
Developing new markets and uses	DNAP has created 'Vegi Snax' turning carrots and celery into processed snackfoods

are both complex and costly. No company can make much headway with just one or two products.

The food processors are very quickly becoming concentrated. In 1987, the top 100 US food processors accounted for US $200 billion in sales[4]—or about 80 per cent of all sales in the industry.[5] Indeed, the top ten companies have sales of US $76 billion or almost a third of the market—a share, for the leading ten, that has jumped by a third in just five years. The rate of mergers in Europe and the United States is simply breathtaking. Fully 25 per cent of the top 100 processors in 1982 have since been swept under the skirts of bigger competitors.[6]

Statistics for the leading food processors worldwide are not as up-to-date as those for the United States, but with notable exceptions, American firms dominate the global industry. A joint research project by economists and sociologists in Quebec and Montpellier does an excellent job of tracking the world's top 100 agribusinesses, however. We have adapted their information with more recent US data to produce the table below. Because of the data problems, the ordering of the top ten companies should only be regarded as approximate.

Among the top ten, the changes have been fantastic. Nestles has acquired Carnation in the USA and many other smaller enterprises but otherwise has

Table 8 The top ten world food processors

Enterprise	'Home' country	Sector Interest	Turnover US$ million Total	Food	States No.*	Subsidiaries No.*
Nestlés	Switzerland	Diverse	21,153	16,804*	63	160
Philip Morris	USA	Tobacco	25,409	12,718	30	121
Unilever	Netherlands	Diverse	25,143	12,450*	58	232
RJR Nabisco	USA	Tobacco	15,978	10,112	34	116
Kraft	USA	Dairy	8,742	7,780	36	180
Anheuser-Busch	USA	Brewery	8,402	7,451	7	45
Coca-Cola	USA	Soft Drink	8,669	7,295	12	39
Pepsico	USA	Soft Drink	9,291	6,607	23	82
ConAgra	USA	Meat/Cereal	9,002	6,600	19	53
S&W Berisford	UK	Sugar	9,177*	6,305	11	36

Source: Robert J. Swienteket al. Food Processing, December, 1987, p. 64; The International 500', Fortune, 3 August, 1987, p. 214; and Agrodata, 'Les cent premiers groupes agro-industriels mondiaux', C.I.H.E.A.M., France, 4th edition, June, 1987, p.15.
Notes:* indicates figure is for 1985 and may include agribusiness beyond food processing;
States = Countries in which enterprise has operations;
Subsidiaries = Subsidiaries to the parent enterprise.

not been an active player in the takeover festivities. Unilever, however, has recently bought such giants as Cheeseborough-Pond and Brooke Bond as well as the Latin American operations of Anderson Clayton. Each of these companies ranked among the world's major food enterprises a decade ago.

Still more impressively, Philip Morris—a giant tobacco house a decade ago—leapt from number 32 rank in 1981 to number 2 on the world scale in 1987. Its major acquisition was General Foods in 1985. But many other companies have also been taken over. Ten years ago, R.J. Reynolds was a tobacco company. In 1986, it took over Nabisco to form RJR Nabisco and moved from 12th in world rank to number 4. ConAgra, another US company, scored as the 80th largest agribusiness in 1981. But after buying into Swift and Momfort meat companies in 1987, it moved into 9th place. The changes continue. As we go to press, Philip Morris made a bid for Kraft and Grand Metropolitan is trying to buy Pillsbury. There are also several moves to buy RJR Nabisco.

Of the first fifty food and beverage corporations identified by the UN Centre on Transnational Corporations in 1976,[7] at least 13 have either been acquired or driven out of the industry. In the process of acquisition, other companies have almost disappeared. Beatrice ranked number six worldwide a few years ago and was second in the United States. By the end of 1988, it will be but a memory. Over the past two years, the company has

Table 9 Top food processors and their stances on biotechnology

Food company	In-house programme	Biotechnology company tie-up	Agreement
Nestlés	Yes	Calgene	Improved soybeans cocoa butter
Philip Morris	Yes	DNA Plant Ergenics	Coffee improvement Process improvements
Unilever	Yes	–	Vegetable oils
RJR Nabisco	Yes	Cetus Biotechnica Int'l	Enzymes etc Improved crops
Kraft	No	–	–
Anheuser-Busch	No	Interferon	Bioprocessing
Beatrice	No	Ingene	Enzymes, sweeteners
Coca-Cola	No	–	–
Pepsico	No	–	–
H.J. Heinz	No	ARCO, Biotechnica	Tomato improvement, low cost amino acid products
Campbell Soup	Yes	Calgene DNA Plant	Tomato and carrot improvement
Sara Lee	No	–	–
General Mills	No	–	–
Archer Daniels Mid.	Yes	DNA Plant	Enzymes
CPC International	Yes	Enzyme Biosystems	Enzymes
Hershey	No	DNA Plant	Cocoa butter
Kellogg	No	Agrigenetics	Equity interest
Seagram	No	Biotechnica	Equity interest Yeast and bioprocessing
Coors Brewery	No	Japanese firms	Food additives
Flavfours and Spices			
Firmenich	No	DNA Plant	Improved flavour production
W.R. Grace	Yes	Synergen	Systems development
American Basic	Yes	–	Onion, garlic improvement
McCormick	No	Native Plants	Improved seasoning products

Adapted from Susan K. Harlander and Theodore P. Labuza, *Biotechnology in Food Processing,* Labuza, Noyes Publications, 1986, p 306.

been systematically dissected with various parts sold off to the highest bidders. The adventurers who took over Beatrice are expected to garner a US $4 billion profit from the exercise.[8]

No plate for the poor

Rapid changes in agricultural and industrial technology have always left the poor the losers. In the 18th century, access to natural dyes was crucial to the European textile industry. Countries and companies attempted to mon-

opolize key plants. The French threatened to guillotine anyone caught stealing plants from their production base on the island of Antigua. By the 1850s, British scientists were working on a process to create artificial indigo. In 1897*, the Badische Aniline Company of Germany was mass-producing synthetic indigo. That same year, planters in Bihar, India, had 574, 000 hectares of indigo in the ground.[9] By 1911, the area had dropped to 86, 600 hectares and many displaced indigo labourers, Martin Kenney tells us, starved to death."'

The Bihar tragedy has a sequel. Almost a century after the production of synthetic indigo, researchers at Amgen (a small US biotech house) tripped over a biotech means of creating indigo dye. If their early calculations prove correct, Amgen may take over an estimated US $100 million market." German chemical workers, however, will probably not go hungry.

India and indigo is an early example of the collapse of a 'natural' Third World industry before the onslaught of a new technology. Economists have recorded the industrial implications of synthetic fibres and petrochemicals in replacing sisal, hennequin, jute, rubber and cinchona, but the world has never given a full accounting of the socioeconomic impact for the traditional producers. A group of new technologies—biotechnologies—are now coming on the scene. While their advent is applauded in the Northern media, the actual impact on basic needs in villages in Asia, Africa and Latin America may prove to be far different from the business headlines.

The factory farm is already here: case studies

Daniel Goldstein told us in Bogève that early developments in biotechnologies have already left Latin Americans on the losing end. Mexico lost control of the production of steroids via its barbasco root to American biotech interests in the 1970s. Goldstein also claims that the research into the use of guayule as a source of natural rubber was lost to the country and taken over by the United States. At one time, Mexico's guayule accounted for 10 per cent of world rubber production and 50 per cent of American rubber consumption. Further, Goldstein cites Argentina's losses in livestock production—for cattle and sheep—as a major failure. A lack of attention to applied research led to other countries surpassing Argentina in R&D and, eventually, lost markets for Argentina's ranchers.'[2]

Case studies in food processing prepared by RAFI indicate that new biotechnologies have the potential to eliminate or displace food and beverage exports on a massive scale resulting in the loss of foreign exchange earnings, displacement of agricultural workers and economic instability in

many Third World nations. In the following pages, several different commodities are examined, and three major trends are identified.

Transfer of production: the case of vanilla

The case of vanilla illustrates the potential of biotechnology to displace or eliminate traditional botanical exports and to transfer agricultural production from the South to laboratories and factories in the industrialized world. Two US based companies are now attempting to produce a natural vanilla product in the laboratory through phytoproduction. Escagen, a small California biotechnology company, is already producing natural vanilla in the laboratory, and hopes to have a product on the market by mid-1989.

Natural vanilla is an expensive flavouring which comes from the bean of the vanilla orchid. It can only be grown commercially in a few Third World countries. Today, 98 per cent of the world's vanilla crop is produced by four island nations: Madagascar, Reunion, the Comoros and Indonesia. Madagascar alone accounts for three-quarters of the world's vanilla production, where up to 70, 000 small farmers are engaged in production of this labour-intensive crop. The economies of these countries depend on the export of vanilla beans, valued at approximately US $67 million annually.

The US based companies who are now culturing vanilla cells to produce vanilla flavour are not manufacturing an 'artificial' product. Their product would be a natural, plant-derived flavouring. If commercially successful, this new technology would have the potential to displace vanilla bean exports on a massive scale. The need for traditional cultivation of the vanilla orchid would be eliminated. Many thousands of jobs related to vanilla cultivation and processing would disappear.

Viewed in terms of world agricultural trade, vanilla export earnings are relatively small and insignificant. But vanilla is just the tip of the iceberg—it represents only one of thousands of plant-derived substances (flavours, fragrances, nutrients, pharmaceuticals, dyes, etc.) which may be future targets of biotechnology research. The worldwide market for all plant-derived products is approximately US $10.5 billion.[13] (For the complete case study, see pages 109-10.)

Overproduction: the case of cacao

Unlike vanilla, cacao represents a major agricultural crop—the second most important agricultural commodity produced from tropical regions in the international trade market. Worldwide, annual exports of cacao beans

are valued at $2.6 billion. Africa accounts for 57 per cent of world production, Central and South America (where the crop originated) account for 34 per cent, and East Asia accounts for 9 per cent.

Various biotechniques are being applied to cacao in the US, Europe and Japan. In the US the largest research effort focusing on biotechnology and cacao is underway at Pennsylvania State University, where over 15 chocolate manufacturers are supporting a multi-million dollar research programme on the molecular biology of *Theobroma cacao* (the cacao plant). Researchers are using both tissue culture and genetic engineering to create higher-yielding and higher quality cacao beans, as well as plants which have greater disease and insect resistance.

The goal is 'to stabilize the export crop for manufacturing countries'. Using genetic engineering, for example, scientists will someday be able to form new cacao plants tailored to meet the specific needs of industry. One long-term project is to engineer a cacao variety containing a gene for thaumatin, a super-sweet protein derived from an African shrub. The end result would be a sugarless, sweet-tasting chocolate product—eliminating the need to add sugar in the manufacture of chocolate.

In the shorter term, researchers hope to develop higher-yielding cacao varieties. Using biotechnologies, scientists predict that it will be possible to obtain future yields of up to 3,000 lbs. of beans per acre—an increase of 750 per cent above today's average yields.

It is likely that the benefits of advanced technologies and high-yielding cacao varieties will be skewed towards large-scale cacao growers. As a result, cacao production will shift from small-scale producers to large-scale cacao plantations. Small-scale producers in Africa, where the majority of the world's cacao is now produced, will be at a particular disadvantage.

Ultimately, dramatic yield increases will result in overproduction of cacao and a sharp decline in cacao prices—a trend which will affect all cacao producers, large and small, and the economies of all major cacao producing countries. (For the complete case study, see pages 111-15.)

Overproduction: the case of oil palm

Oil palm offers another example of biotechnology and overproduction. In the case of oil palm, yield increases are the result of a new method for cloning high-yielding palms developed by Unilever—the world's largest

vegetable oil buyer and largest food enterprise. Unilever is introducing cloned oil palms throughout the tropical world—from Colombia to Brazil, from West Africa to Indonesia, Malaysia and the Philippines.

In Malaysia, Unilever's plantations are already well established, and cloned oil palms have reportedly increased yields by 30 per cent.[14] Malaysian palm oil exports in 1985/86 exceeded 4.8 million metric tons and now constitute about one-fourth of vegetable and marine oils traded in international markets. Almost half of the world's increase in edible oil trade during the past five years is due to increased exports of Malaysian palm oil.[15]

Despite the impressive yields, however, the oil palm boom has not benefited Malaysian producers. Because of enormous surpluses, they are now selling below the cost of production. Virtually all Malaysian palm oil manufacturers produced at a loss in 1986.[16]

The Malaysian palm oil glut is also affecting producers of other edible oils. Small-scale palm oil producers in Africa, for example, may lose their markets because Malaysia is exporting palm oil to Africa. In the Philippines, 700, 000 small-scale coconut farmers have already suffered sharp declines in exports of coconut oil because of the world glut of low-priced palm oil.[17]

The impact of high-yielding oil palms is not limited to Third World farmers. Malaysian exports of palm oil now exceed total world exports of soybean oil—a situation which has resulted in large stocks of US soybeans and a loss of markets for US soybean farmers.[18] As a consequence, the US Soybean Association launched a full-scale offensive against palm oil—labelling it as 'tropical fat' and claiming that it is unhealthy for American consumers."[19] The full effects of overproduction are not yet known, since thousands of acres of Unilever's high-yielding oil palm clones will likely be planted throughout the Third World. (For the complete case study, see pages 116-23.)

Product substitution: the example of oil conversion

The genetic modification of oil seed plants as a means of converting cheap oils (such as palm or soybean oil) into high-quality cocoa butter is now well advanced. 'Discontented with the need to import', *Bioprocessing Technology* magazine warns us, 'companies will produce similar oils from domestic sources, in the process even creating oils not found in nature'.[20]

Several companies in Japan and the US are pursuing this goal. One company, Genencor, has filed patents on a process which could be used to

convert cheap palm oil into expensive cocoa butter. Fuji Oil Co., Ltd. (Osaka, Japan) has also patented a process to develop cocoa butter substitutes from olive, sunflower or palm oil.

Product substitution: thaumatin and other natural sweeteners

Biotechnology offers the potential to displace sugar as an industrial sweetener through the development of new, natural sweeteners from plants. One of the most promising natural sweeteners, the protein thaumatin, is extracted from the fruit of a West African plant, *Thaumatococcus daniellii*.[21] Thaumatin is one of the sweetest substances known, literally several thousand times sweeter than sugar.

Several major corporations and small biotechnology firms in the United States and Europe are now attempting to use recombinant DNA technology to produce thaumatin protein in the laboratory. In 1985-86, the intensely sweet thaumatin protein was successfully cloned by scientists at Unilever (the Netherlands) and Ingene (US).

If the thaumatin protein can be economically produced using genetic engineering, thaumatin could capture a substantial share of the sweetener market, particularly for low-calorie sweeteners in the US, Europe and Japan. (In the US alone, the sweetener market is now worth $8 billion, of which $900 million is low-calorie sweeteners.)

In recent years, other types of substitute sweeteners have already eroded traditional sugar markets. The introduction of high fructose corn syrup (HFCS—a sweetener manufactured from corn using immobilized enzymes) is the most dramatic example. US consumption of HFCS grew from 1.35 million tons in 1978 to 4.3 million tons in 1984, while US sugar imports dropped from 6.1 million tons in 1977 to 1.5 million tons in 1985-86. According to Dutch researchers, the livelihood of an estimated 8 to 10 million people in the Third World is threatened by the loss of traditional sugar markets and the drop in world sugar prices.

If commercially successful, the thaumatin sweetener will not single-handedly displace traditional markets for sugar. However, thaumatin is only one of several plants which produce naturally occurring, sweet-tasting compounds. These plants and other sweetener sources will undoubtedly be the focus of further biotechnology research. The development of a thaumatin product via biotechnology is just the beginning of a transition to alternative sweeteners which will displace Third World sugar markets in the coming years. (For the complete case study, see pages 124—26.)

Product substitution —and the role of NGOs

Gum arabic comes from a shrub grown in Africa and is used extensively in processed foods and soft drinks. Although the techniques used in its substitution are not, strictly speaking, part of biotechnology, RAFI undertook a study of changes taking place in its laboratory production. We discovered that—with the help of the US Agency for International Development —New York companies were capable of moving commercial production from Africa to North America. Gum arabic accounts for 8 per cent of the Sudan's export earnings and brings the country US $60 million in foreign exchange. When we completed our study in September, 1986, we were dismayed to find that the Government of the Sudan was unaware of the USAID information.

In October, 1986, Hope Shand of the RAFI staff met with a visiting delegation of Sudanese labour leaders representing the Sudanese Workers Trade Union Federation.

The Sudanese delegation had no previous knowledge of the threat of gum substitutes. RAFI was able to provide further documentation of this issue and the delegation returned to the Sudan armed with additional data. Unfortunately, when Eva Lachkovics of RAFI visited the Sudan four months later and met with officials in the Government, none knew of the impending loss of one of their country's most important exports. Since then, RAFI has distributed its information to all NGOs in the region.

Although the long-term picture for gum arabic looks glum, the EC in Brussels has stepped in and offered the Sudan an expanded market, at least for the time being, in Europe. This kind of initiative will be needed again and again in the years ahead. (For the complete case study, see pages 127-28.)

> Biotechnology, like all technological breakthroughs before it, will lead to considerable structural change in production, international trade and cooperation. Above all, it poses the greatest challenge to the African economies, with their monocultural production system and their excessive dependence on export earnings derived from one or two commodities. All the tropical crops of primary interest to Africa are at risk. Given the current collapse in commodity markets and prices, biotechnology will simply be the last straw. It will ring their death tolls.
>
> *Dr. Adebayo Adedeji, Under-Secretary-General, UN Economic Commission for Africa, 1987*[22]

Table 10 Tissue culture research on high-value, plant-derived products

Plant	Product	Use	Origin	Who is doing research?	Value	Market size
Lithosperm	Shikonin	Pharm./ Dye	Japan Korea China	Mitsui Petro-Chemical, Japan	$4,500/kg	
Catharanthus	Vinblastine Vincristine	Treat Cancer, Leukemia		Canadian National Res. Council	$5,000/g	$18-20m (US)
Catharanthus	Ajmalicine	Circulatory problems				
Digitalis Lanata	Digitoxin-digoxin	Heart disorders		Univ. Tübingen Boehringer-Mannheim (FRG)	$3,000/kg	$20-55m (US)
Cinchona	Quinine	Malaria Flavour	Indonesia	Plant Sciences Ltd. (UK) Leiden Univ.	$100/kg	$5-10m (US)
Cacao	Cocoa butter	Manufacture Chocolate (use in pharm. & cosmetics)	Ivory Coast Cameroon Ghana Brazil	Cadbury-Schweppes Cornell Univ. Penn. State Hershey/DNAP Nestlés		$2.6 billion (world)
Papaver Bracteatum (Giant Scarlet Poppy)	Codeine Opium	Sedative Painkiller	Turkey Thailand	Plant Science (UK)	$650/kg	$50m (US)
Jasminum	Jasmine	Fragrance			$5,000/kg	$0.5m (world)
Chrysanthemum	Pyrethrins	Insecticide	Tanzania Ecuador Kenya	Univ. of Minnesota Biotec (Belgium)	$300/kg	$40m (US)
	Spearmint	Flavour Fragrance			$30/kg	$85-90m (world)
Rauwolfia Serpentina	Reserpine (raucaffricine)					$80m (US)
Sapota	Chicle	Gum	Central America	Lotte (Japan)		
Thaumatococcus	Thaumatin	Natural sweetener several thousand times sweeter than sugar	Central and Southwestern Africa	Tate & Lyie Unilever Ingene Beatrice	Over $1000/lb	Potential to fill $900m lowcal sweetener market in US

Plant	Product	Use	Origin	Who is doing research?	Value	Market size
Capsicum Frutescens (Chili Pepper)	Capsaicin	Hot flavouring		Edinburgh Univ. Univ. of Minnesota	$120/lb	
Vanilla Planifolia	Vanilla	Flavouring	Madagascar Comoros Reunion Indonesia	David Michaels Co. Escagen Univ. Delaware	$32/lb	$100m (world)
Stevia Rebaudiana	Stevioside	Sweetener (250 times sweeter than sugar)	Paraguay	DNA Plant Tech Stevia Co. Morita Chem. (Japan)		Potential to fil $900mlowca sweetener mK in US
Fragaria sp	Strawberry Flavour	Flavour		Escagen (US) Univ. of Minnesota		
Panax Ginseng	Ginseng	Flavour				
Coffee Arabica	Caffeine	Pharm., Food additive	Ethiopia			
Nicotiana Tabacum	Nicotine; Ubi-quinone 10 carvoxone		Public Salt & Tobacco (Japan) Plant Science Ltd.			
Thalictrum minus, Coptis Japonica, Phelo-dendron amvrens	Berberine	Intestinal antiseptic		Mitsui Petro-chem. (Japan) Kyoto Univ. (Japan)		
Uncaria Elliptica	Rutins	Possible rem-edy for liver disease		Univ. of Singapore		
	Paroven Paboven Venoruton					
Morinda Citrifolia	Anthraquin-ones	Pain-killers				
Coleus Blumei	Rosemarinic Acid					
Galium Verium	Anthraquin-ones					
Galium Aparine	Anthraquin-ones					
Stepnania Cepharantha	Biscoclaurine					

Plant	Product	Use	Origin	Who is doing research?	Value	Market size
Tripterygium Wilford II	Tripdiolide					
Lavendula Vera		Blue pigment				
Mentha sp.	Neomenthol					
Solanum Aviculare	Steriod Olycosides					
Amaranthus Caudatus	Red colored pigment	Dye or pigment	Peru, Bolivia Argentina	London Centre for Biotech.		
Beta Vulgaris (Sugarbeet)	Betanin	Dye or pigment	India	London Centre for Biotech.		
Indigo	Indigo	Blue dye	India	Amgen		US$100m
Hyoscymus Miticus	Hyoscyamine	Sedative		Louisiana St. University		

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Case Study

Vanilla

Issue: Natural vanilla production via tissue culture technology
Crop: *Vanilla Planifolia*—the commercially important species of vanilla orchids
Countries affected: Madagascar, Comoro Islands, Reunion, Indonesia
Impact: Possible loss of up to US $66 million in annual export earnings
When: Imminent
Companies involved: David Michael & Co., Inc.; Escagen Corp. (formerly International Plant Research Institute)

This case study was first published as a *RAFI Communique* in January, 1987

Vanilla is likely to be one of the first commercially successful flavours produced via plant tissue culture. This new technology enables the production of natural vanilla flavour from cell culture eliminating the need for traditional cultivation of the vanilla bean. Several companies based in the United States are now conducting research on the vanilla orchid—*vanilla planifolia* (Andrews), the plant species from which high-quality vanilla beans are harvested.

According to the January, 1987, issue of *Bioprocessing Technology,* cell cultures are now producing vanilla in the laboratory and a natural vanilla product could reach the market in the near future.

Vanilla planifolia is indigenous to Central and South America, but is no longer grown there commercially. Today, 98 per cent of the world's vanilla crop is produced by four countries: Madagascar, Reunion, the Comoros (all of these islands are located off the east coast of Africa), and Indonesia. Madagascar alone accounts for three-quarters of the world's vanilla production, where up to 70, 000 small farmers are engaged in production of this labour-intensive crop.[1]

The economies of these nations depend on the export of vanilla beans, valued at approximately US $66 million annually.[2] Vanilla beans account for up to 10 per cent of Madagascar's annual export earnings, and two-thirds of the Comoros' annual export earnings.[3]

The US is the largest importer of vanilla, accounting for 58 per cent of the world's consumption. In 1985, the US imported $47 million worth of vanilla beans from the four major vanilla producing countries.[4]

Biotechnology and natural flavour production

Today, the worldwide market for flavours is valued at US $2-3 billion, and is expected to grow about 30 per cent per year.[5] Because of the high profitability and rapid growth of the flavour market, many companies are using biotechnology as a means of producing natural flavours.

The use of tissue culture technology to extract flavours and other plant-derived products (fragrances, colours, pharmaceuticals, enzymes, etc.) from cell culture on a commercial scale is called 'phytoproduction'.

The basic technique used to produce vanilla flavour by means of tissue culture technology involves the selection of high-yielding cell tissues from the vanilla plant.[6] The cell tissues are then propagated in suspended cultures. Careful regulation of culture conditions, nutrient mediums and metabolic regulators are then used to induce the production of the desired chemical flavour compound—vanilla. In practice, the technology is complex, and, until recently, inefficient and expensive—at a cost of about US $1000 per lb.[7]

Researchers are now experimenting with a new, more efficient tissue culture process which would allow for continuous production of the desired flavour compound. Using this improved process, the cost of producing vanilla could be reduced from US $1000/lb to $23/lb.[8] The current price of vanilla beans is approximately US $32/lb.[9] Once perfected, the new technology would thus offer a commercially feasible alternative to traditional vanilla bean production.[10]

According to *Food Technology* magazine, 'biotechnology can effectively address the high cost and relatively uneven supply of natural vanilla'. Plant tissue culture technology is especially attractive because it offers virtually complete control over the product's supply, quality and cost:

> Quality and supply can be improved and controlled by the use of production processes based on plant cells. Many of our flavours and other products come from remote parts of (he world, where the political instability of governments or the vagaries of weather yield inconsistent supply, cost and product quality from season to season. In a plant tissue culture process, all parameters...can be controlled.[11]

Current research on vanilla

David Michael & Co. is a privately held company based in Philadelphia, Pennsylvania (US), which specializes in the manufacturing of natural and artificial flavours. They are supporting a three-year research project at the University of Delaware on tissue culture and vanilla. Their goal is 'to improve the genetics of natural vanilla in order to make possible a consistent supply of vanilla beans at a reasonable market price'.[12]

Their research, under the direction of Dr. Dietrich W. Knorr, head of the University of Delaware's Biotechnology Center, is twofold: (1) They are using plant tissue culture to develop new varieties of hardy, disease-resistant vanilla plants which could be grown outside of traditional vanilla-growing areas. (2) They are experimenting with the production of natural vanilla flavour using plant cell technology.

David Michael & Co. reports that they have made significant progress in their efforts to culture plant cells for vanilla flavours, but declines to say when a product might be available for commercial sale. According to Skip Rosskam, Senior Vice-President for Sales and Marketing of David Michael & Co.:

> Developing a vanilla flavour in a controlled environment could be an adjunct to the traditional growing process or an alternative to traditional vanilla production, and to the political, cartel-like control that these [vanilla producing] countries have now.[13]

Escagen Corporation based in San Carlos, California (US), is a private biotechnology company which organized in 1987 to purchase the assets of International Plant Research Institute, which conducted early research on phytoproduction and vanilla. Reorganized as Escagen, the company continues to specialize in phytoproduction of natural flavours for the food processing industry. Under the direction of Dr. Om Sahai, Escagen has successfully established cultures to produce vanilla, grape, and strawberry flavours. The company is focusing primarily on vanilla, and hopes to release a commercial product shortly.[14]

Conclusion

Several US-based companies are now competing to develop a more efficient and cost-effective process to produce natural vanilla flavour via tissue culture technology. If commercially successful, this new technology will have the potential to displace vanilla bean exports on a massive scale. The production of natural vanilla would be likely to shift from Third World island nations to laboratories and factories in the industrialized world, eliminating the need for traditional cultivation of vanilla and many thousands of jobs related to vanilla bean cultivation and harvest.

Notes

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Case Study

Cacao

Issue: Cacao and Biotechnology
Crop: *Theobroma Cacao*
Countries affected: All cacao producing countries of the Third World, especially Ivory Coast, Ghana, Brazil, Cameroon, Nigeria, Malaysia and Ecuador
Impact: Development of high-yielding cacao varieties could lead to overproduction and jeopardize price and stability of cacao-producing countries while shifting production from small-scale producers to large-scale plantations; the use of biotechnology to convert low-priced oils into cocoa butter could drastically reduce the demand and price for cacao beans
Companies involved: US Chocolate Manufacturer's Association (15 US-based companies) and the American Cocoa Research Institute, Hershey Foods, DNA Plant Technology, Genencor, CPC International, Ajinomoto (Japan), Fuji Oil (Japan), Cadbury-Schweppes (United Kingdom)
When: Work on all areas is now in progress
This case study was first published as a *RAFI Communique* in May, 1987

Introduction

Cacao is the second most important agricultural commodity from tropical regions in the international trade market. According to FAO statistics, approximately 1.7 million metric tons of cacao beans are produced annually. Worldwide, annual exports of cacao beans are valued at $2.6 billion. Cocoa butter, extracted from the processed cacao bean, is used to make chocolate and is an important ingredient in pharmaceutical and cosmetic products.

Cacao is grown in a narrow tropical strip between 20 degrees north and south of the equator. Just seven countries—Ivory Coast, Ghana, Brazil, Cameroon, Nigeria, Malaysia and Ecuador—account for 80 per cent of world production. Half of the world's cacao crop is produced on small land holdings. Africa accounts for 57 per cent of world production, Central and South America account for 34 per cent, and East Asia accounts for 9 per cent.'

The cacao plant, *Theobroma cacao,* is indigenous to the Amazon Basin region of South America, although one sub-species, *Lacandonense,* is found in the high forest of Chiapas, Mexico.

The genetic base of cultivated cacao is extremely narrow. Virtually all of the commercial cacao produced today is derived from a few varieties collected 40-50 years ago.[2] As a result, cacao is extremely vulnerable genetically—approximately half of the annual crop is lost to disease or insects.[3]

Various techniques of biotechnology are being applied to *Theobroma cacao* in the US, Europe and Japan. This case study will examine three major focuses of that research and the potential impact on cacao-producing nations of the Third World.

1. The use of both tissue culture and genetic engineering to create higher-quality cacao beans and cocoa butter, higher-yielding plants, and greater insect and disease resistance.
2. The use of enzymatic processes (protein engineering) to convert cheap oils such as palm or soybean oil into high-quality cocoa butter.
3. Cocoa butter biosynthesis—the use of cell culture to create cocoa butter in the laboratory.

Biotechnology research to improve cacao varieties

In mid-1986, a $1.5 million endowed research programme to support the study of the molecular biology of *Theobroma cacao* was established at Pennsylvania State University (Penn State) by two industry-supported groups, the American Cocoa Research Institute and the Chocolate Manufacturers Association of the United States. The research being conducted at Penn State University is the largest research effort focusing on cacao and biotechnology in the United States.[4]

The goal of Penn State's research on biotechnology and cacao is 'to stabilize the export crop for manufacturing countries'. A university publication describing

the cacao research programme explains: The political instability of many of the cacao-producing countries adds to the precarious position of the chocolate industry, which is wholly dependent on this one crop'.[5]

Under the direction of Dr. Paul J. Fritz, the Penn State programme is using biotechnology techniques to develop high-yielding, high-quality cacao plants. The researchers aim to develop varieties which have more cacao pods on each tree, more beans in each pod, larger beans of uniform quality, and trees resistant to drought, cold, fungi, viruses and pesticides.

Cacao is a perennial crop, and it normally requires two to four years for a new variety to flower and fruit. Once researchers succeed in developing superior, high-yielding cacao varieties, the key to widespread use and adoption of these varieties depends on a technique called 'micropropagation'. Micropropagation of superior cacao varieties would enable scientists to regenerate virtually unlimited numbers of genetically-identical cacao plants in the laboratory at a much more rapid rate than traditional breeding techniques or seed propagation. The same technique has been applied to tobacco, tomatoes, bananas, oil palms and other plantation crops. Researchers have attempted rapid micropropagation of cacao for many years, but without success.

The inability to achieve rapid micropropagation of cacao is the major stumbling block to the speedy release of high-yielding, disease-resistant cacao varieties. Dr. Paul Fritz of Penn State University predicts that scientists will succeed in micropropagation of cacao in the near future. According to Fritz, 'It won't be very long until we'll have that [micropropagation] solved—there are too many people working on that who are interested in seeing it happen'."

* * *

Using genetic engineering, scientists will someday be able to form new cacao plants tailored to meet the specific needs of industry. Penn State researchers, for example, have the long-term goal of altering the composition of cocoa butter. Increasing the fat content of the cacao seed by just 1 per cent, for example, could result in millions of dollars of savings to chocolate manufacturers (because of the increased yield of cocoa butter).[7] Another long-term project is to engineer a cacao variety containing a gene for thaumatin, a super-sweet protein which is derived from an African shrub. The end result would be a sugarless, but sweet-tasting, chocolate product—eliminating the need to add sugar in the manufacture of chocolate. According to Paul Fritz, although such projects seem far-fetched now, 'I think that within a few years we could be testing these things experimentally'.[8]

In order to accomplish these and other goals of genetic engineering, scientists must first identify and isolate specific genes, and then try to understand their characteristics, functions and how they are regulated. To this end, Penn State University researchers are now establishing the world's first 'cacao gene library' by splicing DNA into bacteria and preserving it in freezers. According to Dr. Fritz, 'DNA thus preserved is indefinitely stable and is a source of cacao genes much as a library is a source of books'." The cacao genes now being 'catalogued' at Penn State University are the raw materials for the future of genetic engineering and cacao.

* * *

DNA Plant Technology Corporation (Cinnaminson, New Jersey, USA) is an agricultural biotechnology company that specializes in developing plant-based products for industry. In a joint venture with the largest US chocolate manufacturer, Hershey Foods, DNA Plant Technology is using tissue culture and cellular genetics to develop new and improved cacao varieties. The company will not discuss details of their research, but, according to Hershey Foods, new cacao varieties have not yet been field tested.[10]

In addition to research efforts in the United States, European-based chocolate manufacturers are also applying techniques of biotechnology to Theobroma

cacao. Cadbury-Schweppes, for example, has a major biotechnology research project underway at Lord Zuckerman Research Centre in association with the University of Reading, England."

What impact on cacao producers?

Worldwide, the average yield of cacao producers is 350 to 400 Ibs. of beans per acre. Penn State researchers hope to develop new varieties which will yield at least 1, 000 Ibs. per acre.[12] But even higher yields are possible. According to Dr. Russell E. Larson, Science Advisor of the American Cocoa Research Institute, intensive cropping systems combined with new varieties developed via biotechnology will make it possible to obtain yields of up to 3000 Ibs. of beans per acre or more—an increase of 750 per cent above today's average yield."

Scientists and companies working on cacao biotechnology are quick to point out that their research will ultimately benefit the producers of cacao in the Third World by increasing yields and farmers' income. On the surface, this appears plausible. But it is likely that the benefits of advanced technologies and high-yielding cacao varieties will be skewed towards the large-scale cacao growers. As a result, cacao production will shift from small-scale producers to large-scale cacao plantations. Small-scale cacao producers in Africa, where the majority of the world's cacao is now produced, will be at a particular disadvantage. According to Dr. Larson:

> Probably 50 per cent or more of the cacao in the world is produced on small holdings. For economic reasons, it is not feasible for these growers to apply some of the advanced technologies such as adequate fertilizer usage and spray chemicals to control pests...Brazil and Malaysia have a higher proportion of large size plantations and are able to apply advanced technologies quickly. It is probable that African growers will be hard-pressed to achieve the high production levels of Brazil and Malaysia in the near future."

The application of new biotechnologies to cacao will thus facilitate a fundamental shift in the world production of cacao from small-scale producers to large-scale plantations. Future cacao production is likely to be concentrated in Brazil and Malaysia, where advanced technologies and large-scale plantations are now in place.

Malaysia is already the fastest growing cacao producer in the world. Malaysian cacao production increased tenfold between 1974 and 1984, and an estimated 625, 000 acres of cacao will be in production by the year 2000. Malaysian cacao plantations already report the world's highest cacao yields—1, 000 to 1, 200 Ibs. per acre for established plantings.[15]

Cocoa butter substitutes: biotechnology and oil conversion

Another major impact on the future of cacao producing countries involves the use of biotechnology to convert cheap oils into cocoa butter. According to Bioprocessing Technology, April, 1987:

> New technologies have potential to overturn oils and fats markets by reducing reliance on high-priced imports such as cocoa butter. Discontented with the need to import, companies will produce similar oils from domestic sources, in the process even creating oils not found in nature.

Several companies in the United States and Japan are pursuing this goal. A major Japanese food company, Ajinomoto (Tokyo, Japan) has licensed a patented enzymatic process developed by a researcher at the University of Tokyo. The main use of this process is 'synthesis of high value oils such as cocoa butter substitutes from lower value oils'." Fuji Oil Co., Ltd. (Osaka, Japan) has also patented a process to develop cocoa butter substitutes from olive, sunflower or palm oil.[17]

Genencor (South San Francisco, California, USA) has filed patents on another process which creates enzymes for use in upgrading oils and fats. According to the company, enzymes could be used to convert cheap palm oil into expensive cocoa butter.[18] According to Henry Edmunds, Manager of Product Commercialization at Genencor, 'We don't have anything

commercially available yet—but it's certainly a realistic goal'.[19] The company predicts that their fat-producing enzymes may be on the market within two to five years.[20] Genencor is jointly owned by Genentech (South San Francisco, California, USA), Corning Glass Works (Corning, New York, USA), A.E. Staley (Decatur, Illinois, USA) and Kodak (Rochester, New York, USA).

CPC International (Union, New Jersey, USA) holds a patent on a microbial process which involves the cultivation of yeasts with fatty acids. The end product is oil that mimics the composition of cocoa butter. According to early reports, 'Whether or not these oils can produce chocolate that would meet with consumer acceptance remains to be seen, but lab results indicate yes'.[21]

The use of biotechnology to develop cocoa butter substitutes from lower quality oils illustrates the enormous impact that biotechnology may have in altering or disrupting traditional markets for agricultural products produced in the Third World. If a process to synthesize cocoa butter using protein engineering is commercially successful, the worldwide glut of cheap palm oil and other edible oils would undoubtedly replace a large share of the cocoa butter market.

Production of cocoa butter via cell culture

There has been a great deal of speculation about the possibility of someday producing cocoa butter on a commercial scale using cell culture technology. The use of plant cells for the production of desirable products (flavours, fragrances, nutrients, pigments, etc.) is already being used to produce high-value products such as shikonin (a dye and pharmaceutical) and vanilla (see preceding case study). For chocolate manufacturers and other major buyers of cacao beans, the advantages of producing cocoa butter via cell culture are obvious. Product quality could be uniform and tailored to the needs of industry, and supplies would be reliable—without regard to price, weather, season, or politics.

Considerable research has focused on the production of cocoa butter from cultured cells—with extremely limited success to date. Dr. John Kinsella of Cornell University (Ithaca, New York, USA), with support from Hershey Foods, spent several years trying to produce cocoa butter in the laboratory using tissue culture techniques. According to Kinsella, 'In terms of production, we're a long way off'.[22] Thus far, the composition of cultured cells (triglycerides and fatty acids) is significantly different from that of cocoa butter.[23]

Other cacao experts agree that large-scale production of cocoa butter via cell culture is currently an unrealistic goal. According to Dr. Fritz of Penn State University, 'Forget it. It won't work. You just can't get the right fatty acids—and it isn't efficient or economical'.[2'1] Cocoa butter can be produced in the laboratory for about $100/lb. compared to $4/lb from beans. Studies conducted by DNA Plant Technology Corporation reveal that a product must cost at least $80/gram or higher to merit research on its production via cell culture. 'In the case of cacao, it's so cheap we simply can't compete with the natural plant', remarks Maro R. Sondahl of DNA Plant Technology."

If researchers are successful in developing high-yielding cacao varieties in the near future, it is likely that the price of cacao beans will go down—further reducing the incentive to engage in the production of cocoa butter via cell culture.

Conclusion

The application of plant biotechnologies to Theobroma cacao will have a profound impact on the future of cacao production in the Third World. Tissue culture and genetic engineering offer the potential to form new cacao varieties which are specifically tailored to meet the needs of industry.

The development of high-yielding varieties is likely to lead to overproduction, declining prices and economic instability in cacao-producing countries. Advanced technologies and high-yielding cacao varieties will facilitate a shift in the world production of cacao from small-scale producers to large-scale plantations.

If a process to synthesize cocoa butter using protein engineering becomes commercially available, cheap palm oil and other edible oils will undoubtedly capture a large share of the cocoa butter market.

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Case Study

Oil Palm

Issue: Genetic modification of vegetable oils
Crop: All major vegetable oils will be affected; this study focuses on oil palm *(Elaeis guineensis)*
Impact: Production of oil palm is expected to increase dramatically; overproduction will depress world prices for other oils—displacing other oil producers, particularly in the Third World; widespread clonal production of oil palms will lead to greater genetic uniformity and vulnerability of crop
Participants: Unilever (UK); IHRO (France); United Brands (US) with Agrogene; Escagen (US) with Sime Darby (Malaysia); Palm Oil Research Institute of Malaysia
Economic stakes: Present world vegetable oil market is over $35 billion
When: Clonally propagated oil palms are now being field tested; a number of oils transformed through genetic engineering (rapeseed, soybean, sunflower) should be commercialized by the mid-1990s

This case study was first published as a *RAFI Communique* in June, 1988

Introduction to vegetable oils

Worldwide, approximately 50 million metric tons (MT) of vegetable oils are produced annually, valued at approximately $35 billion.[1] The major edible oils are soybean, palm, sunflowerseed, rapeseed, coconut, palm kernel and cottonseed. This report will focus on the four leading vegetable oils, which account for over 70 per cent of world production.

In less than 20 years, worldwide vegetable oil production has doubled from about 25 million MT in 1969 to 50 million MT in 1987. Despite the increase in production, there is still a deficit of vegetable oils throughout most of the world.

Biotechnology offers the potential to radically transform the production, marketing and end-use of vegetable oils. Over 19 companies based in Europe, the United States and Japan are now investing millions of dollars in research and development on the use of biotechnologies to modify and improve the properties of oils and fats (see appendix). Many universities and public research programmes are pursuing similar goals. Current research employing both recombinant DNA technology and tissue culture techniques takes two approaches: (1) genetic modification of oilseed plants to induce production of altered oils, and, (2) post-harvest modification of oils using enzymes or microbes.

According to *Bioprocessing Technology* the potential market for modified vegetable oils is $2.6 billion. There are many diverse goals for improving/modifying properties of vegetable oils. These include: nutritional properties (i.e. lowering saturated fat levels, reducing caloric content, etc.); improving processing characteristics (i.e. lowering costs of processing, improving shelf life); and conversion of low-cost oils into high value products. (About 70 per cent of oils and fats are used in edible products, the remainder are used in production of lubricants, detergents and plastics.)

Soybeans, palm oil, rapeseed and sunflower are currently the major targets of biotechnology research because they are among the least expensive oils and the most easily manipulated using new biotechnologies. New biotechniques will be employed in oilseed varieties of soya, rape and sunflower coming onto Northern markets in the early 1990s. Of these three crops—all widely (but not exclusively) grown in the North—sunflower yields are expected to rise 278 per cent over their 1986 yields with both rapeseed and soyabeans trailing with gains of 189 per cent and 176 per cent respectively. With the exception of sunflowers in the USA and soybeans in Canada, however, the largest increases will take place in the South where yields in the three crops will either double or even triple.[3]

This case study reviews work in progress on the leading vegetable oils, with a special focus on the crop most regard to be the leader in potential market share, oil palm.

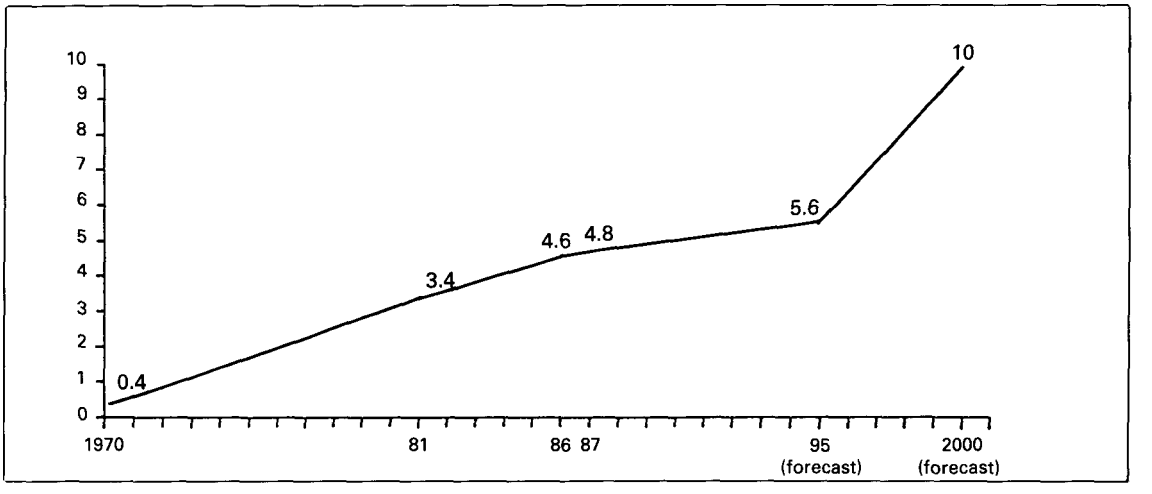

Figure 6 Malaysian palm oil production in million metric tons 1970-2000

Oil palm

Oil palm *(Elaeis guineensis)* is a perennial plant native to West Africa's equatorial rain forest belt. The oil palm produces two vegetable oils—palm oil and palm kernel oil. The former comes from the flesh of the fruit and the latter from the nut or kernel. When properly cultivated the oil palm produces higher yields per acre than any other oil-seed crop, approximately 5.2 tons of oil per hectare annually.

Oil palm is so incredibly more efficient an oil producer than any other plant that it will ultimately, I think, make all other vegetable oil-producing plants obsolete. Imagine a plant that can make 3,000-4,000 lbs. of edible oil per acre per year, starting the third year after you plant it and going on for another 25 or 30 years. Very low cost producer. Right now Malaysia has a corner on the market. But it's being planted very rapidly in Indonesia and Brazil and in all the tropical countries. There's going to be an awful lot of palm oil available in the rather near future. And it's going to decrease the price of edible oil...I can assure you that it is the vegetable oil of the future.[4]

The rise of palm oil as one of the world's leading vegetable oils has been nothing short of spectacular. Even without applications of new biotechnologies, palm oil is expected to gain an even greater share of the worldwide vegetable oil market. In 1980, palm oil accounted for only 9 per cent of the worldwide vegetable oil markets. Experts predict we will see 'an unprecedented increase in world palm oil production', due largely to massive plantings in Indonesia (where up to 1.7 million hectares are to be planted).[5] By 1995, palm oil is expected to surpass soybean oil as the world's leading vegetable oil capturing 21 per cent of the total market. According to *Oil World* magazine, by the year 2000, mature palm oil area is predicted to reach 5 million hectares and produce 18 million MT of oil, compared with 2.4 million hectares and 7.5 million MT in 1986.[6]

In the past decade, Malaysian palm oil exports increased over two and one-half times. Nearly half of the world's increase in edible oil trade over the past five years is due to increased exports of Malaysian palm oil.[7] Malaysia now accounts for 56 per cent of worldwide production, and 90 per cent of global exports.[8] The figure above illustrates the spectacular growth of palm oil in Malaysia.

Biotechnology in the improvement of oil palm

Laboratory techniques for clonal propagation of oil palms by tissue culture have been available for the past 10 years, but commercial-scale production has not yet been realized.

Using this technique, oil palm trees with unique oil composition or specific hybrid combinations can be produced in large quantities. Clonal propagation makes it possible to mass-produce genetically uniform, high-yielding palm trees, by-passing the need for reproduction by seed. The basic technique involves the selection of superior, high-yielding oil palm varieties. Cuttings are grown on a simple growth medium in a test tube environment. Cells from these

cuttings grow and develop into plantlets in response to certain nutrients and growth hormones.

Unilever Laboratories of England and the French IRHO (Institut de Recherches pour les Huiles et Oleagineux) in France initiated research on clonal propagation of oil palms in the late 1960s.

Because of its dominant position as a global producer and seller of oils and fats, the role of Unilever is particularly noteworthy. Over one-third of world trade in oils and fats is controlled by this transnational giant based in the United Kingdom and the Netherlands.[10] Unilever is one of the world's largest food corporations and the largest buyer and seller of oils and fats. With 1986 annual sales of more than US $25 billion, the company ranks number seven on Fortune magazine's list of international enterprises outside of the US.

As of 1985 the company had approximately 66, 000 hectares devoted to oil palm plantations in Colombia, Ghana, Zaire, Thailand, Cameroon and Malaysia.[11]

The first field planting of clonal palms was made in January, 1977, at Unilever's Pamol plantation in Malaysia. The company built facilities in England and Malaysia capable of mass-producing up to half a million clonal oil palms annually. In 1985, Unilever sold oil palm clones worth £1.4 million and enthusiastically predicted that sales of clones would skyrocket to £17.5 million by 1995." Plans were announced for the commercial-scale planting of cloned palms in Unilever's plantation in Colombia. In Brazil, Unilever's clones were sold for US $1 each, where at least six varieties were reportedly being tested in the Amazon region.[13]

The enthusiasm for mass-marketing and commercial-scale plantings of oil palm clones was suddenly dampened in 1986 when Unilever disclosed that experimental plantings in four Malaysian estates (cloned trees planted in 1983) began producing abnormal flowers and fruits. According to Unilever senior scientist, Dr. L.H. Jones:

> Field tests on clones produced in the lab went well, but when we went from lab to scale-up, problems occurred. It will be three to four years before we can check this generation to determine if the flowers are normal.[14]

Unilever scientists claim that the cause of the abnormalities is not yet known, but it has resulted in a major setback for commercial-scale production of cloned oil palms. According to one industry journal, 'no large scale plantings of oil palm clones are expected for at least 10 years in Southeast Asia', as a result of Unilever's problems.[15] Unilever has cut-back production of clones, and sales of cloned trees are now limited to within Unilever's plantation groups.[16]

It is impossible to know how widespread the problem is, or if Unilever and other companies have experienced abnormalities with clones sold and planted outside of Southeast Asia. The problem illustrates the kind of vulnerability and risk that Third World countries may suffer when used as a testing ground for new, but unproven technologies.

Despite the setback, it is certain that research on clonal propagation of oil palms will continue. Several major corporations, biotechnology companies, government institutions and plantation groups have initiated major research programmes to commercialize the technique. The Palm Oil Research Institute of Malaysia (PORIM), a government sponsored institute which supports the nation's palm oil industry, is conducting its own tissue culture research in collaboration with plantation groups. Commercial plantings of cloned palms are foreseen for the 1990s.[17]

In the United States, a small biotechnology company, Escagen Inc., has an agreement with Malaysia's largest oil palm company, Sime Darby, on the development of clonal propagation techniques. After six years of research, the company is just getting to the point of field trials.[18]

In Kasragod, India, the Central Plantation Crop Research Institute has reportedly developed its own technique for producing clonal plantlets of oil palm.[19]

In mid-1987, the United Fruit Company (a subsidiary of United Brands) entered into an agreement with Agrogene Plant Sciences, a small biotechnology company based in Florida, to conduct research on clonal propagation of oil palms (see details below).[20]

Clonal propagation of oil palm for commercial-scale production is in its infancy. Experimental plantings are still the rule, and large-scale commercial harvests have not yet been realized. It is generally recognized that clonal propagation will increase yields by at least 30 per cent. But according to Unilever scientists, 'theoretically yields as high as 17 tonnes of oil per hectare per annum should be possible', a greater than 200 per cent increase over current yields in Malaysia of about 5-6 tonnes per hectare per annum.[21]

Palm oil production in Latin America

Southeast Asia is by far the dominant palm oil producing area, but recent reports indicate that Central and South America represent an untapped region for large-scale oil palm production.

Palm oil production in Latin America has more than doubled since 1979, with Colombia, Ecuador and Costa Rica accounting for almost 80 per cent of the region's total production. Growth of the region's palm oil production has already resulted in a decline of US soybean exports to Colombia and Ecuador.[22] Production is based on large, capital-intensive plantations. Unilever and United Brands are two of the dominant interests in the area, and both are experimenting with clonally-propagated oil palms for large-scale commercial production.

Unilever's first oil palm plantation in South America, Unipalma de Los Llanos, was formed in 1981 and planting began in 1982. According to Unilever, this plantation underwent 'the first commercial-scale planting of clonal oil palms in the Western Hemisphere'.[23] Approximately 2, 200 hectares in Colombia are now planted in cloned oil palms, and about 30 per cent of Colombia's oil palm plantations are irrigated.[24]

United Brands is the world's largest producer and distributor of bananas. Because of the low growth potential in the mature banana market and the spread of the devastating black sigatoka disease in Central America, the company is now re-planting old banana estates with cacao and oil palm. United Brands' Compania Bananera de Costa Rica accounts for about 15, 000 hectares of oil palm out of a total of 18, 450 hectares under production in Costa Rica. As a result of new plantings, palm oil production is projected to increase sharply by the year 2000, to over 112, 000 tons (a 300 per cent increase in production over current levels).[25]

United Brands is also experimenting with the development of high-yielding, clonally-propagated oil palms for its new plantations. In mid-1987, the company entered into an agreement with Agrogene Plant Science, a small biotechnology company based in Florida (USA), to conduct research on clonal propagation of oil palms. Agrogene specializes in tissue culture techniques and has the capacity to clone several million new plants a year. According to Agrogene's president. Dr. John Burrows, the company is developing clonal material for United Brands' palm oil operations throughout Central America.

Ecuador, Latin America's second largest producer of palm oil, is reportedly enthusiastic about establishing oil palm as a major new crop, in an attempt to compensate for an obsolete rubber industry and low crude oil prices. The recent establishment of oil palm plantations in the Amazonian jungle region of Ecuador, where more than 20, 000 hectares have been cleared, has sparked considerable controversy.

In 1986, the Federation of Indigenous Peoples of the Ecuadorian Amazon claimed that cultivation of oil palm in the region threatens the lives of 115, 000 indigenous people living in the area. According to the indigenous leaders,'.. .we also have to face the threats of investors, national and international companies that are planning, with the help of the government, to plow the jungle under. They see us only as opposing progress, or as cheap labour for their plantations and agroindustry'.[26] Ecuador already has 20, 000 hectares

of oil palm under cultivation (major estates are the Palmoriente and Palmeras plantations), and plans are underway to expand production.

Brazil is now a relatively small producer of palm oil, but there is tremendous potential for growth. According to the US Department of Agriculture, 'there is an estimated 50 million hectares, mostly in the Amazon region, that is considered ideal for oil palm cultivation'.[27] The Brazilians are reportedly interested in developing programmes for the use of vegetable oils as a substitute for diesel fuel.

The socio-economic impact

Some would argue that increased production of palm oil will provide a source of much-needed vegetable oils to Third World countries where diets are deficient in oils and fats. The growth and expansion of the palm oil industry in Southeast Asia and Latin America may, in fact, do little to boost the agricultural economies of Third World nations. In addition, traditional, less productive producers of palm oil and other vegetable oils throughout the Third World will find it increasingly difficult to compete with modern, high-technology estates.

The establishment of new oil palm estates is extremely capital intensive. According to Unilever, the cost of setting up a 10, 000 hectare estate is approximately US $75 million.[28] Once established, cloned palms will require considerably greater management than traditional palms. On average, vegetatively propagated plants also require six times greater chemical protection than seed-propagated plants. More costs for poor farmers. Thus, new clonally-propagated oil palms will be controlled primarily by large corporations and government estates, with little or no opportunity for small-scale producers and a greatly reduced need for harvest workers.

New oil palm varieties are designed to maintain plantation profitability despite the predictable drop in edible oil prices which will result from massive overproduction.[29] In addition to high yields and disease resistance, new clones are selected for uniform ripening, low stature and easily accessible fruit—qualities designed to significantly reduce harvesting costs and harvest workers.

Third World producers of competing vegetable oils (particularly higher-priced oils) are already being affected by the glut of low-priced palm oil on the world market. Industry experts predict that, as palm oil captures a larger share of the world market, demand for vegetable oils such as groundnut, coconut and cottonseed oil will continue to decline. By 1995, the market for many of these higher-priced oils will be 'much smaller than they were in I960'.[30]

Countries like the Philippines, where coconuts are the most important export crop, will be especially hard-hit. In the Philippines, some 700, 000 small farmers grow coconuts on plots averaging less than 5 hectares. Nearly one-third of the Filipino population is dependent on the coconut industry.[31] A worldwide glut of low-priced palm oil will undoubtedly depress prices of competing oils—and could cause severe displacement of Filipino coconut producers with a long-lasting impact on the Philippine economy.

One of the socioeconomic factors to be considered is the growing genetic vulnerability of oil palms. The basis for the entire oil palm industry in Southeast Asia is four West African palms that arrived in Indonesia around 1848.[32] By definition, the new clones will do nothing to improve genetic diversity in Asia and could work to heighten the uniformity and risk for farmers in Africa.

Conclusion

The application of tissue culture technology to the oil palm will have a profound effect on the future of vegetable oil producers, consumers and vegetable oil markets around the world. It is virtually impossible to predict the outcome, however, since competing vegetable oils are also subject to manipulation by

biotechniques which will drastically alter their production, sales and end-use. In his keynote address before the 1987 World Conference on Biotechnology for the Fats and Oils Industry in Hamburg, West Germany, Dr. Paul K. Stumpf of the University of California made the following observation:

> ... a versatile oil crop could affect greatly the economy of an entire nation. The oil palm is the principal agronomic crop in Malaysia, Indonesia and some African countries. If a genetically designed rapeseed or soya seed could produce the same type of triglycerides as economically as what is now produced by the oil palm, then the oil palm industry would collapse, and the palm oil producing countries would suffer. Conversely, if the oil palm industry would apply the same techniques to the oil palm that were used to alter rapeseed or soya, then the oil palm would become the prime source of vegetable oils.[33]

A special feature on biotechnology and vegetable oils appearing in Bioprocessing Technology made this prediction about the future of international competition in modified oils and fats:

> Both genetic and enzymatic modification of oils and fats will steal some of the market away from the higher priced oils currently on the market. Expect to see a drop in the market for these oils as the market for modified oils grows. This will affect international competition by giving developed nations ways to produce oils similar to those that are now only available from developing countries.[34]

Cuphea, a wild oil plant found widely in the Americas, may be a case in point. The plant is being promoted in the United States and Europe as a possible replacement for both palm kernel and coconut oil presently used in soaps and detergents.[35] Americans now import half a million tons of tropical oils every year at a cost of US $250 million. The US Soap and Detergent Industry (a trade association) has sunk close to a hundred thousand dollars into cuphea research in hopes of developing the wild plant as a domestic crop. Others studying the plant include Oregon and Kent State Universities and General Foods (a subsidiary of Philip Morris). In Europe, Henkel is exhorting European farmers to consider production there.

Cuphea has all the makings of another 'Cinderella' crop. Aside from detergents, it shows promise as a raw material for chemicals, finishes, resins, cosmetics and—even—insecticides. According to the New England Deaconess Hospital, Cuphea is also a quick source of energy that may help to treat patients unable to absorb fat properly.[36] The plant can grow in temperate climates, if harvesting problems can be overcome. Southeast Asia may lose an important market. Still to be considered, however, is access to Cuphea germplasm. The most promising strains may come from Brazil and Nicaragua.[37]

In fact, Cuphea is but one of a host of potential oil plants. Brazilian plant explorers claim to have discovered at least three Amazonian 'palms'—all with better yield or oil than the original African palms.[38] The range of plant choices grows with every issue of a biotech magazine.

Added to the biological uncertainty is the political uncertainty—even unrest—fomented by the US soybean industry. American soya growers and processors have attacked the palm industry claiming, usually with grossly inaccurate figures, that 'tropical fats' behave more like animal fats than vegetable oils. The Americans want warning labels placed on products containing oil palm and would be delighted to see oil palm banned altogether. The 'tropical fats' battle is, at best, the first salvo in an escalating war between otherwise interchangeable agricultural raw materials. Industrialized countries have a long history of winning such wars.

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Appendix

Survey of companies involved in modification of oils and fats using biotechnologies (198S)

This survey is adapted, in part, from a list appearing in Bioprocessing Technology, September, 1987, p. 5, entitled 'Companies Looking at Oil or Fat Modification'. Other sources include: 'Biotechnology: A Young Industry with Potential' in Journal of the American Oil Chemists' Society, September, 1987, p. 1221-1233; and information compiled by Rural Advancement Fund International.

Agrogene Plant Science, Inc., Florida, USA (a subsidiary of University Genetics Co.). Developing clonally propagated

oil palms for United Fruit Co. plantations in Central America.

Ajinomoto Co., Inc, Tokyo, Japan. Using enzymatic processes to manipulate fatty acids.

AHelix Inc., Mississauga, Ont., Canada. Genetically engineering rapeseed (canola).

Asahi Denka Kogyo, Tokyo, Japan. Using enzymatic processes to produce cocoa butter substitutes from palm oil.

Biotechnica International, Calgary, Alberta, Canada. Genetic engineering of rapeseed (canola) and flax.

Calgene, Inc., Davis, CA, USA. Has approximately one dozen agreements with other companies to use genetic engineering for development of oilseeds and other crops with specific traits.

CetusCorp., Emeryville, CA, USA. Using enzymes to modify oils and fats.

DNA Plant Technology Corp., Cinnaminson, NJ, USA. Tissue culture technology to modify vegetable oil plants.

Du Pont, Wilmington, DE, USA. Funding research at DNA Plant Technology Corp. to develop new varieties of canola.

Escagen, Inc., California, USA. Developing clonally propagated oil palms for a Malaysian plantation group.

Fuji Oil Co., Ltd., Osaka, Japan. Has patent on use of lipase to make cocoa butter.

Genencor Inc., South San Francisco, CA, USA. Protein engineering to modify oils and fats.

Gist Brocades N.V., Delft, Netherlands. Genetic modification of oils and fats.

Henkel Research Corp., Santa Rosa, CA, USA, US-based research centre for German company, developing microbes for oil and fat modification.

Lubrizol Enterprises, Inc., Wickliffe, OH, USA. Modifying sunflower, rapeseed, and corn plants to upgrade oils. Collaborates with Sungene Technologies and others.

Monsanto Co., St. Louis, MO, USA. Transformation and regeneration of rapeseed (canola).

Nippon Steel Corp., Tokyo, Japan. Has agreement with Calgene for genetically engineered specialty oils.

NPI, Inc., Utah, USA.

Oleofina S.A., Brussels, Belgium (subsidiary of Petrofina). Genetic modification of oils for industrial uses.

Sungene Technologies Corp., Palo Alto, CA, USA. Tissue culture research on corn, soybean, rapeseed, sunflower, and sesame.

United Fruit Co., New York, NY, USA. Subsidiary of United Brands, establishing oil palm plantations in Central America, funding clonal propagation research at Agrogene Plant Sciences, Inc.

Unilever, United Kingdom and the Netherlands. Producing cocoa butter substitute semicommercially; studying genetic and enzymatic modification of oils and fats; pioneer in clonal propagation of oil palm.

Case Study

Thaumatin

Issue: The use of biotechnology to producethe intensely sweetthaumatin protein
Plant: Thaumatin is derived from the fruit of a West African rain forest shrub
Countries affected: Product will be marketed as a low-calorie sweetener in Europe, Japan, and US
Impact: In combination with other newly developed sweeteners, these products offer the potential to erode traditional sugar markets
When: A genetically-engineered thaumatin sweetener is now being produced in the laboratory; one company has applied for US regulatory approval
Companies involved: Unilever (the Netherlands); Ingene for Beatrice Foods (US); (unconfirmed: DNA Plant Technology, Inc.forMonsanto, US)

This case study was first published as a RAFI Communique in February, 1987

Biotechnology is now being used to develop new, natural sweeteners from plants. One of the most promising natural sweeteners, the protein thaumatin, is extracted from the fruit of a West African plant, Thaumatococcus daniellii. Thaumatin is generally recognized as the sweetest substance known to man —several thousand times sweeter than sugar.[1] The thaumatin plant originates throughout central and southwestern Africa where its fruits have been used for centuries as a sweetener.

The traditional method of extracting the intensely sweet protein from the thaumatin plant is labour intensive and extremely expensive. Tate & Lyie, a major producer of refined sugar based in Britain, markets a naturally-extracted thaumatin sweetener under the trade name 'Talin'. Since the thaumatin plant will not bear fruit outside its natural habitat, Tate & Lyie's thaumatin comes from plants grown in the Ivory Coast and Ghana. The ripe fruit is frozen and then transported to the United Kingdom where the company extracts and purifies the thaumatin protein.[2] The end product, Talin, reportedly sells for upwards of $1000 per Ib.[3]

Talin is currently sold as a low-calorie sweetener in Japan, the United Kingdom, Austria and Switzerland, and is under consideration for approval in various other countries. In the US, where regulatory approval for new sweeteners is especially lengthy, Talin has only been approved for use in chewing gum.[4]

Biotechnology and thaumatin

Several major corporations and small biotechnology firms in the United States and Europe are now attempting to use recombinant DNA technology to produce thaumatin protein in the laboratory. In 1985-86, the intensely sweet thaumatin protein was successfully cloned by scientists at Unilever (the Netherlands) and Ingene (Santa Monica, California, USA).[5] According to Bioprocessing Technology, 'if researchers can increase the yields to economical levels, production in micro-organisms will give thaumatin a competitive edge over other natural sweeteners'.[6]

Genetically-engineered thaumatin products will be marketed primarily as a low-calorie sweetener. Because of the extreme sweetness of the protein, it can be used in minuscule amounts with virtually no caloric content. Since the product has a licorice-like aftertaste, its application as a sweetener may be limited to certain products and uses.[7]

The following companies are actively pursuing research to develop a thaumatin sweetener via biotechnology:

Ingene (International Genetic Engineering, Inc.) of Santa Monica, California (USA), has been working on the development of a genetically-engineered thaumatin protein since 1982 under contract to Beatrice Foods (Chicago, Illinois, US). Ingene holds a patent on the regulatory genetic sequences it developed to produce the thaumatin protein. The company has applied for US regulatory approval.[8]

Unilever, a transnational giant based in the Netherlands and Britain, was the first company to express genes for the protein thaumatin in microbial hosts.

DNA Plant Technology Corporation of Cinnaminson, New Jersey (USA) has signed a research agreement with Monsanto Corporation (St. Louis, Missouri, US) 'to develop plant varieties that will act as sources of naturally occurring sweeteners' using cell culture technology.[9] The company refuses to discuss details of the research agreement, and will neither confirm nor deny specific interest in thaumatin.[10]

New sweeteners displace sugar market

Biotechnology offers the potential to displace sugar as an industrial sweetener on a massive scale.[11] The substitution of other sweeteners is already underway. In recent years, the introduction of high fructose corn syrup (HFCS—a sweetener manufactured from corn using immobilized enzymes) has seriously eroded traditional sugar markets.

US consumption of HFCS grew from 1.35 million tons in 1978 to 4.3 million tons in 1984, while US sugar imports dropped from 6.1 million tons in 1977 to 1.5 million tons in 1985-86.[12]

The use of sugar substitutes has had a devastating impact on sugar producing countries in the Third World. Caribbean sugar exports to the US, for example, dropped from US $686 million in 1981 to about $250 million in 1985. In the Philippines, sugar export revenues plunged by 39 per cent from 1980 to 1984. According to Dutch researchers, the livelihood of an estimated 8-10 million people in the Third World is threatened by the loss of traditional sugar markets and the drop in world sugar prices.[13]

Conclusion

If the thaumatin protein can be economically produced using recombinant DNA technology, thaumatin could capture a substantial share of the sweetener market, particularly for low-calorie sweeteners in the US, Europe and Japan. In the US alone, the sweetener market is now worth $8 billion, of which $900 million is low-calorie sweeteners.[14]

If commercially successful, the thaumatin sweetener will not single-handedly displace traditional markets for sugar. However, thaumatin is only one of several plants which produce naturally occurring, sweet-tasting compounds. These plants and other sweetener sources will undoubtedly be the focus of further biotechnology research. The development of a thaumatin product via biotechnology is just the beginning of a transition to alternative sweeteners. New products of biotechnology will lead to the massive displacement of Third World sugar markets in the coming years.

Biotechnology research is also underway on the following, lesser-known plants which are sources of natural sweeteners:

Stevia rebaudiana. A plant cultivated in Paraguay, Japan, and other Asian countries which contains substances up to 300 times sweeter than sugar. Japanese and US-based companies are seeking to produce a stevia sweetener.

Lippia dulcis. A natural sweetener (hernandulcin) derived from this plant is approximately 1000 times sweeter than sugar.

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Appendix

Corporate profiles

Beatrice Foods, Chicago, Illinois, USA, is a major food and consumer product corporation, with 1985 annual sales of $12.6 billion. The company ranks 26 on the *Fortune* 500.

DNA Plant Technology Corporation, Cinnaminson, New Jersey, USA, is a small biotechnology firm founded in 1981. The publicly-held company specializes in cell culture technology and has numerous research contracts with major corporations working on products such as palm oil, tomatoes, coffee, cocoa, fragrances and flavours.

Ingene, Santa Monica, California, USA, is a small biotechnology firm formed in 1981 which focuses on genetic engineering to develop pharmaceutical, specially chemical, and food products. Research on thaumatin is the company's largest effort in the area of food additives. Ingene became publicly held in mid-1986.

Monsanto, St. Louis, Missouri, USA, is a major agrichemical corporation with 1985 annual sales of $6.7 billion, ranking 53 on the *Fortune 500.* Approximately one-third of the company's 1985 research budget of $400 million was designated for biotechnology projects.

Tate & Lyle, Reading, England, is a major producer of refined sugar. With 1985 annual sales of $2 billion, the company ranks 247 on *Fortune's* list of the International 500. The company is not working on a genetically-engineered thaumatin product, but is conducting research on enzymes to produce alternative sweeteners.

Unilever, headquartered in Rotterdam, the Netherlands and London, England, is one of the world's largest producers of consumer goods. The company ranks 7 on *Fortune's* list of the world's largest industrial corporations outside of the US, with 1986 annual sales of over US $25 billion.

Case Study

Gum Arabic

Issue: Replacement of major cash crop
Countries affected: Nigeria, Senegal, Sudan and others
Crop: Gum Arabic ('hashab')
Impact: Possible loss of US $60 million in annual export earnings and seasonal employment
When: Very near future

This case study was first published as a *RAFI Communique* in September, 1986

New starch-based substitutes for gum arabic and other water soluble gums threaten to replace a major portion of gum exports from several African countries.

Water soluble gums, especially gum arabic, are widely used throughout the food processing industry—particularly in beverages and confections. In 1984, the United States imported approximately 25 million lbs. of gum arabic valued at $18 million (before processing). The US market accounts for an estimated one-third of all the gum arabic produced for export.

Gum arabic is a dried, gummy exudation which comes from the acacia tree (*A. senegal). A. senegal* originates in the dry savannas of tropical Africa and extends to the Red Sea and eastern India. The Sudan currently accounts for 80 per cent of the world's supply of gum arabic. In 1983, gum arabic accounted for 8 per cent of that nation's export earnings, approximately $57 million. Nigeria and Senegal also produce gum arabic.

Beginning with the 1984/85 crop year, a sharp drop in world wide gum arabic production created a shortage of gum arabic in the US and Europe. In response to the gum arabic shortage, numerous companies have developed substitutes to replace this important ingredient. According to *Food Processing Magazine:*

> The reason for the need of the replacer is that over the past two years a shortage of gum arabic from Sudan has developed. Many factors have contributed to the shortage including dry weather which destroyed a portion of the growing crop, but, also, political and economic factors have contributed to less activity in harvesting the crop which was available. The net result was that the 1984/5 crop was only 10,000 metric tons compared to a typical crop of 40,000 metric tons. However, there will be a time during which no gum arabic will be available on the American market.

Over 30 brand-name gum arabic substitutes are now available in the US. Many of these are aggressively marketed with claims of superior cost-effectiveness to Sudanese gum arabic. Most substitutes are starch-based and contain some portion of gum arabic.

TIC Gums, Inc., a New York City-based food-processing company which specializes in gum products has launched a major advertising and promotional campaign for its newest gum substitute, 'Aragum 3000'. The company refuses to discuss the new product, but one beverage company executive who has tested the substitute claims that it consists of one-third gum arabic and two-thirds starch. Aragum 3000 reportedly costs 20 cents per lb. less than pure gum arabic, and processors can use 20 per cent less in their formulas for processing.

Although the outlook for future supplies and production of gum arabic is improving, it is impossible to say how much the market for gum arabic will be affected by gum substitutes. Herbert Schultz of the US-based Water Soluble Gum Association says that 'starch substitutes have affected about 50 per cent of the (US) market', and he predicts that 'about 25 per cent of that market is recoverable if the price is right'.

According to another industry analyst, Paul Flowerman of P.L. Thomas & Co., 'My assessment is that as much as half of the market may be permanently lost', depending on the price and supply of the 1986-87 gum arabic crop.

An in-depth report on gum arabic prepared for the US Agency for International Development in Khartoum, Sudan, concludes with a grim forecast for the gum arabic market in the US.

> Another year of shortages will eliminate any need to further evaluate the price elasticity of demand of gum arabic: the

product would have by then probably become a specialty ingredient purchased in very small volumes.

In addition to gum arabic, substitutes for other commercially important, natural gums are also being developed. Locust bean gum (often referred to as vegetable gum) is extracted from the seed pod of the locust or carob tree *(CeratoniasiliquaL.)*. The locust tree is indigenous to the near East and Mediterranean areas. Spain, Portugal and Italy are major exporters.

Karaya gum may also be affected by the development of gum substitutes. Karaya gum is the dried exudate of the *Sterculia wens* tree, and India is the sole source of supply.

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Animal Pharm

Animal Husbandry in the 1990s

With the new technologies, our livestock may become 'bio-reactors' or feedstock for the pharmaceutical industry. It would seem only fair. Other proposals for increasing animal productivity will also increase the care and drugs needed for our cows, pigs, chickens and sheep—and the new 'micro-livestock' of the next century. The patient may also be the cure on the Animal Pharm.

> Dr. Strabismus of Utrecht is carrying out research work with a view to crossing salmon with mosquitoes. He says it will mean a bite every time for the fisherman.
>
> *J.B. Morton, English humourist*

According to a US Government study in 1984, at least 63 companies and well over 482 PhD scientists in the United States are actively pursuing biotechnology possibilities in animal genetics.[1] A more recent global survey taken at the close of 1986 identifies 14 biotech firms working on veterinary medicines alone.[2] Still other reports related to animal vaccines imply that more than 145 companies are actively engaged in the development of new livestock vaccines.[3] Whatever their numbers, the companies are scrapping for a market which is conservatively estimated to be worth $1.1 billion by 1995.[4]

Aside from producing veterinary kits for detecting and curing diseases, the range of work on livestock is almost numbing in its scope and consequences. Goats and sheep have been bred in vitro into a new creature, the 'Geep'.[5] Chicken meat has been biologically adapted to taste like beef.[6] Low-grade cuts from the cow have been altered into high-grade restaurant steaks. The molting patterns of hens have been restructured to keep them laying all year round and the fertility cycles of alligators have been coordinated to allow for artificial insemination. In experiments that first saw rat genes inserted into mice to give birth to Supermice in Australia, scientists have soldiered on to produce Superpigs and Supersheep as well. Mouse genes have been inserted into cereal crops to improve water absorption. Insect genes have gone to tobacco plants. Most telling of all, human genes have been inserted into both sheep and pigs.[7] The pig was not a success. Our genes upped its bacon content, but the poor sow was cross-eyed, arthritic, sickly, and stupid. (Will eating a ham sandwich become an act of cannibalism? To paraphrase Pogo: we have seen our dinner, and it is us!)

The stories and the examples are becoming endless. During the Bogève meeting, participants looked most closely at the impact of biotechnology on cattle. Research on bovines crosses back and forth between animal genetics

Table 11 Sex and the single sow: biotechnology and the swine industry

Technique or product	Participating enterprises	Comment
Porcine Follicle Stimulating Hormone (pFSH)	Integrated Genetics	Recombinant product encourages superovulation and, with pFSH has potential world market of US $30 million per annum after introduction in 1988[8]
Infertility Vaccine	Michigan State University	'Artificial castration' by immunizing male against own sex hormones leads to 30 per cent improvement in efficiency or lean meat production[9]
Porcine Growth Hormone (pGH)	Int'l. Minerals & Chemicals	US $200 million per annum market projected for yield enhancing growth hormone[10]
Litter rate increase	Integrated Genetics	Delay of 20-45 days between litters of 12-14 piglets might be cut to 20 or fewer days[11]
Human Growth Hormone (hGH)	Adelaide University	Transfer of human gene increases lean meat and other end-product qualities but has undesirable side-effects[12]
Pseudorabies Vaccine (rPRV)	Upjohn and NovaGene	Sexually-transmitted by 'itinerant wild boars' (MCP),[13] this herpes virus leads to costly litter loss. NovaGene has already administered 600-700, 000 doses in USA[14]

and bioprocessing in the dairy industry. What is being done to the cow is being done to other livestock as well.

The trojan cow
Biotechnology and the dairy industry

Three developments in new biotechnologies may significantly alter the world dairy industry and markets. The development of embryo-transfer technology now makes it possible for a single high-producing dairy cow to generate at least a dozen offspring a year with the aid of surrogate mothers.[15] Embryo-splitting techniques combined with more conventional fertility drugs could increase the number of offspring to fifty or one hundred. Still other techniques may soon be commonly available to ensure that the offspring are female.[16]

Secondly, the development of bovine growth hormone (bGH), when commercialized in the early 1990s, is expected to lead to as much as a one-third increase in milk production and a significant decline in the number of dairy farmers.

Finally, the commercial production of hydrolyzed milk—containing lactose in semi-digested form—in Australia (via a process developed by Sumitomo Chemicals of Japan) now targets the Third World as a major market for milk products.[17] Hydrolyzed milk ends the problem of lactose intolerance which has been a major barrier to milk exports to the Third World.

The desecrated cow

The campaign of the biotech industry to manipulate the reproductive processes of the cow is nothing short of macabre. Artificial insemination—in the pre-dawn glow of the new industry in the 1950s—'immortalized' superior bulls to impregnate thousands of cows long after the bulls had been rendered hamburgers. But 'AI' only allowed for genetic improvement through one side of the sexual equation. Breeders long dreamed of a counterpart process for the female of the species.

By the late seventies, techniques of embryo-transfer ('ET') had developed to the point of viable commercialization, and the dreams of the breeders (and the nightmares of the cows) became realized.

Cows normally bear one calf a year. Usually a single egg is produced each month, however, and the new techniques make it possible to capture the embryo, inseminate it and then insert the fertilized egg into an unsuspecting surrogate when her back is turned. Thus, the superior female inseminated by a superior male can produce a dozen high-value offspring a year. The basic technique is now well established and one company, Rio Vista Genetics of Texas (of course) is shipping about 5, 000 embryos a year to customers around the world.[18]

But this is just the beginning. Integrated Genetics—one among many American biotech firms working in this field—has patented something called Bovine Follicle Stimulating Hormone (BFSH) intended to crank up the reproductive machinery of the cow from one egg to between five and thirty every month.[19] With a stable full of living incubators-in-waiting, an 'ET' mom and an 'AI' dad can theoretically assemble up to 360 calves in a single year.

Still the homogenization is not complete. Even with ET, nature remains fickle and the bovine assembly line could not faithfully reproduce carbon copies. Other work underway at Cambridge and elsewhere has been attempting to remedy this by cloning. The result would be an embryo production line leading to virtually identical calves. In theory, extracting the nucleus from a somatic cell and inserting this into an egg from which the nucleus has been removed would lead to calves virtually identical to the

donor of the nucleus. In time for Christmas, 1987, W.R. Grace proudly announced the birth of the world's first cloned female calves. With considerable help from the University of Wisconsin, the huge chemicals giant has achieved what many researchers felt was still light years away.[20]

Yet another frontier in bovine reproduction has just been crossed. Researchers have now developed commercially viable means of sexing to ensure that the calf to be born is the desired gender.21 What is the result of all this manipulation? Between ET and its related techniques, all the cows in Texas or India could have the same, albeit deceased, parents—a wet-nosed Adam and Eve frozen in a liquid nitrogen Eden, coupling in a test tube and condemned to replicate themselves forever.

More than 100 million 'doses' of sperm are sold each year. Frozen semen have become a major export item in the tied-aid packages of industrialized countries. Assuming the cost of ET can be brought down from its present high of $350 an embryo, mass genetic erosion of bovines will be assured even in areas of diversity in Asia and Africa.

Is the Third World seen as a viable market for such exotic techniques? While participants were talking together in Bogève, *Genetic Engineering News* was interviewing the head of University Genetics, Dr Walton, on the very subject. According to the interview, embryo transfer could prove to be a 'major breakthrough' for the Third World. A 'poor' cow in China produces 1,000 pounds of milk a year whereas a 'poor' American cow manufactures 10,000 pounds. University Genetics is using in vitro fertilization techniques and hopes to bring the price of embryos down to $50 or less.[22]

> You can ship cows to China, which is an expensive process or you can ship embryos. You can get 10,000 of them under your seat on the plane. Using embryo technology, delivering a female calf in China now costs $800. If you can get it to between $100 and $200, there would be a huge worldwide market.[23]

University Genetics is as good as its word. On December 3rd, 1987, as Asian NGOs gathered for a workshop on biotechnology and genetic diversity in East Java, the Indonesian Government signed a US $9 million contract with the company to buy Holstein dairy cow embryos from the United States. The contract was partly funded by the US Department of Agriculture. A second contract will ship embryos to Gansu—China's fifth largest province. University Genetics is also making a bid for the Latin American market through showings at a trade fair in Colombia.[24]

Although superior in one or two characteristics important to industry in the final decade of the 20th century, the remaining genotypes will not meet the needs of the poor now—nor of any of us a few decades into the next century. Moreover, the narrowing genetic base will make the herds more vulnerable to stress and disease. More drugs will be used for their upkeep. The meat will contain more drug residues. So will the milk. The veterinary costs will be reflected in the costs of meat and milk.

The good folks at University College, Dublin, would not agree with our assessment. Together with a private Irish concern known as Masstock, the researchers claim to have slashed ET costs by 90 per cent by rescuing ovaries from slaughtered cows taken from abattoirs. The process allows them to capture 20 or more ova from each ovary and dramatically lower costs. According to Masstock, this 'life-after-death' technique is 'embryo transfer for the masses'. A marketing concern, Ovamass, has been established to sell the mass-produced embryos around the world. Among the first markets: Kenya and Pakistan. Masstock describes the technology as biotech's answer to the Ford Model T.[25] They may well be right. Henry Ford used to say that you could have any colour Model T you wanted—as long as it was black.

Late in the summer of 1987, the London Zoo was using ET to rescue the last captive gaur (a wild bison native to the Indian hill forests) from extinction by inserting an embryo from the one remaining female into the womb of a Friesian cow. This is one way in which embryo transfer should be used. The technique—rather than generating sameness—could be used to preserve and create diversity.[26] Even here, however, the Third World could and should explore other less complex and expensive options. Even as British scientists were using ET to save captive gaurs, Malaysian scientists reported the successful crossing of the gaur with domestic cows on a government research station. In their first six months, the hybrid offsprings' growth rate was 70 per cent greater than their tame cousins and Malaysian researchers were optimistic that both sexes would be fertile.[27] Both ET and traditional technologies have their place.

Not satisfied with jazzing up their genes, the dairy industry has also looked to their end product—milk. Market growth is achievable in several ways. First, cows could be induced to give more milk or to become more efficient at converting feed into milk. Second, it may be possible to extend the marketability of dairy products. The industry has used the new biotechniques to do both.

Bovine growth hormone

The first strategy, increasing milk yield, is embodied in the Bovine Growth Hormone (bGH). The US Government's Office of Technology Assessment predicts that bGH will increase US milk production by 3.9 per cent per annum by the year 2000.[28] This, they point out, will lead to a substantial decline in the number of dairy farmers. Some studies suggest that the number of farmers will drop by between 25 and 30 per cent. Despite outcries from both farmers and consumers, bGH is expected to be in the marketplace by 1991.[29] A Sandoz subsidiary is building a bGH facility in Kundl, Tirol, Austria, in anticipation of regulatory approval in the EC. The Bogève meeting was offered a case study of the impact of Bovine Growth Hormone in the North American context (see pages 142-44).

Since Bogève, opposition to bGH has spread widely in Europe in the face of governmental initiatives there to make the product available to the dairy industry. Farmers in both Europe and North America are discussing the need for a full consumers' boycott of not only bGH milk but of the marketing enterprises.

Meanwhile, and despite major technical hurdles, biotech companies have begun to test bGH cows widely in Africa, Asia and Latin America. The first real battle over agricultural biotechnology will probably be fought over bovine growth hormone.

> The scene is a dusty western cow-town. Comedian Bob Hope saunters into the local saloon, bellies up to the bar and orders, 'Milk'. As the tough-looking cowboys turn to stare, Hope adds, '...in a dirty glass!'

Spiked milk

Of course the logical solution to milk overproduction is overconsumption. Find new markets. Take one of nature's more perfect products and make it 'different'. The folks at DRINC (Dairy Research Inc. in the United States), for example, are pushing carbonated milk and fighting for a slice of the multi-billion dollar soft drink market.[30] They still have a shelf-life problem —the bottled milk has to remain cold—but biotechniques are allowing the industry to hope for a 5 per cent share of the overall beverage industry.

So far, the carbonated product shows all the signs of success. Industry spokespeople claim it tastes like an ice cream soda without the ice-cream. Pour it and it bubbles up like beer. Shake it and it spurts around the room. With still a year or more before carbonated milk hits the corner store, DRINC is hard at work developing a whole new galaxy of flavours. Among

those being tested: chocolate, coconut, pina colada and—for the benefit of Bob Hope—whisky.[31]

If you don't like your milk carbonated, how about hydrolyzed? Biotech research undertaken by Sumitomo Chemicals in Japan has led to a commercially acceptable means of producing hydrolyzed milk for world export. This is milk whose lactose content has been partly digested, so that even people with lactose intolerance can drink it.

Since June of 1985, the Drouin Cooperative Butter Factory near Melbourne has used the Sumitomo technique to disgorge 4, 000 litres an hour of almost universally digestible milk. The Sumitomo process breaks down the lactose into digestible sugars at about a third of the cost of earlier methods. A large portion of the world's adult population is presently unable to drink milk due to lactose intolerance.[32]

According to the Australian Information Service, hydrolyzed milk is the answer to a dairyperson's prayers. The massive surpluses already available in that country and elsewhere can now be targeted in foreign aid packages to the Third World in the form of skim-milk powder, whole milk, yoghurt, and even ice-cream. Protein and calcium deficiency problems can be reduced. A great step forward for world nutrition.

The alternative view is that Northern (and Australian) surpluses will be 'dumped' in the Third World (sometimes in lieu of quality aid) and will inevitably find their way into inappropriate forms of infant feeding, affecting people's culture and eating traditions as well.

Concerned organizations such as IBFAN (International Baby Food Action Network) which spearheaded the drive to establish a Code of Conduct on the marketing of infant formula through the World Health Organization may now find themselves doing battle not against formula but against milk itself. The problems of price, dilution, unsanitary water, and storage still remain. Cow's milk is even less appropriate for infants than the better quality formulas. The risks, in fact, increase.

Whatever the limitations, the demand in the Third World will almost certainly grow with hydrolyzed milk. Consumer biases will be bent away from more traditional and less expensive sources of protein and calcium toward the high-priced import. Scientific research—which should help to increase the yield and availability of local sources of nutrition—will be

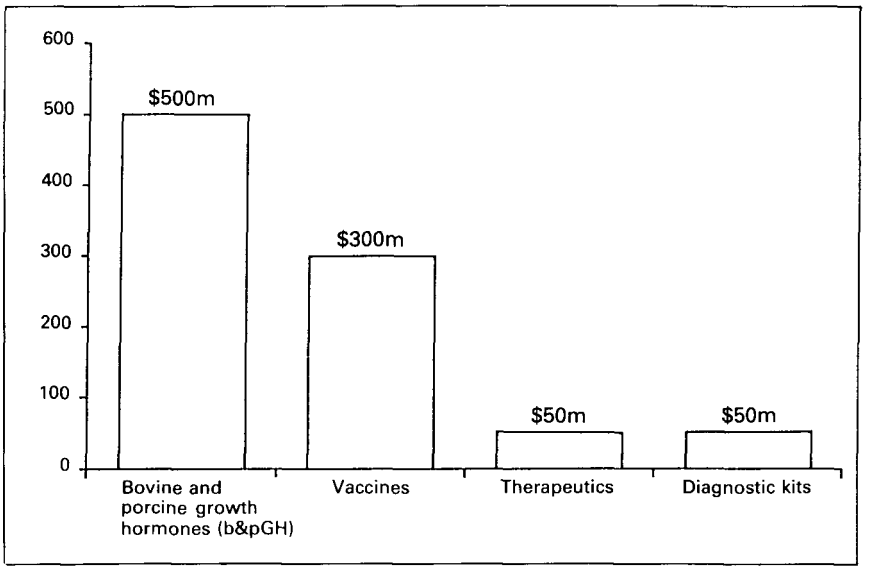

Figure 7 Livestock biodrugs market in 1990 (US $ million)

directed to other goals. Ultimately, industry and governments will move to strengthen the local dairy industry. Then cometh the whole alphabet of initials—ET, AI, bGH all lined up to make new demands on the rural infrastructure and economy—demands which will be served with imported, dependency-creating inputs. The biotech package will convert land to pasture, subvert other foods, and add to the disparities between the farmers who can afford the new milk production technologies and those who cannot.

Animal pharm farm

There is a tendency to think of biotechnology as fundamentally natural. Natural processes are simply being stimulated or expressed. This can hardly be said of the impact of biotech on the cow—or on the dairy industry.

Although the bovine growth hormone may exist naturally, the effect of the administered doses has its downsides. bGH-fed cows, for example, tend to 'overheat'—a problem which may delay their introduction into tropical countries—causing numerous side-effects including respiratory problems. Upjohn, a leader in bGH research, has not ignored this window of opportunity and is patenting new biotech drugs that will treat the respiratory ailments.[33]

Still more severe is the bGH problem of mastitis. Big milk producers wind up with big udders and the mass production strategy of bGH puts a huge strain on that part of the anatomy.

Another bGH company, American Cyanamid, is patenting new enzymes to

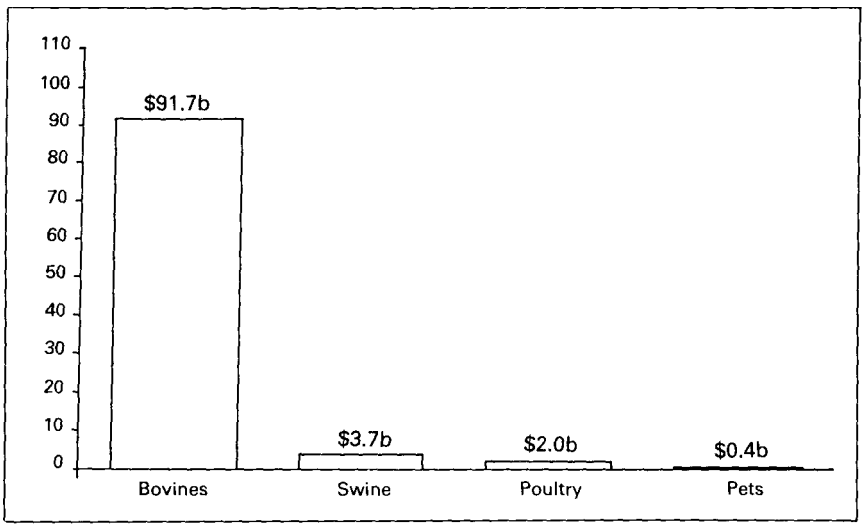

Figure 8 World cost of animal diseases: projected biodrug market (US $ billion)

meet the burgeoning new demand for drugs. Given the quantities involved, Cyanamid has taken some pains to assure us that the new drugs are digestible for humans and have no negative side effects for milk drinkers.[34]

The total market for veterinary medicines and animal diagnostic kits is substantial. Estimates for the short-term range between $900[3][1] and $1100 million.[36] There is a half billion dollar market for bovine and porcine growth hormones and at least another $300 million for animal vaccines. Diagnostic kits and therapeutics combine for another $100 million.

Losses due to livestock diseases (cows, pigs and poultry) approximate $100 billion a year worldwide. Farmers have good reason to be interested in any new drugs that might cut these losses. Over 90 per cent of the losses involve cattle.[37]

More than half the losses in bovines come from foot and mouth disease followed by mastitis, shipping fever, parasites and scours (extreme diarrhoea). The biodrug companies have focused on these five economically important diseases almost to the exclusion of others.[38]

Despite the commercial opportunities in hydrolyzed and carbonated milk, the dairy industry still anticipates gross overproduction. The industry is at work on a spreadable butter with half the calories, fats and cholesterol of margarine. They are also brewing up a high-calcium milk. One glass would meet more than two-thirds of the daily calcium requirement.[3]"This will help but it will not be enough.

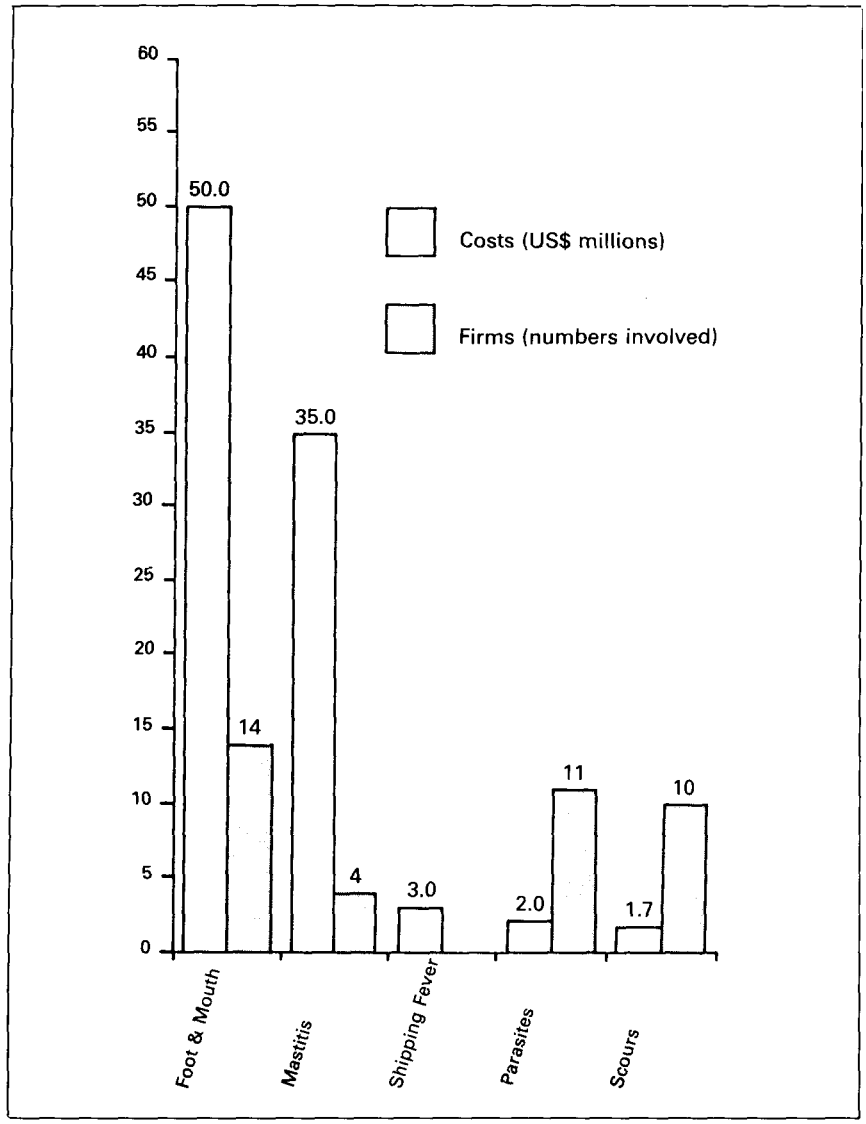

Figure 9 Top 5 bovine diseases: costs and number of R&D firms involved

Could milk have other markets? Yes, indeed! According to Dynatech (a small US biotech enterprise), the whey by-product of cheese production can be used to de-ice American highways. Experiments in New York State have proven that a warm whey bath does wonders for the roads, cutting back on road repairs while reducing auto body corrosion.[40]

But cow's milk can aspire to yet loftier goals. At the end of 1987, Integrated Genetics succeeded in transferring human genes to mice so that an otherwise scarce heart disease drug known as 't-PA'[41] found in small quantities in

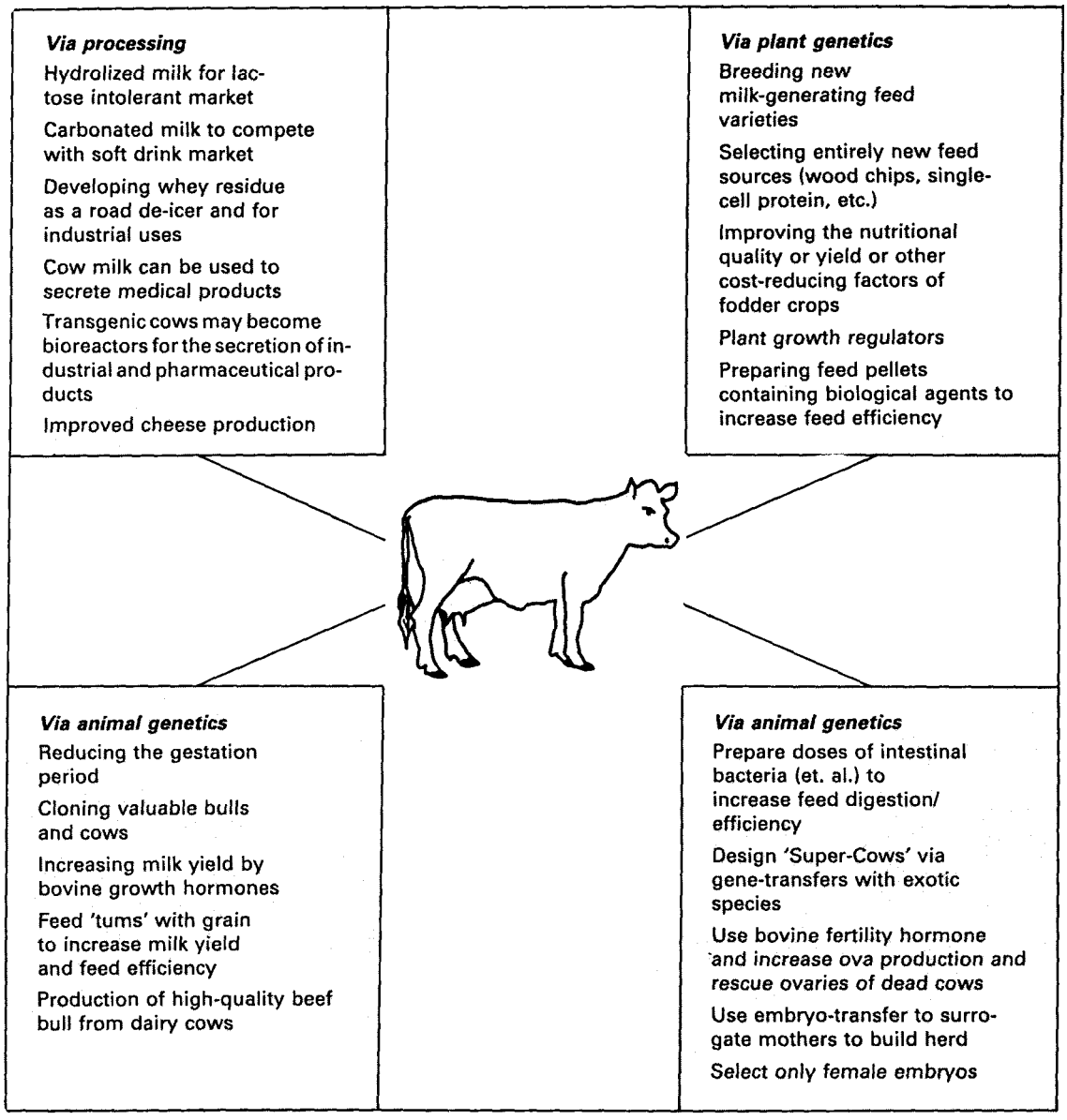

Figure 10 Biotech strategies for increasing productivity of corporate cows

people could be secreted in mouse milk. As *Biol'Technology* magazine was quick to point out, 'This opens the door to large-scale molecular farming of valuable (human and other) proteins from transgenic domestic animals'. Farmers who have reached their milk quotas can switch to 'milking' drugs instead. So long as ruminants can keep their start-up and maintenance costs below those of bioreactor cell culture facilities, the dairy industry has a new market.[42] By September, 1988, the same magazine was headlining the era of

'micro-livestock' and predicting a rosy future for cows, pigs, sheep and chicken as living 'bio-reactors' for a whole range of new medicinal and industrial products. The livestock have become feedstock!

It is instructive, perhaps, to note that of the 63 biotech enterprises identified by the US Office of Technology Assessment as being engaged in animal research, 42 are also using biotechniques in the pharmaceuticals industry. This is only logical. The techniques that work on cows or pigs may also work on us. Molecular Genetics noted the advantages of experimenting with animal veterinary medicines when they first moved into the business. It takes 12 to 18 months to have an animal drug approved compared to 5 to 7 year delay for approving human drugs.[43]

If biotech can clone a cow, can we be far behind?

All animals are equal. Some are more equal than others.
George Orwell, Animal Farm

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Case Study

Bovine Growth Hormone and the Dairy Industry

Product: Bovine Growth Hormone (bGH) or Bovine Somatotropin (BST)
Purpose: Designed to dramatically increase milk production in dairy cattle
Countries affected: USA and Europe initially
Corporations involved: American Cyanamid, Eli Lilly, Monsanto, Upjohn and Sanofi (France)
Impact: Drop in milk prices, loss of 25-30 per cent of US dairy farmers, changes in cropping patterns, narrowing of genetic base of dairy cattle
When: Product now awaiting approval by US Food and Drug Administration; could reach market in 1989

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What is bovine growth hormone?

Bovine growth hormone (also known as bovine somatotropin) is a naturally occurring protein which has the potential to dramatically boost milk production in dairy cattle. If granted approval by the US Food and Drug Administration, it will become one of the first products of agricultural biotechnology available for commercial sale—possibly by 1989.[1]

Bovine growth hormone (bGH) is produced naturally in miniscule amounts in the cow's pituitary gland. It is one of the factors that regulates the volume of milk production. Using recombinant DNA technology, scientists have successfully isolated the gene which is responsible for producing bovine growth hormone, and they have transferred that gene to ordinary bacteria cells. Using fermentation technique, the altered bacteria can be mass-produced and the growth hormone (produced by the bacteria) can then be isolated and purified for large-scale, commercial use.

Bovine growth hormone is being tested on 30—40 cows at Cornell University. Daily injections of the hormone at the rate of 44 milligrams (approximately one-thousandth of an ounce) per cow have demonstrated increases in milk production between 23 and 41 per cent, with feed efficiency improving 10-20 per cent.[2]

Cows receiving daily doses of bGH will require additional feed to sustain increased milk production, although tests show that, overall, cows will produce more milk per pound of feed. At the farm level, increased feed requirements will result in additional crop production and/or greater off-farm feed purchases. Studies at Cornell University estimate that, depending on feed management and the individual cow's response, the cost of concentrate will increase by 30 to 110 per cent.[3]

Who stands to profit from bGH?

Four major agrichemical corporations, including American Cyanamid (Wayne, NJ), Eli Lilly (Indianapolis, IN), Monsanto (St. Louis, MO) and Upjohn (Kalamazoo, MI) have invested heavily in the development of bovine growth hormones, and are likely to compete for a piece of the market once the product is available for commercial sale.[4] These companies are currently conducting field tests on bGH products in the United States and Europe. Sanofi, a French subsidiary of the Elf-Aquitane oil group, is also developing a bGH product.

Monsanto claims that it has spent in the 'tens of millions' developing its product and estimates that the worldwide market for bovine growth hormone could reach $1 billion per year.[5] According to Robert P. Mooney, manager of American Cyanamid's animal product division, 'Even in the European system where you have quotas, there will still be a market [for bGH] because it allows the farmer to produce a pound of milk at lower cost'.[6] Mr. Mooney also foresees the marketing of bGH in milk-deficit countries such as Israel.[7]

However, the European market is by no means certain. The European Economic Community has released a study on the effects of bovine growth hormone in Europe. In this context, Prof. G. Piva, Institute of Science and Nutrition, Catolica University of Piacenza, recently made the following comments ab-

out the use of bGH in Italy. Dr. Piva predicted that Italian cattle herds would drop by 500,000 head, with a parallel 'drastic decrease' in the number of farms. For the dairies that remain, gross revenues would increase 5 to 30 per cent. The number of cattle reared would be down 16 per cent and total fodder cultivated reduced by 10 per cent. He concluded that, 'The scenery of Italian livestock resources is fated to change radically in the next ten years'.[8]

Monsanto has decided that the best defence is a strong offence. They are aggressively pursuing markets in Eastern Europe as well. Monsanto Co. is exploring a future market for bovine growth hormone in the Soviet Union. It has also been disclosed that scientists in Leningrad are using bGH experimentally on 150 cows to determine whether the product can increase milk production under Soviet dairy management. According to Monsanto, 'Recombinant porcine growth hormone also represents a significant market opportunity in Russia'.[9]

US taxpayers are footing the bill for a portion of the research and development of bGH. Approximately $1.2 million in federal funds support basic and applied research on bGH. Another $2.5 million in private funds are supporting research at publicly supported schools in the US agricultural research system.[10]

The development of new technology to dramatically increase milk production comes at a time when the United States is already plagued by massive dairy surpluses. The US Department of Agriculture's price support policies have led to a government-owned stockpile of more than 3 billion pounds of dried milk and cheese and a federal dairy programme which has cost more than $1 billion annually in recent years. In April, 1986, the government launched a $1.8 billion surplus reduction programme which pays farmers to slaughter their dairy cows or sell them for export.[11]

What impact on the US dairy industry?

Widespread adoption of bGH will undoubtedly cause severe economic dislocation and accelerate the trend toward fewer, larger dairy farms. Surveys of dairy farmers in the US reveal that 80 to 90 per cent of dairy farmers will adopt bGH within 3 years after it becomes available for commercial sale.[12]

Bovine growth hormone is already being promoted as a product which 'requires no capital investment' and will be 'particularly important to the small family farmer'.[13] In reality, bGH is only one part of a sophisticated, capital-intensive package, which will require substantial long-term investment:

> ... the introduction of bovine somatotropin will likely be accompanied by computer programmes that optimize feed nutrient levels at the least economic cost. Computerized feeding stations, which tailor the feed mixture and amount of feed provided to an animal's unique performance characteristics, will also be necessary, as will automated environments that reduce the stress to the animal from abnormal weather conditions.[14]

Large dairy farmers will be the first to adopt bGH, and the most likely to survive a major restructuring in the US dairy industry.[15] Commercial sale of bGH will push milk prices down and may force 25 to 30 per cent of the nation's dairy farmers out of business. According to Cornell University agricultural economist, Dr. Robert Kalter:

> We are estimating that within the first three years of product introduction milk prices may need to fall 10—15 per cent, and the number of dairy farms may decline by as much as 25 to 30 per cent to restore equilibrium.[16]

The widespread commercial adoption of bGH will also affect livestock numbers and land use changes. By the end of this century, the size of our national dairy herd is expected to decline by 30-40 per cent if growth hormone products are widely used.[17] According to a Cornell University study, 'The requirement for less producing cows and changes in cropping patterns may ultimately result in land use changes throughout the agricultural sector'.[18]

Narrowing the genetic base

Virtually all tests of bGH have been conducted on Holstein dairy cows, the most efficient and produc-

tive milk breed. Holsteins now represent well over 90 per cent of the US dairy cattle population and will undoubtedly be the breed selected for commercial application of bGH and other technologies designed to enhance milk production. Adoption of bGH (in combination with a reduction in the number of dairy cattle) will thus facilitate a narrowing of the genetic base of dairy cattle in the US and abroad.

Genetic diversity is vital to the future of modern livestock production. Minor dairy breeds, for example, carry invaluable disease and pest resistance and many other qualities (e.g. hardiness, high butterfat content, better roughage conversion) which Holsteins may not possess. Minor breeds must be maintained in sufficient numbers so that their unique genetic material is available for future breeding programmes.

Vocal opposition

In April, 1986, a coalition of groups opposing the licensing of bGH petitioned the US Food and Drug Administration to prepare an environmental impact statement on bovine growth hormone. Those seeking to delay and eventually halt the licensing of bGH include the Wisconsin Family Farm Defense Fund, the Foundation on Economic Trends, the Humane Society of the US, and Douglas LaFollette, secretary of state in Wisconsin. According to one Wisconsin dairy farmer representing the coalition:

> It is legitimate to question whether technological advancements are social progress ... Demand for milk will not increase and we already know that the government under the new price support programme will not buy the surpluses. Something will have to give ... When 20 per cent of the farmers are forced out and another 20 to 25 per cent will be impacted and pushed toward going out, who is benefiting from the use of bGH?[19]

More to come

Bovine growth hormone is only the first on a long list of biotechnology products which are now being developed to enhance growth and stimulate productivity of livestock. Similar products are also being developed for beef cattle, swine and poultry. Like bGH, these products will have a major impact on feed requirements, farm prices, land use, and ultimately, on the survival of small and middle-sized family farmers. The widespread use of 'superior' breeds is likely to narrow the genetic base of the US livestock breeds even further.

Notes

1. *Agricultural Genetics Report,* July/August, 1986.
2. *Bio/Technology,* Vol. 4, May, 1986.
3. Kalter, Robert J. et al., *Biotechnology and the Dairy Industry: Production Costs, Commercial Potential and the Economic Impact of the bGH,* Dept. of Ag. Economics, Cornell University, Dec., 1985.
4. *Agricultural Genetics Report,* July/August, 1986.
5. *Chemical Week,* April 23, 1986, and *Bio/Technology,* Vol. 4, May, 1986.
6. Telephone conversation with Mr. Mooney, November 10, 1986.
7. Ibid.
8. *McGraw-Hill's Biotechnology Newswatch,* Vol. 8, No. 1, January 4, 1988, p. 4.
9. *Biotechnology Newswatch,* January 4, 1988, p. 4.
10. National Agricultural Library, pre-publication of 'Special Reference Brief on Bovine Growth Hormone', 1986.
11. *Farmline,* USDA, Economic Research Service, April, 1986.
12. Kalter, Robert, J., et al., op. cit.
13. Robert P. Mooney, Manager of American Cyanamid's animal products division, in testimony before US Congress, June 11, 1986.
14. Kalter, Robert, J., 'The New Biotech Agriculture: Unforeseen Economic Consequences', *Issues in Science and Technology,* Fall, 1985, p. 130.
15. Ibid., p. 128 and 131,
16. Ibid., p. 128.
17. Kalter, Robert J. and Magrath, William, *'Biotechnology: Economic Challenges and Opportunities for Agriculture',* N.Y. State Agriculture 2000 Project, Cornell University, no date.
18. **Ibid.**
19. 'Dairy-Output Drug Opposed', *The Washington Post,* April 2, 1986.

On the High Reef of the Human Dawn?

Biodrugs: The 'Clean' Revolution

Say what we will about the risks of releasing genetically-altered organisms into our fields or about the economic impact of sudden industrial change, most of us agree that the new biosciences could make an important contribution to human health. The industry tells us to expect cheaper medicines with fewer side-effects; new vaccines and cures for virtually every known ailment. Unlike the other areas of biotechnology, the medical revolution is regarded as the 'Clean' Revolution. Nevertheless, this Clean Revolution still prompts some of the mix of Socioeconomic and technological concerns that its agricultural counterpart—the Green Revolution—had before. At Bogève, Jiraporn Limpananont led our discussion over the pharmaceutical aspects of biotechnology and provided some of the data incorporated below. Martin Abraham, Eva Lachkovics, Mira Shiva and Vandana Shiva also contributed greatly to the discussion.

> In you two lineages that had run parallel
> met where the cradle both of man and light
> rocked in a wind of thorns.
> Mother of stone and sperm of condors.
> High reef of the human dawn.
>
> *Pablo Neruda,* The Lessons of Macchu Picchu

Improving health standards in the South is a relatively simple matter: a large daily dose of clean water and clean food will do the most. Better sanitation and waste disposal will also do wonders. Finally, increased access to essential medicines and medical advice is important. In other words, the 'miracle drug' urgently needed in the Third World is a cure for poverty. Modern medical science can—and does—offer tools that help. Armed with new biotechnologies, the medical community can do even more.

In fact, the potential is dazzling. If ever there is a place to believe in 'silver bullets' or technological 'fixes' it is in the health sciences—the mass immunization programmes and test kits that let us dream of a safe childhood and a robust old age for all the world's people.

But there are no technological fixes. Biotechnology may give us medicine, but medicine—even good medicine—does not equal health.

Unlike agriculture, the health issues are so intensely personalized for all of us that society tends to suspend its critical analysis when it comes to these issues.

This is dangerous. Biotechnology is not a cure for poverty. Neither are the

The Poverty Context: The Situation in Thailand

The example of Thailand can illustrate some of the Socioeconomic impacts of modern medicine on the health of the people:

1. Forty percent of the 1986 health budget was spent on pharmaceuticals (27,000 million Thai Baht). This expenditure is expected to increase by 10-15 per cent annually. An analysis by the Drug Study Group suggested that not more than a third would have been needed and the rest of the budget could have been allocated to the priority need of preventive health care.

2. About 25,000 registered formula drugs are available in the Thai market—a hundred times more than would be necessary according to WHO. To aggravate the situation, they are available without a doctor's prescription.

3. Approximately 95 per cent of raw materials for pharmaceutical end production in the country are imported, many of them overpriced due to transfer pricing methods.[1 2]

4. Like other Third World countries, Thailand experiences double standards applied by the drug industry, such as dumping—the marketing of drugs banned or not yet approved in industrialized countries (e.g. clioquinol and dipyrone), and the provision of misleading drug information by the companies and others.

Health Action International (HAI) has analysed these situations in detail. Some of this work is discussed in *Development Dialogue* 1985: 2 (Another Development in Pharmaceuticals). It shows the inadequacy of the pharmaceutical technology in solving social problems as well as the great potential for abuse. Modern medicine treats symptoms impressively. But it also diverts attention and resources from the priority of prevention of ill-health. WHO'S euphoric slogan of 'Health for All by the Year 2000' cannot be brought about by technology, not even if it were in the hands of the most well-meaning people.

new techniques neutral. Huge sums of money and very bright minds are now being focused on pharmaceutical biotechnologies. The opportunity cost must be examined closely. That money and those minds are not working on clean water, food and housing.

Humanity must consider its options. The new technologies are also costly. Who will pay? Can poor people afford them? What will not be done? Who will profit?

From reading the press, it would seem that the first act of the pharmaceutical industry in working on biodrugs is to give its critics a frontal lobotomy. Our health is too important to allow us to suspend critical judgement. The medical issues are exceedingly complex but—even at the risk of error—the Bogève group felt it important to open a critical dialogue with medical science.

Biodrugs and diagnostics

The financial and medical opportunities offered by biotechnology are enormous. A cure for cancer? A vaccine for AIDS? Progress in either area can propel a small biotech company into the ranks of the Fortune 500. Genentech's 'Activate' heart disease drug, for example, costs US $2, 200 a dose and is probably giving health administrators as many heart attacks as it is relieving.[3] Thus it should come as no surprise that human and capital resources are being deployed at unprecedented rates.

Let's look at some of the major areas of bioresearch in health care—always bearing in mind their potential impact on the poor.

The focus of biotech companies has remained steadfast on the top markets. Industry analysts see drugs for heart disease, cancer and AIDS-related disorders as worth a billion dollars each. Diabetes is seen as a $320 million market while growth hormones weigh in at $200 million. Drugs for anaemia and kidney dialysis are lumped together for another $200 million. The market for all of these drugs is forecast at $2 billion around 1990, and $4 billion a few years later.[4]

The front-running biotech houses include Genentech, Cetus, Amgen, BioGen, and Chiron—all US-based. European and Japanese interests are definitely in the race, however. Companies like Ajinomoto and Hoffmann-La Roche, for example, have joint interests with Immunex of the United States in developing Interleukin-2, a drug that may be used against leukaemia, AIDS, lymphomas and solid tumours. One of the top heart

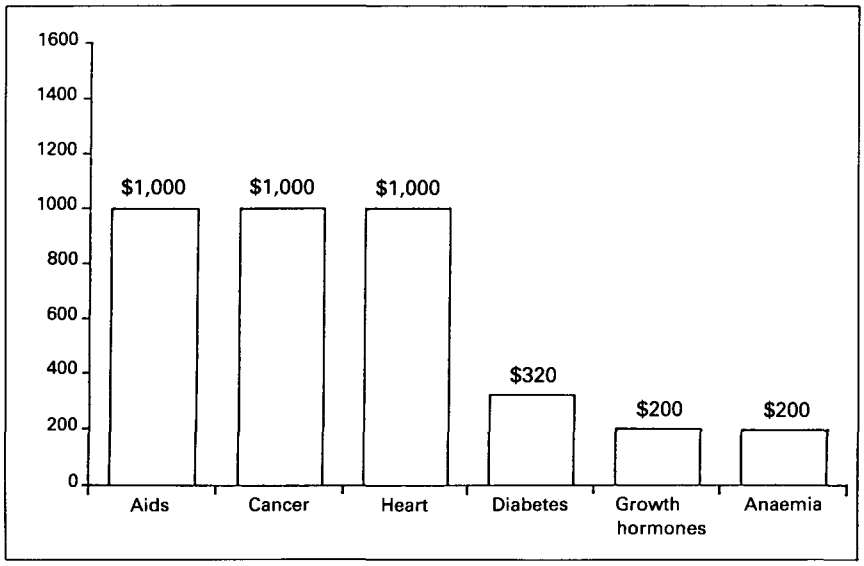

Figure 11 Biodrug development: market in 1990 and beyond (US$ million)

drugs (known as t-PA) is being developed aggressively in Europe by Britain's Wellcome Foundation and Genetics Institute.[5] In the short run, the start-up biotech houses will do well with the new biodrugs but most observers agree that the medium and long-term belongs to the regular pharmaceutical transnationals. The largest number of patents issued by the US Patent and Trademark Office over the last few years went to major pharmaceutical companies.[6] For example, Eli Lilly led all firms in 1986 with 28 US biotechnology related patents. The top ten foreign companies receiving US biotechnology-related patents (including everything, not only pharmaceuticals) in 1986 were all based in the North. With such concentration already underway, few of the new biotech companies other than the largest, like Genentech, are given much chance of surviving in their current form.

The immediate money, however, lies in the development of diagnostic kits through the use of monoclonal antibodies (MAb). The 1990 market is valued at $1 billion. Because these kits are used outside the body they do not face the same kind of regulatory pressures as drugs. They are cheaper to develop and they can reach the market faster. Of the billion, $450 million will come from tests for sexually-transmitted diseases including AIDS and herpes. Pregnancy tests will count for another $100 million. Diagnostic kits for heart and cancer will bring in $300 million. By 1990, kits for other infections will be worth $250 million.[7]

Among the most prominent diagnostic tests based on monoclonal antibodies are AIDS tests. An AIDS diagnostic kit could make a major contribution in the Third World if the present medical infrastructure and

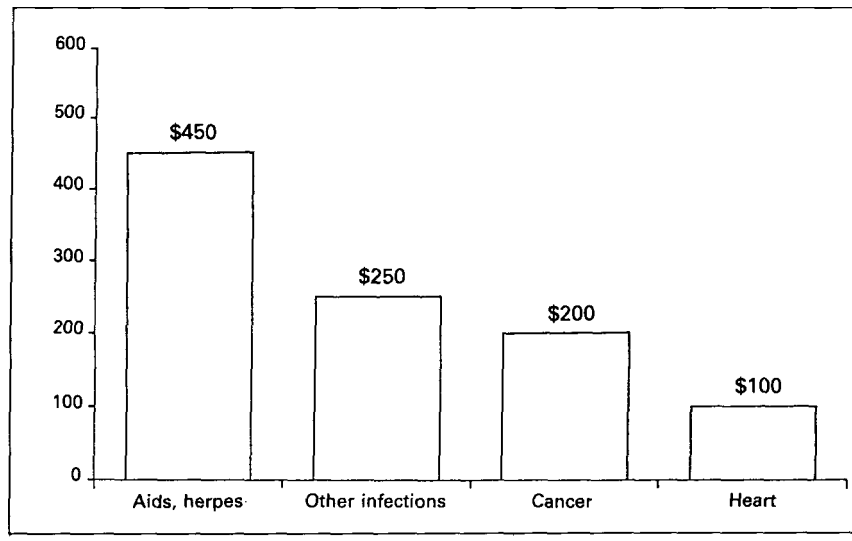

Figure 12 Bio-diagnostic kits: the near term market (US $ million)

potential financial resources were available to allow it. At the moment, the market for AIDS kits is US $50 million but this is expected to jump, by 1991, to anywhere from US $105 million to US $220 million.[8] Although the Third World is not excluded in market calculations, biotech companies see their future in Europe and North America.

Given the ease of meeting government approval requirements and the relative simplicity of the technology involved, we will be awash in test kits by the mid-nineties and some of them will have some value for the South. This is especially true because—South or North—the products that will prove the most saleable will be those that can be handled without extensive training and outside of hospital conditions.

Since they offer early detection of health problems, diagnostic kits don't come with side-effects and they could improve health while reducing general medical costs. In an award-winning series of articles in 1987, however, the *Wall Street Journal* provided us with another interpretation. More than 19 billion diagnostic procedures involving 1, 380 kits or tests were run in the United States in 1987. With an average of 80 tests per citizen, the cost to the American health system was about US $100 billion—or about one-fifth of the country's total health bill. Twenty billion dollars worth of these tests are judged unnecessary according to *Time* magazine and the error rate for the remainder can run between 20 and 40 per cent for common but important procedures like pap tests (for cervical cancer).

Few of these tests were derived from the new biotechniques, however.

Biotech companies can argue that their kits will be safer and cheaper than those already on the market. They may have a point. But, in the same way good health has little to do with medicine, biotechnology has little to do with good doctoring. The overuse and abuse of tests are because doctors often have their own in-house laboratories and can pick up extra money by running more tests and, as well, because laboratories are paid by the test meaning that overworked technicians may scan more than a hundred slides a day in what *Time* calls 'Pap-mills'.[9]

Further, anti-body research invites full-line pharmaceutical houses to develop 'package' deals for doctors and patients much in the same way the same companies devise package inputs of seeds and chemicals for farmers. Celltec and American Cyanamid, for example, are putting together such a package for diagnosis, treatment and prognosis of tumours. Squibb is said to be preparing another package of cardiovascular products.[10] As Surendra Patel advised us in Bogève, the South has a long and painful experience with tied technological packages.

Third World health officials can argue, quite convincingly, that they have all the diagnosis they need—their patients are suffering from poverty—and the solution is not more tests.

Vaccines: for the poor?

The real area of biotech research that appears to have the concerns of the poor in mind is the creation of new vaccines. But history suggests vaccines tend to be most available to those who need them the least. The great victory over tuberculosis and many early childhood diseases were victories won in the North. Only the smallpox vaccine made it to the South thanks to the concentrated work of the World Health Organization.

Developers of the new biotech vaccines claim to be creating more effective drugs with fewer side-effects and—almost for the first time—vaccines that could be of direct benefit to the health of people in Asia, Africa and Latin America.

Fourteen new vaccines are expected to be commercially available by 1990. Among them are drugs to resist Malaria, Yellow and Typhoid fevers, Hepatitis A and B and Influenza. Another nine vaccines are anticipated to make their debut about 1996, including new drugs for Leprosy, Cholera and Chicken Pox. Eight more vaccines, including a defence against Schistosomiasis and Shigella (dysentery) will come on stream around the year 2000. Will this help the poor?

Table 12 Biotech vaccines and markets[11]

Disease/Condition	Market		R&D Groups				
	Industrialized countries	Third World countries	Private enterprise	Public institute	Cases (million)	Deaths (thousands)	Demand
Early 1990s							
Herpes Simplex 1 and 2	*		9	9	–	–	–
Rotavirus			–	–	–	–	–
Pertussis (whooping cough)		–	8	16	–	–	–
Hepatitis A			5	2	5	14	Low
Parainfluenza			–	–	75	125	High
Cytomegalovirus		–	2	4	–	–	–
Meningitis			–	–	0,3	35	Some
Hemophilus Influenza type B		*	–	–	0,8	145	High
Malaria	+	*	11	27	150	1500	Travellers
Typhoid Fever			4	10	30	581	Travellers
Rabies	+	*	2	10	0,035	35	Low
Influenza viruses A and B		–	9	25	–	–	–
Hepatitis B			33	53	5	822	Medium
Yellow Fever	–		–	3	0,085	9	Travellers
Totals	9(12)	10	83	159			
Mid-1990s							
Coccidioidomycosis (valley fever)	*	–	–	–	–	–	–
Chicken Pox		–	–	–	–	–	–
Streptococcus group B	+	–	–	–	–	–	–
Cholera	–		4	4	7	122	Travellers
Leprosy	*		2	10	1	1	Low
Respiratory Syncytial virus		*	–	–	65	160	High
Streptococcus group A	+		–	–	100	10000	Medium
Japanese Encephalitis virus	-		–	–	0,042	7	Travellers
Streptococcus Pneumoniae	+		–	–	–	–	–
Totals	3(6)	6	6	14			
Late 1990s							
Gonorrhea		–	2	6	–	–	–
Leishmaniasis	–	*	–	–	–	–	–
Schistosomiasis	–	*	4	8	–	–	–
Shigella (dysentery)	+		–	–	250	654	Low
E. coli enterotoxins	+		–	–	630	775	Low
Trypanosomiasis	–		–	–	–	–	–
Filariasis	–		–	–	–	–	–
Denque	+		–	–	35	15	Travellers
Totals	1(3)	7	6	14			

* Identified by Industry as relevant
\+ Identified by RAFI as relevant

According to Manny Ratafia, president of the Technology Management Group (a consulting company that has studied the impact of biotechnology on health), 19 of the vaccines, are almost exclusively for Third World problems.[12]

Our own analysis argues that at least 12 of the 14 vaccines due around 1990 will be of major interest to and for primary use by the North. Although there are already vaccines for Meningitis in industrialized countries, the vaccines cannot be administered to infants under the age of two—ruling out protection for the most vulnerable age group. A new vaccine that could be used for babies would have a viable commercial market among worried parents. Similarly, no popular rabies vaccine for humans is available in the North. Farmers and other high-risk groups would be a ready market for a truly effective drug.

Among those illnesses targeted by drugs coming on stream by the mid-90's, the Technology Management Group sees Streptococcus as a Third World problem. This is news to the thousands who regularly encounter this ailment every year in Europe and North America. Even a leprosy vaccine would find a reasonable market as an 'Orphan Drug' in the North.[13] Of those vaccines expected at the turn of the century, at least two that industry sources argue are for the Third World will find a comfortable niche in the North. Shigella (dysentery) and E. coli enterotoxins are both reasonably common in hospitals, nursing homes and military barracks. Their commercial success is assured.

The flagship of the Third World vaccines is for Malaria. Eleven private companies are at work—second in numbers only to Hepatitis B research and, although figures are not known, AIDS. (Predictions for the world market for AIDS vaccines, drugs and diagnostic kits run as high as US $3 billion by 1996 with 73 companies at work on diagnostic kits alone.[14]) Two billion people are exposed to Malaria and 300 million are afflicted. The annual death toll is estimated between two and four million.[15] AIDS will have to work long and hard to catch up to this old and unromantic killer. With sufficient foreign aid and local government support, industry suggests that the short-term market for a Malaria vaccine could reach one billion doses.[16] Whatever the cost, the eradication of Malaria as a world health threat would amount to a major contribution to the well-being of humanity.

But even a Malaria vaccine is not so obviously going to be used by the Third World. Who, after all, takes the preventative drugs for Malaria now? Almost exclusively, the local elite and foreign visitors. Who will buy the

new vaccine? For which group of customers is the drug to be priced? Will vaccines for Typhoid and Cholera be treated differently?

In fact, fully two-thirds of the vaccine research programmes underway in the private sector focus on four diseases, Hepatitis B, Malaria, Herpes and Influenza. The primary market for all four vaccines will be First World buyers.

Other significant research programmes are looking at exotic Third World diseases like Dengue fever, Plague and Rift Valley fever. Interest in these diseases is coming from the military and relates to biological warfare. (Note the chapter on this important topic on pages 194-211.)

If we are skeptical of who will benefit from the development of new vaccines, history gives us reason. The books record the efforts of Finlay to track yellow fever in Cuba[17] and tales are told of the heroic death of Clare Louise Maass in submitting to the bites of the culex mosquito in the cause of science.[18] Rather than developing vaccines and cures for tropical diseases in order to help the poor, the poor have been used as guinea pigs to test vaccines that would eventually help the rich. The ethics of the original Cholera vaccine tests in India in 1893 and for Plague during an epidemic in Bombay in 1896 have been much debated.[19]

This is not just ancient history. From Singapore to India to Argentina, the pharmaceutical industry needs to test its new biodrugs on people before risking the enormous costs of clinical trials and the whole regulatory maze of the US Food and Drug Administration. Access to biodrugs as guinea pigs does not equal access to good health.

Immunization versus mutation

Indeed, the whole history of vaccination campaigns is troubled. Diseases don't stand still. They tend to mutate. In 1796, Hufeland wrote *Macrobiotics or the Art to Prolong One's Life* and English physician Edward Jenner postulated that exposure to Cowpox could provide immunity to Smallpox." Thus began a long and difficult relationship between cows, people and pox. The idea of inoculation with a disease to prevent a disease has always been a little hard on the popular imagination. Efforts at mass inoculation in England in the latter half of the 19th century led to violent protests and riots.[21] In fact the only early inoculation campaign that appears to have met with success was one led by a Guatemalan doctor in 1803 that resulted in widespread Smallpox vaccinations throughout Spanish America.[22]

When the World Health Organization took on the campaign to rid the world of Smallpox, it was winding down another campaign to wipe out Malaria. Starting in 1957, WHO combined DDT and Chloroquine in a $6 billion anti-malaria effort.[23] By 1963, Sri Lanka, which had a million malarial victims at the outset of the campaign, had only 17 cases of whom 5 were imported. WHO was preparing to celebrate its great victory when the tide turned and scientists discovered that the mosquito had developed resistance to both the pesticide and the drug. Twelve years later, Sri Lanka had 600,000 'official' Malaria cases and four times that figure unofficially. The Malaria drive had boomeranged and the world is now faced with a more virulent disease than ever before.[24]

However, in the case of Smallpox, the World Health Assembly was officially informed, in May of 1980, that this disease had been eradicated. This stands today as one of the great triumphs of science and a genuine victory for the poor. WHO can be justly proud.

Biotech companies are putting a lot of faith in the Vaccinia virus—a large, easy-to-handle virus that can be frozen and dried and shipped about the world easily. It is large enough, they hope, to carry perhaps a dozen vaccines at once—a kind of 'one stop shop' for preventive medicine. Other researchers are concerned that while such an approach might make vaccines cheaper and safer, not enough is known about the ability of the human immune system to handle such a heavy dose of vaccine. Tests on chimpanzees also indicate that a second 'shotgun' blast of vaccines via the same virus is dramatically less powerful—about 10 per cent the effectiveness of the first dose. What if people need inoculation against other diseases after their childhood dose? One answer is to introduce massively stronger doses. This, however, could lead to other complications. Finally, scientists are worried that we are relying too heavily on Jenner's Vaccinia when we should be searching for other options.[25]

Yet, the message is not to quit. Humanity must always work from present knowledge. Millions of lives have been and are being saved through vaccination. But we must be humble. Biotechnology has the potential to produce much safer and effective vaccines than ever before. But biotech also works with materials which may perform in ways we do not now understand. The power of the technology to do such good, implies the potential for greater harm as well.

> In the sixties, the important technology was the one that let you have sex without reproduction. In the eighties, it seems the key technologies are the ones that let you have reproduction without sex. ...I fear I have lived too long!
>
> *Heard from a Catholic Nun during a religious conference near Dallas, Texas, 24 May, 1988.*[26]

Strongly linked to the diagnosis and treatment of disease is the effort to 'map' the (estimated) 3 billion nucleotides in the human genetic code. Originally expected to take ten years and cost $3 billion, some scientists now speculate that the genetic sequences can be tagged for one one-hundredth the price and in about a third of the time.[27] Three thousand inherited disorders stemming from genetic defects afflict human beings. There may be a genetic role in cancer, high blood pressure, schizophrenia and Alzheimer's disease to name but a few. According to Dr. Victor McKusick of Johns Hopkins University, 'Once you know where a defective gene is on the map, you can design a diagnostic test' to predict susceptibility to the particular disease.[28]

Such developments will represent a major advance for western medicine, but will be less valuable in the South where the primary health care infrastructure is still largely undeveloped.

Ethicists and medical researchers with the US National Academy of Sciences are also pointing to the 'challenging issues regarding rational, wise and ethical uses of science and technology'.[29] This is an understatement. The feminist movement has been properly critical of the biotech approach to human reproduction as being invasive, manipulative and anti-woman.

Mapping the human genome may sound impressive. More impressive is what biotechnicians can do with our genes once they have the map.

In theory, everything is possible (make your own wish list):

- in vitro 'adjustments' to ova or sperm to prevent genetic diseases;
- monoclonal antibodies targeted to attack every known disease;
- products that facilitate acceptance of transplanted tissues and organs;
- the faithful regeneration of damaged tissues or organs.

Most of the news media talk, of course, emphasizes the exotic potential for test-tube babies, surrogate motherhood and eternal youth. With the possible exception of the latter, much work is underway. Its relevance to the poor—North or South—is dubious, however. Although much of the focus

has been on conception, a number of unique experiments are under way for contraception. As interesting as these possibilities are, however, such high-tech contraceptives, if successful at all, are not likely to contribute to a solution to Third World population problems. The fear, in fact, is that some Third World governments may be handed biotech tools that will allow them to impose sterilization programmes on large populations.

This does not mean that the poor are without a role to play. As we have already noted, industry has not hesitated to use poor people as guinea pigs for new drugs. Gaps in national legislation have made this easy. Clinical trials have been carried out in the South to avoid stricter legal requirements in the North. For example the controversial injectable three-month contraceptive Depo-Provera was used on tribal women in northern Thailand and data for long-term effects gathered from them, which could then be used for registration applications in industrialized countries.

If legislation has not been adequate to deal with industry practices so far, it will even be less adequate to cope with the biotechnology industry. As the North is becoming more and more wary of the risks of biotechnology, one does not need much imagination to anticipate an even more intensive use of the South as a testing ground for pharmaceuticals. Furthermore, controversial production plants may be transferred to the South where few safety stipulations and controls stand in the company's way.

Not to be too critical, prenatal diagnosis of serious congenital diseases will certainly be useful. A method for the prenatal diagnosis of thalassaemia, a serious blood disease endemic in various countries of the South, is already in use and is much welcomed. However, genetic screening related to the suitability of people for particular jobs, including tolerance to some irritant or toxic substances associated with a particular job, are also already underway. Genetic screening aimed at creating 'designer babies' would be particularly troublesome. The technology could easily lend itself to discriminative or even racist abuse.

Gene therapy aims at 'fixing' genes in the human body. It would involve genetic manipulation of human cells resulting in a partially genetically manipulated human being. Although at present this seems hardly feasible for humans there have been certain successes in animal experiments. Whether gene therapy will have great medical significance even in industrialized countries is hard to estimate at this point. But it might have some significance in terms of breaking down moral, ethical and cultural barriers to the genetic manipulation of human beings.

One of the most disturbing aspects of the biotechnology industry is a tendency to try to adjust the environment and people to the needs of industry rather than industry to the needs of environment and people. While chemical companies try to adapt plants to their herbicides and industry-associated scientists express hopes of gene-manipulating the dying European trees so that they can tolerate acid rain, drug companies concentrate on people. A few years ago a US drug company advertised a tranquillizer by praising its ability to suppress the feeling of monotony of conveyor belt workers.[30] In a promotional film the Swiss drug giants, Ciba-Geigy, Hoffmann-La Roche and Sandoz said: 'Today we can only regard our instincts and emotions, which have become meaningless, as diseases. The readjusted human being, nightmare or wishful thinking, is in any case a biological necessity.' (Translation from German.)[31] The alteration of people to fit places—via drugs—is not so new. In the last century it was gin in England. Now it is beer in America and, up until recently, vodka in the Soviet Union. Biotechnology may offer industry more delicate instruments with fewer negative side effects.

Gene therapy and human growth hormone research can bring genuine and important benefits to suffering people. To a remarkable extent, however, much of the research appears directed to western-style 'cosmetic genetics' —the stuff that lets us all have blond-haired, blue-eyed Barbie dolls for children and makes sure that every boy is a basketball player.

One diagnosis is easy to make—none of us is getting any younger. That we are concerned about this is demonstrated by the gigantic cosmetics industry. As the head of Merck pharmaceuticals pointed out many years ago, there is more money to be made in helping healthy people than sick people.[32] The move of drug companies into the $21.6 billion world cosmetics market is a matter of companies putting their money where the lipstick is.

If cow spleens, avocados and rice oil can sell for $60 an ounce as an anti-aging skin cream, then what will people pay for a cell-cultured product that offers a sevenfold increase in dermal proteins and really does make your face 'younger'?[33] Some companies are at work on products that genuinely do retard the aging process in skin and limb. One biotech company, Repligen, has contracted with Gilette (a world leader in personal care products) to produce deodorant and something to remove dental plaque.[34] Repligen is also developing a hair colouring dye that uses a natural pigment and retains the original texture—plus another product that gives an almost 'natural' curl to hair.[35] All of these are seen as big money-makers.

Most profitable of all may be the work being done in the American mid-West on suppressing bovine respiratory diseases. Researchers tinkering with immuno-modulators and growth hormones on the thymus gland have recognized that subtle adjustments to this gland could retard the aging process in humans. Although it is not Ponce de Leon's Fountain of Youth, it could delay cancer from, say, age 57 to age 65 or 70. 'And that could be fairly important', James Roth of Iowa State University says, 'especially if it applies to you'.[36]

> With the discovery of the structure of DNA and the interpretation of the genetic code, a feedback loop stretching from molecules to men and back again has finally closed. In biological terms, a human being is the physical result (phenotype) of the interpretation of its genetic information (genotype) in the context of a specific environment. The process of biological evolution throughout the last 3.5 billion years has, in us, yielded a genotype that code for a phenotype capable of manipulating its own genotype directly: copying it, altering it—or replacing it altogether in the case of artificial life.
>
> *Chris Langton, 'Toward Artificial Life',*
> Whole Earth Review, *No 58, Spring 1988, p. 77*

***Prudent* paranoia?**

The speculation on the uses and abuses of biotech in human health care is almost endless. While the potential for exotic human manipulation does exist, we are strongly inclined to believe that the important impact of the new technology in health will be in the direction biotech pulls health research and budgets and in the relationship between the new techniques and the world's poor. We report the following more exotic aspects of biotech with considerable misgiving. In the end, we have opted to include some of the 'paranoid' prospects for biotech because—in the long term—they raise ethical and practical issues society cannot afford to ignore.

In the Spring of 1987, short days after the end of our Bogève workshop, an Italian anthropologist announced the in vitro fertilization of chimpanzee ova by human sperm. While claiming that this experiment had taken place on several occasions in various laboratories, the professor did not offer substantive details. Nevertheless, few in the field doubt the feasibility of the experiment. With rather more gross and colourful methods, Parisian scientists had attempted the same experiment back in the 1920s. No less a figure than Queen Elizabeth's personal gynaecologist had warned against the possibility of using other primates as surrogate mothers on several occasions. Chimpanzees and people have so many genes in common that the

successful combining of the two is actually no more surprising than horses and zebras or tigers and lions.

At first glance, the development of a subhuman species seems absurd. Society would not tolerate the psychic trauma it would entail.

Or would we? The possibility of a race of knuckle-dragging street-cleaners is genuinely ridiculous. As long as the rich have the poor—and biotechnology poses no threat here—a servant species is redundant.

Physicist Freeman J. Dyon claims that 'the age of mental exploration' is at hand and that the technology will soon exist 'to read and write memories from one mind into another'.[37] The 160 scientists—biologists and computer specialists—who gathered for the first-ever Workshop on Artificial Life in, of course, California, were prepared to go one step further and discuss the genuine creation of life from inanimate matter. Its organizer, Chris Langton, makes the point that, 'There is no special "vitality" brought to a living system by any of its ingredients'. Life depends on the functional relationships developed between biomolecules if you happen to be the right molecule in the right place at the right time with the right other molecules, life is the result. Sponsored in part by Apple Computers, workshop participants clearly saw the creation of artificial life as the timely result of the marriage of artificial intelligence (computers) with biotechnology. A 'time' whose ideas and molecules had come.[38]

As is evident from the previous account of animal genetics in livestock, it is now theoretically possible to clone ourselves and for animals to secrete human substances in their milk. Both of these developments were not thought to be possible at the time of the Bogève meeting.

It has also been since Bogève that Cornell University unleashed its particle gun—the latest word in human gene therapy. The gun is a gene-transfer system *par excellance*. As many as a thousand plasmids are coated on particles of tungsten which are then inserted by the thousands into the latest in biotech hardware—the shell of a .22 calibre rifle. The shell is then blasted at its target at a 1000 miles per hour (making it the fastest gene transfer in the West). The particles pass right through the target causing no visible damage and leaving the DNA behind. Originally intended for human gene therapy, researchers now think it has great potential for plant and animal breeding.[39] [40] If humans find this revival of the shotgun marriage a little rough on the genes, plants seem to like it fine. These possibilities are on the fringes of science and their relevance for health or for the poor is doubtful.

Table 13 Top ten US biodrug enterprises and links with major pharmaceutical companies

Biotech enterprise	Revenue US$m 1986	Major pharmaceuticals related partners	World rank
1. Genentech	85.6	Baxter-Travenol	
		Bayer (Miles Labs)	(5)
		Ciba-Geigy	(4)
		Daiichi Seiyaku	(41)
		Eli Lilly	(9)
		Hoffmann-La Roche	(15)
		Kabivitrum	(75)
		Kyowa Hakko	(46)
		Mitsubishi	
		Monsanto	(61)
		Toray	
		Pfizer	(6)
2. Cetus	50.0	Eastman Kodak	
		WR Grace	
		ScheringAG	(29)
		Schering-Plough	(22)
		Smith Kline	(12)
3. Amgen	23.4	Abbott	(8)
		Kirin Brewery	
		Johnson & Johnson	(16)
		Smith Kline	(12)
		Upjohn	(13)
4. Centocor	22.3	Abbott	(8)
		Du Pont	(101)
		FMC	
		Hoffmann-La Roche	(15)
		Smith Kline	(12)
		Toray	
		Warner Lambert	(7)
5. Biogen	21.4	BASF	(51)
		Baxter Travenol	
		Hoechst	(3)
		Merck	(1)
		Monsanto	(61)
		Novo	(64)
		Schering-Plough	(22)
6. Collagen	21.4	Bristol-Myers	(10)
		Eli Lilly	(9)
		Monsanto	(61)
		Schering-Plough	(22)
7. Genetics Ins	17.1	Baxter Travenol	
		Boehringer Mannheim	
		Chugal	(54)
		Sandoz	(14)
		Wellcome	(24)
8. Genex	16.5	A.H. Robins	(47)
		Bendix	
		Bristol-Myers	(10)
		Green Cross	(49)
		Hoechst	(3)
		Monsanto (Searle)	(61)
		ScheringAG	(29)
		Schering-Plough	(22)
9. Cal Bio	9.6	American Home Products	(2)
		Eli Lilly	(9)
		Ortho	
		Fort Dodge	
10. Collaborative Research	9.4	Akzo	(31)
		Dow	(28)
		Green Cross	(49)
		Johnson & Johnson	(16)
		Shell (Triton)	
		Sandoz	(14)
		Sterling	(13)
		Warner-Lambert	(7)
		Smith Kline	(12)
		Squibb	
		Sumitomo	(36)
		Suntory	
		Wellcome	(23)

Source: Various publications but especially Mark D. Dibner and Nancy G. Bruce, 'The Greening of Biotechnology: The Growth of the US Biotechnology Industry' in *Trends in Biotechnology, October,* 1987, p. 272: MarkD. Dibner, 'Biotechnology in Pharmaceuticals: The Japanese Challenge', in *Science*, Vol. 229, 20 September, 1985, pp. 1231 and 1233; and, Mark D. Dibner and Jane T. Osterhaus, 'Biotechnology and Pharmaceuticals: Merging Together' in *BioPharm,* September, 1987, p. 60.

Notes: Revenues are in US $millions and include research contracts as well as sales. Some partnership agreements may have been completed. Only contracts with significant enterprises are listed. There is limited information on contracts with European pharmaceutical houses.

Monocorporate antibodies?

The US Office of Technology Assessment study of 1984 noted that 125 companies and well-over 623 PhDs were engaged in biopharmaceutical research and development.[41] By 1986, 137 enterprises were in the field

—most of them in diagnostics and clinical tests[42] or vaccines. Meanwhile, the number of researchers has climbed into the thousands.

The scope of the activity is impressive. The top ten biotech companies, however, dominate the field and may be the ones to watch as the industry struggles to bring products to market. Watching these ten, are the world's traditional pharmaceutical companies. The table on the opposite page indicates the close connections between the new biotech firms and the old drug majors.

Despite the birth of a host of brave new biotech enterprises, most expect the long-term development of the new technologies in this industry to be controlled by the existing transnational enterprises.

The industry is already surprisingly concentrated. Although there are more than 10,000 'drug' houses in the world, the top 100 supplied 80 per cent of the world's shipments of pharmaceutical products in 1985. More to the point, almost 52 per cent of all these shipments were controlled by the top 25 firms while the top 50 accounted for nearly 68 per cent of shipments.[43] With estimated total world sales in 1985 of US $94, 561 million, the table below makes it evident that the world's largest 15 firms have over 31 per cent of sales.[44]

Table 14 Top 15 pharmaceutical transnationals in 1985

Company	Pharmaceuticals sales (US $ millions)
1 Merck & Co.	2,824.0
2 American Home Products	2,523.0
3 Hoechst	2,396.4
4 Ciba-Geigy	2,277.6
5 Bayer	2,267.3
6 Pfizer	1,961.0
7 Warner-Lambert	1,872.0
8 Abbott	1,866.0
9 Eli Lilly	1,786.0
10 Bristol-Myers	1,753.2
11 Glaxo	1,709.7
12 Smith Kline	1,654.1
13 Upjohn	1,593.0
14 Sandoz	1,592.2
15 Hoffmann-La Roche	1,546.5
Top 15	US$29,622.0 (31.3%)

Source: Numerous private investment sources including the WHO Survey 'The World Drug Situation', DPA/87.5 Restricted, adapted from Annex 1, page 5, table 7.

Table 15 Leading global pharmaceutical houses and biotech interests

Enterprise	Biotech partnerships
1. Merck (USA)	Biogen
	Chiron
	Clinical Res. Institute
	Shionogi
2. American Home Products (USA)	Cal Bio
	Chiron
	Moleculon
3. Hoechst (FRG)	Biogen
	ELectro-Nucleonics
	Genex
	Immunex
	Max Planck Inst
4. Ciba-Geigy (Swiss)	Biogen
	Biostar
	Chiron
	Genentech
	Kyowa Hakko Kogyo
	Synergen
5. Bayer (FRG)	Genentech
	Genetic Systems
	Boots-Celltech
	Synbiotics
6. Pfizer (USA)	Genentech
	Oncogene Sciences
	T. Cell Science
7. Warner-Lambert (USA)	Centocor
	Viratek
	Cistron
8. Abbott (USA)	Amgen
	Centocor
	Dainippon
	Immunonuclear
	Mitsubishi Yuka
9. Eli Lilly (USA)	American Dade
	Baxter Travenol
	Biotechnology Australia
	Bio Response
	Cal Bio
	Collagen
	Damon Biotech
	Du Pont
	Genentech
	Hybritech
	Shionogi
	Synergen
10. Bristol Myers	Biotechnology General
	Collagen
	Genex
	Genetic Systems
	Mem Sloan-Ketter
	Moleculon
	Oncogen
	Praxis Biologics
11. Glaxo (UK)	Unknown
12. Smith Kline (USA)	Amgen
	Applied Microbiology
	Biogen
	Cambridge BioSciences
	Cetus
	Centocor
	Immunex
	Nippon Zenyaku
	Walter Reed Army Hospital
13. Upjohn (USA)	Amgen
	Biotechnica Int'l.
	Molecular Genetics
14. Sandoz (Swiss)	Genetics Institute
	Collaborative Research
15. Hoffmann-La Roche (Swiss)	Amgen
	Biogen
	BTC Diagnostics
	Centocor
	Damon Biotech
	Fort Dodge Labs.
	Genentech
	Genetic Diagnostics
	Immunex
	New York University
	Penn State University
	Takeda
	Unigene

Source: Data for non-US enterprises has come from various sources and publications while US data is derived largely from Mark D. Dibner and Nancy G. Bruce, 'The Greening of Biotechnology: The Growth of the US Biotechnology Industry' in *Trends in Biotechnology,* October, 1987, p. 272; and. Mark D. Dibner, 'Biotechnology in Pharmaceuticals: The Japanese Challenge', in *Science,* Vol. 229, 20 September, 1985, pp. 1231 and 1233; and, Mark D. Dibner and Jane T. Osterhaus, 'Biotechnology and Pharmaceuticals: Merging Together' in *Bio Pharm,* September, 1987, p. 60.

After a surge of merger activity in the late sixties and early seventies, the top core of transnationals has remained relatively constant—playing a gentle game of musical chairs in the top ranks over the past decade—but surprisingly monolithic.

The table opposite indicates the contractual and/or equity connections between some of the largest pharmaceutical houses and leading biodrug companies.

This control has been somewhat increased by recent mergers in the industry. Monsanto, for example, bought G.D. Searle while American Cyanamid took over Lederle, and Baxter Travenol gave up American Critical Care to Du Pont. Meanwhile, Sterling Drugs strengthened its position by capturing Winthrop pharmaceuticals. But, by early 1988, Hoffmann-La Roche was in a US $4.2 billion battle to take control of Sterling and the Rorer Group was moving in on A.H. Robbins. Rumours abound that Hoechst, Bayer, ICI, Du Pont and Dow are all looking for biodrug companies to buy.[45] During 1987, Glaxo in the UK and Hoffmann-La Roche in Switzerland disected and swallowed Biogen's European operations, and Bristol-Myers built up its equity interest in a number of small biotech houses. The old pharmaceutical giants have learned the lesson of monoclonal antibodies. They are either capturing the new invaders one-by-one or cloning the newcomers' technology to use for themselves. The once-staid drug industry may be shifting into gear.

A news conference is called on Wall Street. Jivaro, a small biotech enterprise has an announcement to make. It is submitting nine new bio-drugs for regulatory approval. Each of the new products has already undergone exhaustive human trials and has been found effective. Reporters rush to their telephones and market analysts hurriedly re-evaluate pharmaceutical stocks advising their favoured clients to buy. The nine new products are:

- a treatment for malaria;
- an anaesthetic;
- a muscle relaxant;
- a painless way of removing diseased teeth;
- a tooth decay preventative;
- a means of clotting blood instantly;
- a drug that reduces swelling;
- a salve that heals broken bones;
- a 3-month contraceptive.

To their horror, Wall Streeters discover that the Jivaro company is unlisted. In fact, it is not a company at all.

Medicinal plants: the South's biodrugs go North

In all the talk of how the new biotechniques can help the Third World, the North loses sight of how much the Third World has done and is doing to help the North. And, more importantly, how well the poor can use their own medicinal plants and wisdom to help themselves.

Table 16 The value of medicinal plants for Latin America

Plant	Purpose
Pau D'Arco (Taebuia species)	Reported sales of almost US $200 million. May have effect on a variety of diseases including cancer and immune system disorders. Used for flu, colds, infections, pain, etc. Traditional uses include both malaria and cancer. A major component, lapachol, is effective against certain types of bacteria and fungi. Destroys Brucella fungi.
Tecoma	Sometimes substituted for Pau D'Arco and has similar purposes. May have value for diabetics.
Sweet Herb or Stevia *(Stevia rebaudiana)* or caaehe	Sweetens soft drinks, candies, soups, and other products. 300 times sweeter than sugar. Used as an antacid and diuretic, regulates blood pressure, lowers excessive uric acid. Is non-toxic and doesn't promote tooth decay. Currently in weight-loss tea blends.
Quassia *(Picraena excelsa)*	Traditionally used to cure debilitating fevers. Improves digestion and appetite. May decrease putrefaction in digestive tract and reduce acidity. Kills intestinal worms and other invaders such as giardia, a protozoan that contaminates water. Used by travelers to avoid problems from food and water. Taken with each meal prevents parasitic infection. Can also reduce cravings for alcohol. Externally used as a hair rinse to discourage dandruff and other scalp problems.
Peruvian Bark *(Cinchona sucirubra)* or Cinchona, bark tree	Source of natural quinine; used to cure malaria and heart palpitations. Used as an antiseptic on external wounds and for throat and mouth problems due to bacterial or fungal infections.
Suma (*Pfaffia paniculatal)or* Brazilian ginseng	Adaptagen helps the body cope with stress and increase resistance to all types of disease. Used in South America to treat diabetes, joint diseases, and certain types of cancers. Research has focused on anti-tumour effect on cancers of the bone, lymph, skin, and gastric system. Constituents such as germanium may strengthen the immune system; another lowers blood cholesterol levels; a third, allantoin, is a skin, bone, and ligament healer.
Guarana *iPaullinia cupana)*	Stimulant in tablets and teas. Diet supplement. Helps body tolerate extreme heat. Natives claim it prevents disease and is an aphrodisiac. Used for digestive problems and as a nervine.
Mate *(Ilex paraguariensis)* Paraguay tea	A popular drink in South America. In US is used in tea blends. Like guarana, contains caffeine and is used for headaches, nervousness and insomnia, but large amounts of mate can cause these problems. Helps body tolerate heat and increases stamina.
Ipecac *(Cephaelia ipecacaunha)*	Strong emetic (substance that induces vomiting). Traditionally known as cure for amoebic dysentry and was added to expectorant syrup to reduce lung congestion and spastic coughing.
Muira Pauma *(Ptychopetalum olacoided* and *P. uncinatum)* or Potency bark	Native Brazilians use it as a cure for impotence and as nerve tonic. Is a light stimulant to the central nervous system that stimulates appetite and is said to regulate the menstrual cycle. Studies show evidence that it strengthens the circulatory and digestive systems. Contains compounds known to reduce cholesterol levels in the blood.

Source: Kathi Keville, 'The Herbalist—Exploring South America's Medicinal Plants', *Vegetarian Times*, April, 1987, p. 46-40.

The Jivaro people live deep in the Brazilian and Peruvian Amazon. They long ago taught the world to embrace quinine to fight malaria and to use curare as a muscle relaxant and anaesthetic. But the world got little more from these people until it realized that the key to understanding the more than one thousand medicinal plant species named by the Jivaro rested usually with the older women.

Now a wife and husband team from Washington University in St. Louis, Missouri, is in the midst of a three-year programme to gather the plants and collect the wisdom of the Jivaro women. Helping out is another St. Louis neighbour, Monsanto Corporation. Monsanto has already begun laboratory testing of Uruchnumi—a plant that appears to stop bleeding almost instantly. The Jivaro use it for bleeding gums and Peruvian doctors have been known to recommend it for ulcers. In the first two of six expeditions planned, the St. Louis team has obtained more than one thousand plant species of potential value.[46]

Interest—particularly biotech company interest—in medicinal plants and traditional medicines has skyrocketed in the past few years. Between 1976 and 1980, the world value of medicinal plant imports doubled, from $225 million to $581 million.[47] While clear global figures are not available for the eighties, national figures indicate that plant imports doubled again in the early eighties.[48]

One reason for the interest is growing recognition in the pharmaceutical industry that the destruction of the rainforests is leading to the extinction of thousands of potentially lucrative plants. Toward the end of 1986, the market study group, Scrip, warned in its *World Pharmaceutical News* that some 200 drug-yielding species were in danger of being lost. Referring to an article in *The Guardian,* Scrip suggested that the pharmaceutical industry could lose 100 billion in prescription medicine value. The price tag on the extinction of each medicinal species, says Scrip, is $203 million.[49] Were environmentalists to use figures like this, they would be in line for extinction themselves. Such figures are no less speculatory when cited by industry. They do, however, give some perspective on the economic potential of traditional medicines.

In a broader sense, biodrug companies are interested because at least one-quarter of all prescription drugs sold contain some plant component. Until the advent of biotechnology, only 7 major drugs could be synthesized more cheaply than they could be gathered from fields or forests.[50] Pharmaceuticals are a more than $100 billion industry worldwide. It is clear that

exotic plant compounds could have a major role in the industry's future. With perhaps half of all modern medicines traceable to plants,[51] biotechnology now makes it at least theoretically possible to screen and actually use these exotic plants economically.

During 1987 alone, new reports came out on the potential of medicinal plants gathered in Paraguay,[52] Papua New Guinea,[53] Thailand[54] and Saudi Arabia.[55] The US National Cancer Institute launched a five year drive to collect medicinal plants that could prove useful in chemotherapy. Three teams are being sent out to search the tropical rainforests and to talk to traditional medicine makers. Each team is to bring back at least 1, 500 specimens a year at an average cost of $418 a sample.[56] Asian NGO's have already encountered one team collecting in The Philippines and Sarawak late in 1987. Asked about the political implications of their research, the collectors claimed that their work was 'fairly pure' in that the information gathered would be available to anybody—including pharmaceutical houses.[57]

The interest is not only in plants but yeasts and bacteria as well. MYCO-search, for example, is a small American biotech operation that specializes in collecting non-sporulating fungi around the world.[58] Jack Kloppenburg at the University of Wisconsin reports that MYCO-search charges $2,000 per sample for material they pick up freely in the Caribbean and Latin America.59 Drug companies take rare fungi seriously. Two of Eli Lilly's top money-earners in the mid-seventies were taken from a sewage outlet off the coast of Sardinia.[60] And, at the beginning of 1988, Mitsubishi announced the marketing of a streptomycin-based antibiotic to be used as a feed additive for swine and poultry. The antibiotic was isolated from soil found in Argentina.[61]

In all this there is a sense of something wrong. Japanese companies are collecting herbs in Asia. American companies are after plants in Latin America. European companies are opening up research centres in Brazil and India. There is money to be made. But none of it will be made by the people who first discovered the value of these traditional medicines. Neither the Jivaro women nor their counterparts in Sarawak or Ethiopia will see any part of the $418 per sample used by the plant explorers. Neither will they get a share of the $2,000 finders' fee charged by MYCO-search. Yet, as the National Cancer Institute makes very clear, the world wants not only their weeds but their wisdom as well. Ethno-botanists are spending as much time with the people as they are with the plants. Yet, when all is said

and done, the patent will be taken out by Hoffmann-La Roche or Monsanto or Eli Lilly—not by the Jivaro, not even by Brazil.

The natural emotional response of a poor country is to shut it all down. To close the borders and keep the explorers out. But Madagascar's rosy periwinkle is saving children from leukemia today. If the borders had been closed the children would be dead.

The solution is genuine respect for those who have discovered and protected medicinal plants—and genuine international cooperation on the further development of these plants. National governments and WHO have a role to play here. But the most important role rests with local people and local wisdom.

Some new biotechniques may also be very helpful. But the people must not lose control over their medicine. The poor cannot risk trusting the rich with their health. There is no good health and no end to poverty—without self-reliance. As we have said before, the medical community must exercise humility. There are no silver bullets.

> Western scientists look for the truth by tearing life apart.
> *Erich Fromm*

> The exponential rate of physical and intellectual destruction of native peoples is resulting in the irrecoverable loss of sustainable development systems and unique resources, 99 per cent of which are being conserved in situ for mankind by these peoples without recognition or appropriate compensation. The other 1 per cent is being precariously conserved ex situ at an estimated minimum cost of one billion dollars per year.
>
> *Declaration of Belem, First International Congress of Ethnobiology, Brazil, July, 1988.*

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2. Drug Study Group, 'Drug Pricing Policy', 1987.
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The 'Clean-up' Revolution?

Bio By-products for the 'Greenhouse'

The most commercially important link between biotech and the environment probably lies in the famous 'Greenhouse' effect. The increase in atmospheric CO_2 over the past thirty years and the decrease in the ozone layer created by 'aerosols' (chlorofluorocarbons or CFCs)—although separate factors—are well on their way to creating a major world crisis. Agriculture will experience one part of this crisis.

According to Dr W.D. Kemper of the US Department of Agriculture, current CO_2 levels stand at 345 parts per million compared to 315 parts per million in 1958. The North has the most CO_2, but the gas is slowly dispersing around the globe. By 2050, atmospheric CO_2 will be 650 ppm and agricultural production will be in chaos—as will everything else. CO_2 is causing the earth to warm, the sea levels to rise and will lead to the flooding of both coastal and inland communities.[1]

To make matters worse, researchers at the Chemical Institute of Munich report that although alternatives to aerosols may save ozone in the stratosphere, they actually help form photochemical smogs containing high levels of ozone closer to the ground. Ozone in the lower atmosphere has doubled in the past 100 years and is toxic to plants.[2]

Meanwhile folks at the Worldwatch Institute point out that reforestation would reduce the release of carbon into the atmosphere by about 17 per cent.[3] Therefore a global plan to save the tropical rainforests and to replant deforested areas could help us all at least reduce the Greenhouse effect. On the other hand, a joint Belgian/US study argues that Greenhouse gases may counteract atmospheric ozone depletion. Increased carbon dioxide causes the Earth's surface to warm but the stratosphere to cool, deaccelerating ozone destruction. The combined effects result in a 1 per cent ozone loss in the tropics and temperate zones and a slight ozone increase near the poles.[4] In other words, reforestation could accelerate ozone loss or, conversely, the denuding of the Amazon, may have some marginal benefit for Northern latitudes.

However we look at it, atmospheric pollutants pose a major threat to much of the inhabited planet and place enormous new pressures on the earth's food supply. Through the development of fast-growing trees and the adaption of pollution-tolerant crops and crop varieties, biotech companies will claim a major role in shaping our future.

Such wisdom was not lost on the 20 business people who gathered in room

201A of the Toronto Convention Centre at the end of June, 1988. Although more than 350 delegates from around the world came together in Toronto to discuss the Greenhouse effect, only the small business session was closed to reporters.[5] Although outsiders joked about the industry need to convert snow skis into water skis, biotech companies clearly see an opportunity in adversity. With predictions that the next half-century will see greater climatic shifts than have taken place in the past 18, 000 years, the market potential may only be exceeded by the opportunity to pressure governments to pass legislation and regulations that give biotech a freer hand than ever.

In this, the biotech industry is joining forces with the nuclear industry. Arguing that the world must reduce its consumption of fossil fuels—a major cause of Greenhouse gases—by turning to nuclear power, the atom-smashers expect humanity to prefer a nuclear winter to a global warming. Similarly, biotech companies hope governments would rather 'switch' than fight and give the green light (or thumb) to gene patenting and transgenic species manipulation.

They are probably right. Biotechnology may be useful. It is also important to bear in mind, however, that biotechnology will be looking to the South's genetic diversity for the genes needed to maintain agriculture.

As Vandana Shiva and Martin Abraham pointed out at an NGO Conference on Global Warming organized by the Foundation on Economic Trends (with RAFI) in October, 1988, the South is not prepared to shoulder responsibility for cleaning up the messes of the North. World Bank reforestation programmes, Shiva says, contribute to genetic erosion and destroy the economic options for local people. Proposals for world climate laws, Martin Abraham warns, could easily have the effect of pressuring Third World countries not to 'develop' while allowing the North to 'phase out' of fossil fuels and Greenhouse gases at their leisure. If the North needs the South's help, Martin Kohr of SAM, Malaysia, adds, they had better prepare to negotiate.

Other environmental effects

For many of us, our sense of biotechnology began back in 1980 when a man named Chakrabarty won a patent on a bug that runs on gas. Not an old Volkswagen, this bug was a microbe that could break down oil slick into 'safe' compounds. With this revelation, many of us sat back to await the unfolding of a new era of clean water, air and food. We were, industry propaganda promised, standing on the verge of a new era of environmental sanity.

A great deal of talk—and some work—has indeed gone into environmental clean-up. Virtually all of it, not surprisingly, has focused on the needs and interests of the North. There has been helpful work on biological methods of protecting trees from acid rain, for example. Scientists estimate that fully 10 per cent of crops grown in industrialized countries are lost due to air pollution—particularly the decline in the ozone layer.[6] Other work in Dutch Elm disease also gives some hope that a solution can be found before all the elms are dead.[7]

There has also been renewed interest in renewable forms of energy and in the use of waste products as sources of energy. To this end, northern biologists have made great strides in fermentation technology. The market for fermentation products in the United States (largely a market for ethanol/biomass) will come to about US $60 billion in 1988 and climb to US $72 billion by 1998.[8]

Most of the 'environmental' work, however, has gone into industrial waste management and the related field of mineral bioextraction. Detoxifying waste-water has become big business. The world market for the clean-up of inorganic materials in waste-water is between US $1 and $2 billion per year. The control of toxic wastes (including solid wastes) is expected to cost US industry $10 billion by 1990.[9] That is a powerful incentive for innovation. The market is enhanced by the fact that the strategies used in biotechnology to clean up waste-water can also be used in the mining industry either to control environmental pollution or to aid in the extraction of marketable metals.[10] Microbial metal recovery is a US $450 million a year business in the US alone and is growing at 12-15 per cent a year.[11] Between 1990 and the year 2000, the world market for bioextractors is expected to be US $90 billion and involve the mining of gold, silver, copper, uranium, cobalt, platinum, chronium, manganese, nickel, titanium, tungsten and vanadium.[12]

In mining: Trade journals have recently reported numerous examples:

Waste from the pharmaceutical industry (dead micro-organisms) and forms of seaweed are being developed to assist in the more efficient recovery of heavy metals.[13] After a hundred years of using cyanide in gold and silver production, the mining industry is experimenting with a microbial process that would reduce costs to less than a tenth of the current price and eliminate the need for special facilities.[14] At the manufacturing end, biotech has contributed to the development of new metal adhesives and binders. Genes taken from the roots of Jimson weed and Monkey flower have been

used to bind cadmium and copper metals.[15] In each case, dangerous chemicals are being replaced by what the industry hopes will be less-expensive and environmentally-safer renewable resources.

In petrochemicals: The petrochemical industry is also gaining from the new biotechniques, for example:

A new biotech company is developing starch-plastics that can be used as rubbish bags and dustbin liners. The film is environmentally degradable and can replace the old petroleum-based products.[16] Battelle is experimenting with processes that convert sewage into diesel fuel.[17] Field tests are underway to use microbes in recovering oil from dying wells.[18] Occidental Petroleum is funding research on an amoeba that breaks down plastic.[19] Scientists at Braunschweig (FRG) are using bacteria that in turn use hydrogen to convert nitrates in the water to nitrogen. Given the increasing problem of nitrogen fertilizers in Europe's water supply, the bacterial process may prove commercially viable.[20]

Other researchers are working on a plant known as the Two-grooved Milk Vetch—a common weed—to protect wild life refuges. Large accumulations of selenium have been found in irrigation run-off that threatens wildlife. The weed absorbs huge quantities of the selenium and can be gathered, and recycled back to the industry—so they can pollute again but feel better about it.[21]

In waste disposal: The biggest market of all is for the companies now winning patent rights to technologies that will rid society of the messes these companies have left us with over the past century or more:

Manville Corporation—once a leading asbestos polluter—has devised a process using bacteria that slashes the time it takes to degrade phenol in waste.[22] According to Israeli researchers, waste products from the food and beverage industry can be used to grow a fungus that absorbs heavy metals in waste-water.[23] Japanese firms have discovered a bacterium that completely digests soft rubber.[24] Biotech has something for everyone. For environmentally-sensitive arms manufacturers, biotechnology has developed a bacteria that gobbles up TNT and other munitions chemicals in waste-water.[25] Soon we will hear industry talk about the 'peaceful uses of the microbe'! After half a century of using PCBs, General Electric has found a bacterium that degrades the extremely dangerous chemical. Taking over an old car dealership, GE has launched a field test that has led to between 20 and 30 per cent of the PCBs being degraded in 13 weeks.[26]

If we are to give the new technology a report card for its first term in improving our environment, we would have to point out that, at least so far, not much has happened. The potential improvement to polluted waters and soils is still theoretical. The same techniques are, however, already in use when it comes to metal recovery in the mining industry.

This is not to say that biotech clean-up products will not come to market. They will. It remains to be seen, however, if the introduction of genetically-altered micro-organisms will help clean up the environment—or add new environmental problems. It is worth pointing out, again, the irony that those who may be the first to benefit from the patent monopolies being developed in biotech are the very companies that have done the polluting.

Some of the most innovative work has been done in the South—in Brazil, Chile, Cuba and Thailand. Much of this work has been in the area of renewable energy and waste management. Working with a Japanese company, Thailand has developed a process that vastly reduces molasses waste from distilleries and turns the waste into methane. The Thais have managed to cut their energy costs by half in the process.[27] The Cubans and Brazilians have worked extensively on biomass and the recycling of by-products.

The use of bio-extractors in mining is widely expected to take place in more remote geographic locations—especially in the South. With support from UNIDO, for example, Chilean scientists are developing a bacterium that is expected to reduce the costs of leaching copper to about one-third of the present level. The energy savings will be substantial.[28] The real question is: who will benefit from the savings? In most cases, it will be transnational mining companies.

We have already discussed the work underway in developing herbicide-tolerant plant varieties and encapsulated embryos. Biotech companies see this as environmentally responsible research. Some of the work on herbicides is undoubtedly useful. The man who made biotechnology popular —Professor Chakrabarty—has done it again. Together with a colleague, Professor Chakrabarty has come up with a bacterium that loves to eat Agent Orange.[29] Better late than never.

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Part Three

The Political Laws of Life

The Lords of Life

Corporate Control of the New Biosciences

Are Europe, North America and Japan locked in a titanic struggle to control the new technologies—or are transnational enterprises absorbing the start-up companies in order to take control? Pierre Benoit Joly, Calestous Juma and Pat Mooney launched the discussion at Bogeve with considerable insight from Martin Kenney and others. The most obvious trend? Breweries are making drugs; pharmaceutical companies are growing crops and food processors are into just about everything. The process of homogenizing life and capital is well underway.

> In fact, what is now emerging throughout the corporate sector in the US, Europe and Japan is a new, unprecedented institution of economic and political power: the multi-faceted, transnational 'life sciences' conglomerate—a huge company that will use genes to fashion life-necessity products just as earlier corporate powers used land, minerals or oil.'
>
> *Jack Doyle, Environmental Policy Institute*

According to Jeremy Rifkin, biological knowledge is currently doubling every five years, and in the field of genetics, the quantity of information is doubling every 24 months. It is rather remarkable to reflect that commercialization of biotechnology has taken place in little more than one decade.

In 1973, foreign DNA was first successfully inserted in a host micro-organism. In 1976, the first company to exploit recombinant DNA technology was founded in the US—Genentech of South San Francisco, California. Today, barely a dozen years later, a worldwide biotechnology industry is emerging and still taking shape. Products have thus far been slow to move from the laboratory into the marketplace. But by all accounts, the market potential is enormous.

The market muddle

Market analysis for the economic impact of the new biotechniques vary rather dramatically. Food processors talk of a US $200 billion market before the end of the century. Agricultural biotech analysts point to a potential world market of US $40 billion although the market prediction for 1988 is a humble US $25 million and one projection for 1992 is ncwnore than US $700 million.[2] Other analysts claim agricultural biotechnology will be selling US $2 billion in products by 1995.[3] Although there are only a half-dozen or so biodrugs available for commercial sale, Wall Street estimates that the market for genetically-engineered pharmaceuticals will grow to US $3 billion by 1990." Stouter hearts argue that the market for AIDS-

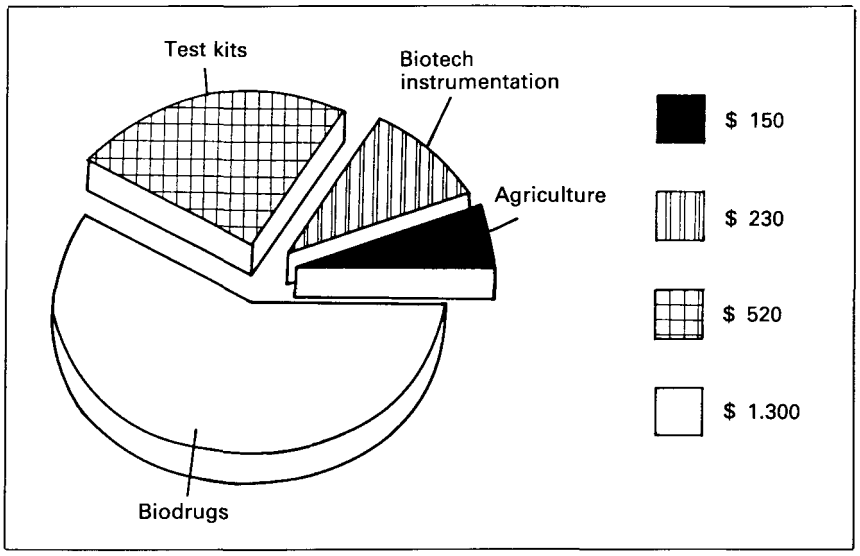

Figure 13 Biotech assets by sector: the focus of venture capital 1987-88 (US $ million)

related bioproducts, alone, will reach US $3 billion in the next few years.[5] Yet, another industry study predicts that sales of all biotechnology-based products, in 1997, will be a modest US $10 billion.[6]

The focus of the new technologies may also be shifting. In the early eighties, staff at DNA Plant Technology Company, for example, were showing one and all market studies that suggested that the big target for biotech would be agriculture with plant improvements raking in US $30 billion while biopharmaceuticals accounted for only US $5 billion. Food ingredients were expected to offer a US $2 billion market.[7] By the mid-eighties, the assets breakdown for US biotech firms showed a very different priority. Pharmaceutical applications were drawing 60 per cent of biotech assets with agriculture attracting a scant 7 per cent. Why? Although convinced that biotech can have a huge and fast impact on agriculture, investors are sceptical that companies can overcome the environmental concerns related to the release of genetically-altered organisms. For this, the credit or blame goes to Jeremy Rifkin.

In the midst of a revolution, such confusion is not surprising. The extreme uncertainty has affected biotech's big investors, however. During 1987, publicly-traded US biotech companies lagged behind the boom market in the USA—and agricultural biotech firms fared the worst. On the eve of the 19 October market crash—while all stocks had climbed 35 per cent during the year—ag biotech start-ups had gained only 1 per cent. After the crash and by the end of the year ag biotech stocks stood at a mere 61 per cent of their value at the beginning of 1987.[8] As Paine-Webster's Linda Miller told biotech companies in early 1988, Wall Street 'doesn't believe yet that the

Force is with you'. Another indication of this uncertainty is that, across the board, institutional holders of biotech stocks run at 18 per cent of total stock. Institutional ownership of ag biotech stock is only 8 per cent.[9]

Many observers see 1988-89 as the 'make-or-break' period for the start-up biotech houses. Before we add our voices to the cacaphony predicting the industry's future, it is appropriate to consider its origins.

The three-piece lab coats

The biotech industry got its start in the United States, and it is generally agreed that US efforts to commercialize biotechnology have been (at least until recently) the strongest in the world.

Early on, the essential ingredient for commercialization was specialized scientific training and know-how. Not surprisingly, commercial biotechnology has its roots in academia. Genetic engineering as a commercial venture was launched in 1976 when Herbert Boyer, a University of California bacteriologist, joined forces with a young venture capitalist and formed the world's first company to commercialize recombinant DNA techniques.

In the late 1970s, major advances came principally from university research laboratories. According to Bogève-participant Martin Kenney:

> All of the earliest genetic engineering companies were founded by university professors. The initial research was undertaken in university laboratories, and even when the companies secured laboratory space some of the professors did not resign their university positions. Rather, professors chose to remain faculty members and work for their companies.[10]

Kenney notes that in molecular biology departments across the US, affiliation with a biotechnology company became the norm. Suddenly, a new breed of entrepreneurs (wearing white lab coats instead of 3-piece suits) emerged from the country's foremost universities and research labs.

Describing the industry's 'Founding Fathers', *Bio/Technology* magazine noted that fully half of all the founders of biodrug enterprises were from the public sector and, from the 121 companies surveyed, over 42 per cent of all of biotech's founding fathers are from public institutions and universities.

When *Genetic Engineering News* published its first list of biotech's 'molecular millionaires' in February, 1987, almost half of those listed were PhDs —and many made their fortunes working for new biotech firms while

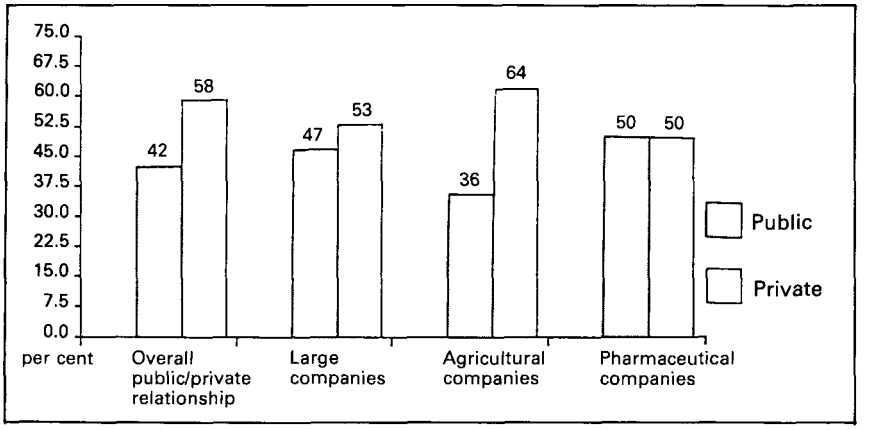

Figure 14 The biotech founders: private and public origins of biotech enterprises 1977-87 (in per cent)

holding university positions. Genentech's Herbert Boyer tops the list of former university professors turned millionaires—with an estimated personal fortune of $88 million. William C.Rutter, formerly of University of California Medical Center and now Chairman of Chiron Corporation is worth an estimated $21 million. Steven Gillis and Christopher Henney, formerly microbiologists at the University of Washington made their fortunes (worth an estimated $6.3 million each) at Immunex."

The list goes on and on. It illustrates the integral role played by molecular biologists and other leading scientists in the founding of the US biotechnology industry—principally through the creation of small, entrepreneurial firms devoted to commercializing some aspect of biotechnology research.

The close corporate/university ties are spawning increasing concerns over conflicts of interest. Universities and university scientists are being asked to serve two masters—one public, the other private. Can free, unfettered, intellectual inquiry take place in a university where private contracts dictate research agendas? Can free exchange of information between students and faculty and among faculty (some of whom may work under contracts with different, competing companies) take place when faculty are engaged in proprietary research and have a personal interest and contractual obligation in seeing that the results of their research remain private? Can students learn when their professors are afraid to talk to one another and to their students? At Bogève, Martin Kenney had his doubts. Old Anton von Leeuwenhoek—the man who started it all—would have agreed with Kenney. Shortly before his death, he wrote:

> The professors and students of the University of Leyden ... so far as I can judge, for almost all of the courses they teach there are for the purpose of getting money through knowledge or for gaining the respect of the world by showing people how learned you are, and these things have nothing to do with discovering the things that are buried from our eyes.[12]

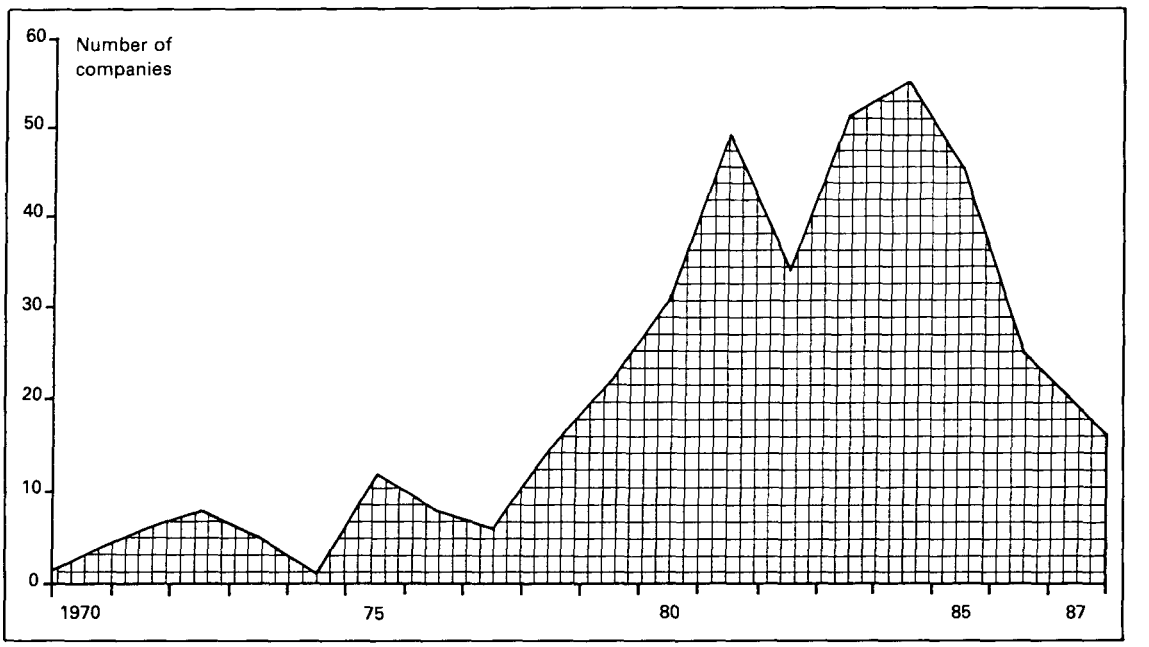

Figure 15 The growth of biobiz: the founding years 1970-87

The boom years

From 1979 to 1983, more than 250 small biotech firms were founded in the US alone—a boom made possible by an abundance of venture capital.[13] According to a study prepared by the US Office of Technology Assessment, 'the launching of embryonic high-technology industries by entrepreneurial firms is a phenomenon unique to the United States'.[14] The same study concludes that the proliferation of small biotech companies gave the US a competitive lead in the early stages of biotechnology's commercialization.

The newly-formed biotech companies were risking their very existence on the unproven potential of biotechnology, and they have since functioned as a litmus test for larger, corporate investors who soon followed in the biotech boom.

Larger, established corporations around the world were gaining an increasing awareness of the potential and power of this newly emerging growth industry, but most large corporations in the US did not begin in-house biotechnology research and development until 1981.[15] Du Pont, for example, announced in 1981 a new, $120 million programme for research and development in the life sciences with an emphasis on biotechnology.

Similarly, in Europe and Japan, most companies did not make major investments in biotech until after 1981.[16] Hoffmann-La Roche (Swiss) for example, spent $59 million on biotechnology R & D in 1981. Ciba-Geigy's $19.5 million biotech centre in Switzerland was launched in 1981, and their

$7 million agricultural biotechnology laboratory in North Carolina (USA) was completed in 1984.

Strategic alliances

With few exceptions, most large corporations were reluctant to invest in the unchartered waters of commercial biotechnology by diving in head-first. Most corporations began by forging strategic partnerships with small biotech firms and university research programmes. This route offered reduced financial risk, but also insured early access to products or production technologies and knowledge.[17] The partnership between large corporations and small biotech firms is mutually beneficial for both parties. The small biotech firms desperately need capital to sustain their basic research and early-stage product development. The corporate partner can provide capital, regulatory experience, and marketing knowledge. It also makes the new firm appear more investment-worthy if it choses to seek public financing.

Today, a wide variety of 'partnering' agreements such as R & D contracts, joint ventures, licensing, patenting and marketing agreements exist between the small biotech firms and large, established corporations. (See appendix, pages 314-319, for company profiles and examples of partnering agreements between biotech firms and corporations.) The contractual agreements are by no means limited to US companies. The flow of capital and biotech investments extends far beyond national borders.

In 1983, for example, US biotech firms forged approximately the same number of relationships with non-US corporations as they did with US corporations.[18] The largest biotech company in the US, Genentech, currently has 13 US corporate partnerships, at least 7 partnerships with Japanese corporations, and 4 European partnerships. Given the international transfer of capital and technology in the biotech industry, and the very nature of transnational corporations who view their markets as global, it becomes almost a false distinction to categorize biotech industries by nationality.

The shake-out

A survey of US biotechnology companies conducted by the North Carolina Biotechnology Center gives the following description of today's average biotech firm:

> Currently, the average US biotechnology firm is six years old, has fewer than 100 employees, and operates with a research and development budget of approximately $4 million. The typical firm will have a total income of approximately $10 million for the 1987 fiscal year and will not operate at a profit.[19]

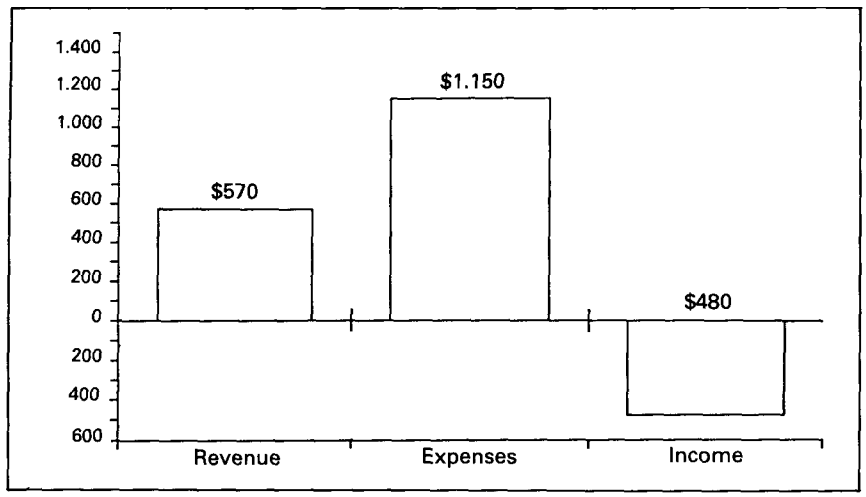

Figure 16 Biotech balance sheet: the industry in 1986 (US $ million)

Even in the late eighties, few biotech firms aspire to profits. In 1986, the US industry lost US $480 million. Only Genentech looks to be turning a secure profit.

For years, industry analysts have predicted a major 'shake-out' in the US biotechnology industry. Both fierce competition among the smaller firms and the continued increase in large corporate involvement signal a gradual shift to the larger corporations playing a dominant role in biotechnology. Monsanto, for example, recently opened a new, $150 million-plus Life Sciences Research Center. The company now devotes approximately $100 million to biotech research and development, and predicts that by the 1990s a third of its business will come from the life sciences.[20] Fully one-third of Du Font's $1 billion research budget is now devoted to biotechnology. Kodak has also recently bought both pharmaceutical and agricultural biotechnology enterprises.

The resources available to the small biotech companies stand in sharp contrast to the well-established corporations which are now developing significant in-house operations in biotechnology. A comparison between the 10 largest US biotech firms and the 10 largest US pharmaceutical companies reveals that the latter corporations 'have 233 times the average revenues in 1986 and 163 times the average number of employees. The average R & D budget of the pharmaceutical companies was more than 17 times the average total revenues of the largest biotechnology firms.'[21]

The large corporations are establishing their own programmes and gaining solid in-house expertise to support biotechnology programmes. Meanwhile, the number of new biotech companies being formed every year is decreasing. According to some industry analysts, it is just the beginning of a

long-term trend. Roger Shamel of Consulting Resources Corporation believes that the number of US biotech companies will decrease by 33-50 per cent every 10 years until only about half a dozen survive. He predicts that half of this consolidation will come from company failures and half from mergers and acquisitions.[22] This prediction may not be farfetched. Paine-Webster analysts claim that as many as half of the agricultural biotech companies in the USA will be gone by the end of the year.[23] As though to emphasize the point, two major plant biotechnology firms, Agricultural Genetic Sciences and DNA Plant announced the first major merger of biotech companies in January, 1988.[24]

The Japanese connection

The world's focus on the high-visibility American activity, has tended to blur our view of the industry in Japan. Japan has always been recognized as a leading player in biotechnology, and its influence appears to be increasing over time. An article appearing in *Science* magazine in September, 1985, made the following observations about the Japanese effort in biotechnology:

> The country predicted to have the greatest potential impact on the commercialization of biotechnology is Japan. Although the new biotechnologies have been largely developed in the United States, the Japanese are expected to soon take the lead in commercialization of these technologies. A large part of their success will be based on products first developed in the US.[25]

In contrast to the Americans, Japan's strength in biotechnology did not arise from newly formed, small biotech firms. The 1988 'Guide to Biotechnology Companies' published by *Genetic Engineering News* lists only 16 Japanese biotechnology companies, compared to 379 in the United States. Biotechnology in Japan is being commercialized almost exclusively by large, established corporations representing virtually all industrial sectors (food and beverage, pharmaceutical, chemical, etc.).[26]

Similarly to their US counterparts, Japanese corporations initially turned to US biotech firms for basic research assistance by forming a variety of collaborative agreements. In the area of pharmaceuticals, for instance, there were 72 joint or contractual agreements between US biotech firms and US corporations from 1981-1985, compared with 43 such alliances between US biotech firms and Japanese corporations.[27]

In the initial stages of biotechnology development (late 1970s), Japan suffered from a lack of basic researchers with training in molecular

genetics.[28] To compensate, Japanese corporations formed numerous partnerships with US biotech companies and thus gained access to 'frontier developments' in the field.[29] (Japanese corporations also established partnerships with European biotech firms, but most of the alliances have been with large European corporations.)

The Japanese are generally recognized for their superior knowledge of fermentation technologies. Since fermentation techniques are essential for industrial-scale production of many biotechnologies, Japanese corporations may outpace the US in commercialization of modern biotechnology. Nevertheless, American and European companies have remained competitive in antibiotic production and other areas, and are quite able to acquire needed expertise in fermentation. The outcome of this corporate battle, so often seen through our nationalistic lenses, is by no means assured.

The Japanese government has played a very visible role in supporting biotechnology programmes, but some analysts feel that its role in catalysing technological advancement is overemphasized. In fiscal year 1986, the Japanese government's budget for biotechnology was just $196 million, about one-fifth of the US government's commitment.[30] According to *Biol Technology* magazine, a report published in 1988 by the US Department of Commerce, *Biotechnology in Japan,* stresses that private industry has played the major role in making Japan a world class biotech player. In 1986, 325 Japanese companies maintained significant research and development efforts in biotechnology, spending approximately $860 million.[31]

In 1987, Japanese corporations continued to forge strategic partnerships with US and European biotech companies (30 agreements were formed between Japanese and US biotech companies in the first seven months of 1987).[32] However, researchers at the North Carolina Biotechnology Center note that these partnerships appear to have been decreasing in importance over the past few years. They conclude:

> This could indicate that the Japanese view their internal expertise in biotechnology as having attained a level sufficient to maintain future growth. Although it is likely that Japanese corporations will continue to form partnerships with companies worldwide, this strategy now appears secondary to the building of internal technological strength.[33]

And how do the Japanese view their competitive biotech position? A 1987 survey of Japanese companies involved in biotechnology reveals that 11 per cent believe their industry is ahead of US competition, and 54 per cent feel

Japan is second to the US. Two years ago, none of those surveyed felt Japan outranked the US, and 24 per cent said it lagged far behind.[34]

The rise of Europe

Biotechnology in Europe may be even less understood than biotechnology in Japan. The term 'European biotechnology' is probably a misnomer. Despite the existence of several programmes transcending national borders, lumping together the diverse number of company, government and academic initiatives both misrepresents and underestimates the scope of work in progress.

Without a doubt, the basic research being conducted in Europe in the field of biotechnology is considered 'world class'.[35] As an aggregate, European biotechnology comes close to the US effort in terms of the number of companies, scientific training and government funding.[36] But there are several important differences.

The European industry is concentrated in large, established corporations which have long-term research and development programmes and strong cash reserves. In the absence of venture capital, relatively few new biotech firms have been established to commercialize biotechnology. (The major exception is the United Kingdom, where about 24 biotech firms have been established.) Large European corporations and national governments have been the driving forces in the development of European research.[37]

Similar to US and Japanese corporations, major European-based corporations gained access to basic research by establishing agreements with US biotech firms. According to data compiled by the US Department of Commerce, Western European-based corporations entered into 173 agreements with US biotechnology firms between 1981 and March, 1986. The United Kingdom topped the list with 35 agreements, followed by the German Federal Republic (31); Switzerland (26); and France (21). This compares to 141 Japanese agreements with US biotech firms during the same period.[38]

In contrast to Japanese corporations, European-based companies have established a significant presence in the United States. At least ten major European corporations, for example, have major US operations (research or manufacturing facilities).[39] And at least eight European companies have put together US subsidiaries focusing on biotechnology. These include Bayer (FR Germany), Biocon (UK), Boehringer-Mannheim (FR Germany), Elf Acquitaine (France), Fisons (UK), Gist Brocades (the Nether-

lands), BASF (FR Germany) and ICI (UK).[40] Conversely, while US biotech houses have also founded bridge-heads in Europe, these have not tended to be successful and companies such as Biogen have had to sell off their operations to other European firms such as Hoffmann-La Roche and Boots.

In contrast to the US government's support for biotechnology which focuses almost exclusively on *basic* research, many European government programmes have focused on commercial goals of biotechnology by supporting *applied* research and development efforts. Many industry analysts feel that the emphasis on transfer of research from government laboratories to industry will facilitate the commercialization of biotechnology in Europe.[41]

Four European nations (Spain, the Netherlands, France and FR Germany) have national programmes to support and coordinate biotechnology efforts. The governments of Denmark, Sweden and Italy have also proposed such programmes.[42]

The greatest involvement in biotechnology is in the United Kingdom, where the British government has launched a variety of publicly-supported initiatives.[43] A recent example is the government's sponsorship of a consortium of 11 British companies, both large and small, to conduct a US $4.5 million research effort on plant biotechnology.[44]

In addition to the efforts of individual nations, the Commission of European Communities has also created programmes to consolidate biotechnology efforts in Europe. The European Community's biotech R&D budget for 1987-1991 is approximately US $150 million. About $25 million of this will go to the Biotechnology Action Programme (BAP). Founded in 1985, BAP supports research and training, coordination of government policies involving biotechnology processes, uniform regulatory policies, patent laws and other projects. About $5 million of the European Community's budget is earmarked for risk-assessment research, and the same amount is designated for a feasibility study on sequencing and mapping the human genome. The European Community's programme for 1990-1995 will be known as BRIDGE (Biotechnology Research for Industrial Development and Growth in Europe). According to *Bio/Technology* magazine, BRIDGE will be more closely linked to industry than past efforts.[45]

Other groups serving biotechnology interests in Europe include: The European Molecular Biology Organization (EMBO) based in the German

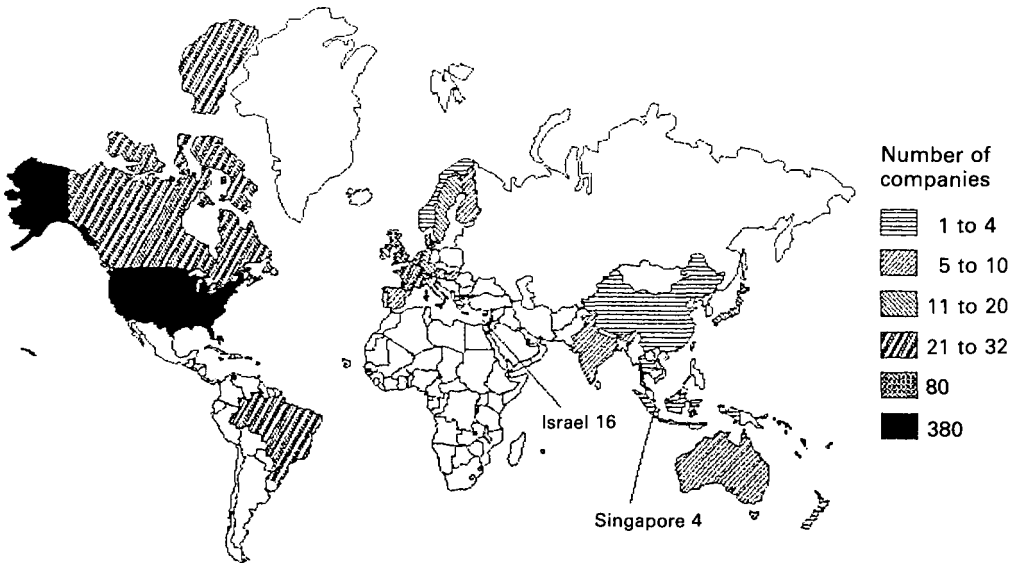

Figure 17 World biotech companies

Federal Republic which promotes transfer of information, basic research, and training in molecular biology; the European Federation of Biotechnology, founded in 1978 to promote biotechnology through conferences and documentation; and the European Biotechnology Information Project (Science Reference Library, London) which coordinates biotechnology information within the European Community.

The future

The worldwide biotechnology industry, with a history of little more than one decade, is rapidly emerging as the largest growth industry of this century.

Commercial biotechnology made its start in the United States with initial research conducted in university laboratories, and later the creation of several hundred new biotechnology firms. Today, transnational enterprises around the world are playing a much more visible role in biotechnology research and development. Whether through a variety of 'partnering' agreements with small biotech firms or their own in-house research, these corporations may soon dominate the field.

Numerous studies prepared by industry and governments on the subject of biotechnology tend to focus on the competitive positions of Europe, Japan and the United States in the race to commercialize new biotechnologies. In reality, the question of which *country* will dominate in the field of biotechnology misses the mark.

In all areas of the world where biotechnology is being commercialized the common denominator is the increasingly significant role played by giant, transnational enterprises. Ultimately, these corporations pledge no allegiance to individual nations or geographic boundaries.

In fact, the only significant geographic boundaries may be those between South and North. As the map indicates, Africa is virtually devoid of any commercial biotech activity while the activity in Brazil, India and Singapore often appears to be little more than exploration and testing platforms for European biofirms.

We are witnessing not only scientific and technological breakthroughs, but dramatic transformations in the structure of traditional industry sectors. Corporate mergers, acquisitions and product diversification are not new to the corporate world, but biotechnology adds a new dimension to the current trends.

Under the general, all-encompassing description of 'life sciences' or 'genetic supplies', corporations are diversifying into every field or specialty which uses living organisms as a means of production. Traditional industry sectors are thus becoming less distinct, and corporate boundaries virtually unlimited.

In recent years, for example, large, non-pharmaceutical corporations have developed a new emphasis on pharmaceutical efforts through biotechnology R & D. These include Du Pont, BASF, Nestlés, Monsanto, Proctor & Gamble and Dow, among others. In Japan, at least 10 major Japanese chemical companies, 15 food processing companies and 4 textile companies have announced biotech-related pharmaceutical projects. Because of their history with fermentation technologies, Japanese brewers and distillers like Kirin and Suntory are now becoming players in pharmaceuticals.[46]

Once, 'power' was land—controlling what grew on it and what came from under it. Then 'power' became manufacturing—the smokestack industries. Today, 'power' is life. BASF found that the same fungus could either be a fungicide or a tranquilizer. Henkel has learned that the same plant can either be used in medicine, to wax cars or make detergents. And 'life' is becoming the private preserve of transnationals and venture capitalists.

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On Mars and Microbes

Biological Warfare: Plants and People

The ancient Roman condemnation of well poisoning, printed below as a motto for this chapter, bears witness to the fact that chemical and biological warfare is as old as societal taboos against it. Historically, these taboos have reinforced the practical difficulties in using chemical and biological warfare (CBW)—namely that its use is dangerous and unpredictable even for the aggressor. Today, biotechnology is rekindling the interest of the military in CBW and threatens to fuel yet another arms race, an arms race in diseases and toxins. Cary Fowler guided us through a long evening discussion on biological warfare at Bogève.

Armis Bella Non Venenis Geri
(War is waged with weapons, not with poisons)

A look back

In the middle ages plague struck Europe, killing some 25 million people. It was spread in part as the result of biological warfare. In 1346, the Mongols, frustrated by their unsuccessful three-year seige of Caffa (the present-day Feodosija, a Crimean seaport), placed plague-infected bodies on their hurling machines and pitched them over the walls of the city. (There are reports that the Russians used similar methods against Swedes in the 1700s.)[1] The disease spread rapidly. Half the inhabitants died. Those that could, fled the city, taking the plague with them all over Europe.

By the 16th century—just two hundred years later—manuals were being published in Italy describing how to construct artillery shells filled with disease.[2] Two centuries later the British infected blankets with smallpox and gave them to tribes of American Indians to 'extirpate this execrable race'.

In World War I, Germany used poison gas against Allied troops resulting in one million casualties, but biological warfare (BW) was never a serious threat, even though Germany carried out several sabotage missions. They infected South American pack animals being sent to Europe with anthrax, and in the US, a spy working with a home laboratory succeeded in introducing glanders to some cattle.[3] Later, Italy employed gas extensively in its war against Ethiopia in 1935-36.

In World War II, however, the threat of biological warfare became quite real. Churchill reportedly considered the use of anthrax against major German cities. Anthrax is a disease which can strike both animals and people. Inhaling the spores of anthrax almost always leads to death from suffocation within a few days. The spores can live in and contaminate the

soil for years and are resistant to quick freezing, boiling and disinfectants. In preparation for possible use, the British tested anthrax on the Scottish island of Gruinard, which is uninhabitable to this day. But they never used it against Germany perhaps out of fear that the Germans would retaliate. And they could have. The Germans had stockpiles of poison gas around the country. But Hitler, who himself had been exposed to mustard gas in World War I, was disinclined to use the gas in open warfare for a combination of personal and tactical reasons—though it was used with deadly effectiveness in the concentration camps.

Both Japan and the United States had major CBW programmes, however. In the early 1930s a Japanese army surgeon, Shiro Ishii, established a lab at the Harbin Military Hospital where he began experimenting with biological warfare agents. Ishii was talented, dedicated and ambitious. He knew the Geneva Protocol of 1925 prohibited the use of biological weapons and so reasoned they must be very potent. He persuaded the government of their potential usefulness, and in 1937 the government authorized him to establish a major biological warfare research institution. Established in Pingfan in Manchuria far from where any mishap could harm the Japanese, Ishii assembled a staff of 3000.[4] There Ishii and his colleagues worked with some of the world's most deadly diseases. To test his diseases, Ishii sacrificed thousands of animals—500 sheep, 200 horses and thousands of mice and guinea pigs in one two-year period.[5] More horrifying were Ishii's records which contained numerous references to experiments with monkeys, for years later researchers were able to confirm that Ishii's 'monkeys' were in fact human beings. According to science writer Jeanne McDermott:

> Initially, he experimented on Russian, Chinese, Korean, and Manchurian prisoners of war, bandits, spies, dissidents, petty criminals, and others he deemed somehow inferior [including, according to other reports, American, British and Australian prisoners of war][6]. The experiments ranged from the gruesome to the horrific: Ishii's researchers injected tetanus into the heels of prisoners; left naked men outdoors in temperatures 40 degrees below zero until their limbs froze solid as rock; fed them typhus-contaminated tomatoes; placed prisoners in glass rooms and sprayed them with anthrax, cholera, typhoid, plague-infected fleas, and other diseases to calculate the minimum lethal dose; contaminated chocolate, bread, tooth powder, milk, cream, and butter with anthrax spores; tied prisoners to a stake and then exploded germ bombs overhead while soldiers wearing protective gear timed their deaths with stopwatches; infected women with syphilis, impregnated them and, after the child's birth, vivisected both; drained blood from humans and replaced it with horse and monkey blood in order to create artificial blood; dissected prisoners alive. In these hellish ways, three thousand died. But the death toll might have been three to four times higher.[7]

Table 17 Diseases and agents studied by Japanese BW research workers during 1933-45

Anthrax*	Plant Diseases
Botulism*	Salmonella*
Brucellosis*	Typhus*
Cholera*	Songo*
Dysentery*	Smallpox*
Fugu Toxin	Streptococcus*
Gas Gangrene*	Tetanus*
Glanders*	Tick Encephalitis*
Influenza	Tuberculosis*
Meningococcus*	Tularemia
Mucin	Tsutsugamushi*
Plague*	Typhoid*

* = used on human subjects[8]

In addition to these 'in-house' experiments, the Japanese conducted 'field trials' in China by attacking at least eleven Chinese cities. Thousands were hospitalized. Hundreds were infected with plague. In the countryside of Central China, the Japanese army spread 130 kilos of anthrax and paratyphoid.[9] Apparently Ishii lobbied for more wide spread use of his diseases (including their use on Iwo Jima). And in 1944, a ship loaded with biological weapons was sent to the Pacific island of Saipan, but it sank before arriving.[10]

Ishii's programme ceased only with the arrival in August 1945 of the Russian army, which later estimated the productive capacity of the experiment station at eight tons of bacteria a month.[11] Realizing the end was near, Ishii ordered the destruction of his experiment stations and fled with reams of data from his years at Pingfan. Later the Americans tracked down Ishii and during a series of interrogations offered him a deal he could not refuse. The US had concluded that, 'The value to the US of Japanese BW data is of such importance to national security as to far outweigh the value accruing of "war crimes" prosecution'.[12] So, in order that 'individuals who voluntarily contributed this information will be spared embarrassment...' and to get the data for themselves while preventing the Russians from getting it, the US traded immunity from war crimes prosecution for the data (including 8,000 slides) and then proceeded to deny for three decades that anything very sinister had occurred at Pingfan.[13] Most of this data is still 'classified' by the US government.

Compared with Japan, the US began its biological warfare programme late in the game. Officially initiated only in 1943, the effort was headed by

George Merck of the giant Merck drug company. The US chemical warfare effort, however, was without equal. The US ended the war with 135,000 tons of poison gases compared with Japan's 7,500.[14] And as the war was ending, the Americans were shipping anticrop agents to their bases in preparation for a mission against Japan's rice crop.[15] Secret work was initiated at 28 universities, most of it concentrated on botulism and anthrax.[16] Before the war's end, the US had conducted tests with anthrax on Horn Island off the Mississippi coast in the Gulf of Mexico[17] and had constructed an anthrax manufacturing plant in Vigo, Indiana, capable of producing over 500,000 anthrax bombs a month.[18]

Post war: the war continues

While the plant never went into production, research and development of biological weapons continued after the war. Merck argued successfully that 'work in this field, born of necessity of war, can not be ignored in time of peace'...[19] Thus the world's first peacetime biological warfare programme was born.

Between 1945 and 1969, the US military conducted well over 200 known experimental disseminations of micro-organisms, spraying some 239 populated areas.[20] All were top-secret at the time. For six days in 1950 scientists from Camp Detrick together with the US Navy 'attacked' the city of San Francisco with *Serratia marcescens,* a supposedly harmless bacterium, from a navy ship in San Francisco Bay. Scientists calculated that virtually every person in the city was exposed. Controversy still exists over whether the experiment caused any deaths, as it turns out that the bacterium is not quite as harmless as originally thought.

The military sought to test its weapons in virtually every possible situation and in every ecological niche: in Alaska, in the deserts, in national forests, in San Diego, San Clemente and Santa Barbara, California, in Saint Louis and Corpus Christi, in Savannah, off the shore of Virginia, in Hawaii, along the Pennsylvania Turnpike and at military bases across the US. It ventured across the border, testing on the Canadian prairies (Alberta) and in the maritime provinces. In the summer of 1953, the city of Winnipeg, capital of the Canadian province of Manitoba, was sprayed with a mixture of zinc sulphide and cadmium sulphide. Cadmium is highly toxic but authorities claimed that the amount citizens were exposed to was within acceptable limits. Even in the US, the government continued to use organisms 'long after some medical experts had published reports describing human illnesses, and even death, resulting from infection with the same type of organism', according to US Senator Richard Schweiker.[21]

Crop and livestock diseases were tested as well. Fields in Minnesota, Florida, Kansas, North Dakota and Texas were sprayed. And stockyards in several midwestern states were the subject of experimentation.[22]

At Washington D.C.'s National Airport, unsuspecting passengers were 'infected' with bacteria to test dispersal characteristics. And in a particularly ambitious experiment, the subway system of New York City was attacked. Researchers report that subway passengers simply brushed off the powder spewing forth from ventilating shafts and went on with their business.[23]

The real diseases were also tested in open-air situations, many at the army's Dugway Proving Ground in Utah. At the University of Washington, the military dropped Newcastle disease over the university's chicken farm.[24] And according to McDermott, 'At the University of Maryland, prisoners from Maryland's state penitentiary became the first human volunteers to be deliberately infected with diseases as a means of testing vaccines'.[25] The army also experimented on Seventh-Day Adventists, a religious sect which objects to formal military service, but does not object to non-combat service—in this case as guinea pigs for the army's biological warfare research. McDermott states that this programme sought vaccines for anthrax, Q-fever, tularemia, psittacosis, and Venezuelan equine encephalitis, 'as well as information about the symptoms of the diseases and infections and the lethal nature of the strains that cause them'.[26]

Apparently the 'real' diseases were not only tested, but used. Information about actual deployment is sketchy for obvious reasons. But evidence exists that the CIA seriously considered several political assassinations and actually attempted using biological weapons against Patrice Lumumba, the first Prime Minister of the Congo (Zaire), Iraq's Colonel Abdul Kassem, and, of course, Cuba's Fidel Castro. Elaborate and bizarre plots were hatched against Castro, including one to expose him to a powder to make his beard fall out, thus—according to the CIA—rendering him less charismatic![27] Serious evidence has also been uncovered linking the CIA with the introduction of African Swine Fever into Cuba in 1971. Cuba was the first country in the Western hemisphere to experience this particularly virulent disease, which killed half a million hogs on the island.[28] And it has since spread to Haiti necessitating the extermination of hogs there.

The US was not alone in the testing and use of biological weapons. The British government subjected virtually all of England to open-air testing and performed tests in the Bahamas as well. And while information about

the activities of the Soviet Union and East European countries is scarce, it seems clear that they too were involved at least in research.

Despite all the testing and the isolated examples of use, it has never become very acceptable to engage in chemical or biological warfare. Through the ages it has always been more civilized, more decent to kill with spears, guns and atomic bombs. Even today as politicians and military leaders casually talk of firepower and megatons, the subject of chemicals and bugs seems impolite. In fact, in virtually every case in the past where chemical and biological warfare has been employed, it has been used against the defenseless. And in every case there has been a concerted attempt at anonymity,

Limitations of BW lead to 'disarmament'

The biggest problem with CBW has always been the difficulty of targeting. Biological weapons could be frighteningly effective. But they could not be controlled. Infecting one's enemy was often tantamount to committing suicide. It was difficult to prevent the disease from returning to infect you.

Added to this was the negative public opinion associated with these bizarre and lethal weapons. Since the effectiveness of biological weapons is linked in some ways to their oddity (and the resulting lack of natural defences), it has always been clear in the past who was responsible for the deed during any conflict. Few countries have felt comfortable being known for 'playing dirty' in warfare.

For these reasons, the military of most countries has not viewed CBW as viable. In 1969, after years of testing and stockpiling, President Nixon ordered the destruction of US CBW agents. Three years later, the US signed the Biological Weapons Convention (now adhered to by over 100 nations, excluding most notably Israel, Syria, Egypt and Iraq). The Convention bans development, production and stockpiling of biological weapons and is the only disarmament treaty that bans possession. Fifty years after the drafting of the Geneva Protocol of 1925, declaring the signatories' opposition to the first use of these weapons, the US signed the document and began further negotiations on a chemical weapons treaty. Thus, from the use of chemical agents in World War I, to research and development and stockpiling of CBW agents after World War II, we came to a period of disarmament from the late 1960s to the mid 1970s.

From disarmament to rearmament

The trend to disarmament was fueled by the two big practical problems in the use of CBW: targeting and public opinion. By the mid 1980s, break-

throughs in biotechnology—specifically, genetic engineering—were making it possible to solve both of these problems.

With the new-found ability to move genes, scientists gained the ability to create 'new' diseases specifically designed for a particular situation, a particular population—possibly even a specific ethnic group. For the first time sophisticated targeting was feasible.

With the insertion of new genes, naturally infectious agents could be increased in virulence. Harmful genes could be inserted into benign organisms, which would then be recognized as 'normal and safe' in the plant or person to be infected. The new biological warfare creations could be made resistant to known antibiotics and vaccines. Conversely, vaccines could be developed to protect at least a portion of one's population from the effects of a weapon used against others. Yet, since it would always be faster to create a new disease than it would be to anticipate the new disease and develop a vaccine, no real defence against biological warfare would be possible in the age of biotechnology. Biotechnology, therefore, presented aggressors with a natural advantage. Aggressors could now create a disease so novel that no defence was likely or practical. One need not build a better missile or a bigger bomb. Quantity hardly mattered, for the first use of a biological weapon for which there is no defence is quite sufficient.

Biotechnology also effectively addressed the problem of adverse public opinion. With biotechnology, alterations could be made to an organism to interfere with its diagnosis or evaluation. Who is to say if a new disease or more virulent form of an old disease is caused by human intervention or natural mutation?

By the 1980s 'biotech warfare' would allow war to be waged secretly with just as much effect as any bomb or rifle. But with biotech warfare, only the victim is identified. The aggressor remains anonymous. The benefits are obvious.

These benefits did not go unnoticed. The number of unclassified US Department of Defense projects using recombinant DNA and monoclonal antibodies jumped from zero in 1980 to over one hundred in 1984. Expenditure for the now mushrooming American programme increased by over 900 per cent between 1979 and 1986. And while federal support for university research in the life sciences was withering under the Reagan administration, military funding of university research was enjoying a revival, up by 50 per cent in the first four years of the decade. Over 100 corporate and university

laboratories as well as 18 government laboratories are now involved in this work.[29] Indeed, current US expenditures for its 'defensive' biological warfare programme adjusted for inflation now far exceed the budget given to the old offensive programme in the 1960s. The 1988 budget for America's CBW programme is close to 1.5 billion dollars!

Indicative of what may be a new trend involving private industry, the US Department of Defense awarded a three-year $1,762,000 contract to Molecular Genetics, an international animal health care and agricultural biotechnology company to work on Rift Valley Fever virus, a disease affecting cattle and people in the Middle East and Africa.

The US is not the only country involved in CBW. The US State Department estimates that ten to twelve countries now have offensive CBW capabilities. Among non-government experts the estimates run as high as twenty-five.[30] According to Marc Lappe, a noted health policy expert at the University of Illinois, 'As early as 1919, Lenin established a bacteriological weapons institute, and evidence suggests that Russia has pursued a biological warfare programme uninterrupted since then'.[31]

The increased research in CBW is now yielding accusations between the super-powers, both that CBW has actually been used in Afghanistan and Southeast Asia, and that 'defensive' research programmes are really offensively oriented. Both the US and the USSR have recently charged each other with trying to develop a virus or bacterium with cobra venom genes, for example. Such allegations now threaten to ignite a CBW arms race despite the existence of the Biological Weapons Convention, the first treaty to ban even the possession of an entire class of weapons.

CBW and low-intensity warfare

Thus far most of America's unclassified research projects have dealt with human diseases: anthrax, plague, Dengue virus, gonorrhoea, salmonella, etc. However, we suspect that the ultimate target of biological warfare will not be people, but agriculture. Two factors prompt this conclusion:

1. Agriculture offers splendid opportunities for targeting. While industrialized country crops are certainly vulnerable, most low-intensity wars are fought in Third World countries. In such conflicts, outright military victory is often very costly or simply not possible. Such wars are long, drawn-out wars of attrition, where the economy is as much a target as the military. Biological warfare offers the opportunity to sabotage agricultural systems —particularly those made more vulnerable by monoculture and lack of

genetic diversity. One country's coffee crop, another's cocoa could easily be destroyed with no effect on the crops of a neighbouring country and certainly no effects on entirely unrelated first world crops. And given the thousands of plant diseases and the equally large number of vectors, the possibilities are as endless as they are effective.

2. Public opinion is less aroused by a plant epidemic than, let us say, an outbreak of cobra bite symptoms in New York or Moscow. Plants lack immune systems and must depend on natural genetic resistance to fight most diseases. The prevalence of monoculture helps make plant epidemics relatively common. Who could tell if an epidemic striking Nicaragua's coffee crop was the result of a chance disease mutation and bad luck, or was the deliberate introduction of a genetically-altered disease? In fact, who can say with certainty that Florida's recent experience with citrus canker (wherein millions of trees had to be destroyed) was not biological warfare? After all, the disease was only found in nurseries, the perfect place to strike if one's aim is to spread a disease. Finally, with agriculture, suspicions do not have to be raised by mass vaccinations of one's own population or military. Any mass public health campaigns to vaccinate a population against an obscure disease would obviously create alarm. But an attack against agriculture creates no such suspicions and thus increases the possibility that the operation can be carried out in secrecy.

Alexis Shelikoff, a virologist with the Salk Institute, the largest contractor with the US Army Fort Detrick's biowarfare programme noted that, 'A desirable weapon is one that affects, say, livestock, and may affect people but not kill them. Rift [Rift Valley Fever] ....has a very high virulence for a number of animals, so presumably if you used it as a biological weapon, what would happen is you would wipe out sheep, cows, horses, and cattle, all kinds of animals, and give humans a flulike illness maybe'.[32] Rift Valley Fever could be used to incapacitate enemy troops. And a vaccine might be helpful to US troops were they to be active in North Africa. But it would be most effective as a natural and anonymous method for dealing a blow to an adversary's agricultural system.

US interest in agriculture and CBW was confirmed in CIA testimony to the Senate Select Committee on Intelligence Activities in the 1970s, before biotechnology was fully appreciated in military circles. The CIA acknowledged that it had developed 'methods and systems for carrying out a covert attack against crops and causing severe crop loss'.[33]

Virtually no country's agriculture is completely safe. In an unpublished

paper, 'Biological Terrorism: A Direct Threat to Our Livestock Industry', two Ohio State University veterinarians state that a certain three diseases, if intentionally spread in the US could destroy 90 per cent of hog, beef, dairy and poultry stocks.[34]

The biological weapons convention

The landmark Biological Weapons Convention, which went into force in 1975, is today threatened by the growing belief among the world's military establishments that biotechnology could be used to make biological weapons feasible and useful.

The Convention is a far reaching and potentially strong document, but it has several significant weaknesses. While it outlaws the development, production, possession and stockpiling of biological weapons for offensive, military purposes, it allows research, development and possession for 'prophylactic, protective and other peaceful purposes'.

This language begs the question, 'What is a protective or peaceful purpose?' With biological warfare, a reliable defence is a prerequisite to any offensive use. Countries may say they are researching defences against a novel disease, but to do so they must first develop that disease. Thus the steps towards developing an offensive capability are indistinguishable from defence. Successful defence is necessary as a tactical ingredient of offence.

A number of scientists, like MIT's Jonathan King, have argued that there is a fundamental flaw in the argument that defence against biological weapons is feasible. Given the thousands of diseases and the almost infinite versions of them that could be concocted, a successful defence would depend on (1) knowing what disease was going to be used by the enemy; (2) knowing the nature of any alterations made to that disease; (3) having the time, ability and resources to discover, develop and mass-produce an effective vaccine; (4) successfully administering the vaccine to one's own population without the knowledge of the enemy, and (5) being granted enough time—in some cases, several weeks—for the vaccine to take effect before the attack. All five of these conditions would have to be met to defend against a biological warfare attack. But in order to launch a successful attack, one would only have to have administered a vaccine to those one wished to protect prior to the attack. Were the attack aimed at agriculture, not even this precaution would be needed.

These factors make countries very suspicious of their rival's 'defence-oriented' research programmes. Despite its billion dollar 'defence' against

Table 18 States parties to the 1925 Geneva Protocol; the 1948 Genocide Convention; and the 1972 Biological Weapons Convention

Number of parties as of 31 December 1987

1925 Geneva Protocol (GP)	111
1948 Genocide Convention (GC)	96
1972 Biological Weapons Convention (BWC)	110

	GP	GC	BWC		GP	GC	BWC
Afghanistan	1986	1956	1975	France	1926	1950	1984
Albania		1955		Gabon		1983	S
Algeria		1963		Gambia	1966	1978	S
Argentina	1969	1956	1979	German Democratic Republic	1929	1973	1972
Australia	1930	1949	1977	FR Germany	1929	1954	1983
Austria	1928	1958	1973	Ghana	1967	1958	1975
Bahamas		1975	1986	Greece	1931	1954	1975
Bangladesh			1985	Grenada			1986
Barbados	1976	1980	1973	Guatemala	1983	1950	1973
Belgium	1928	1951	1979	Guinea-Bissau			1976
Belize			1986	Guyana			S
Benin	1986		1975	Haiti		1950	S
Bhutan	1978		1978	Holy See (Vatican City)	1966		
Bolivia	1985	S	1975	Honduras		1952	1979
Botswana			S	Hungary	1952	1952	1972
Brazil	1970	1952	1973	Iceland	1967	1949	1973
Bulgaria	1934	1950	1972	India	1930	1959	1974
Burkina Faso (formerly Upper Volta)	1971	1965		Indonesia	1971		S
				Iran	1929	1956	1973
Burma		1956	S	Iraq	1931	1959	S
Burundi			S	Ireland	1930	1976	1972
Byelorussia	1970	1954	1975	Israel	1969	1950	
Canada	1930	1952	1972	Italy	1928	1952	1975
Cape Verde			1977	Ivory Coast	1970		S
Central African Republic	1970		S	Jamaica	1970	1968	1975
Chile	1935	1953	1980	Japan	1970		1982
China	1929	1983	1984	Jordan	1977	1950	1975
Colombia		1959	1983	Kampuchea	1983	1950	1983
Congo			1978	Kenya	1970		1976
Costa Rica		1950	1973	Korea Dem. People's Rep			1987
Cuba	1966	1953	1976	Korea, Republic of (South)		1950	1987
Cyprus	1966	1982	1973	Kuwait	1971		1972
Czechoslovakia	1938	1950	1973	Lao People's Democratic Republic		1950	1973
Denmark	1930	1951	1973				
Dominican Republic	1970	S	1973	Lebanon	1969	1953	1975
Ecuador	1970	1949	1975	Lesotho	1972	1974	1977
Egypt	1928	1952	S	Liberia	1927	1950	S
El Salvador	S	1950	S	Libya	1971		1982
Ethiopia	1935	1949	1975	Luxembourg	1936	1981	1976
Fiji	1973	1973	1973	Madagascar	1967		S
Finland	1929	1959	1974	Malawi	1970		S

	GP	GC	BWC		GP	GC	BWC
Malaysia	1970		S	Sierra Leone	1967		1976
Maldives	1966	1984		Singapore			1975
Mali		1974	S	Solomon Islands			1981
Malta	1970		1975	Somalia			S
Mauritius	1970		1972	South Africa	1930		1975
Mexico	1932	1952	1974	Spain	1929	1968	1979
Monaco	1967	1950		Sri Lanka	1954	1950	1986
Mongolia	1968	1967	1972	Sudan	1980		
Morocco	1970	1958	S	Sweden	1930	1952	1976
Nepal	1969	1969	S	Switzerland	1932		1976
Netherlands	1930	1966	1981	Syria	1968	1955	S
New Zealand	1930	1978	1972	Taiwan	*	+	1973
Nicaragua	S	1952	1975	Tanzania	1963	1984	S
Niger	1967		1972	Thailand	1931		1975
Nigeria	1968		1973	Togo	1971	1984	1976
Norway	1932	1949	1973	Tonga	1971	1972	1976
Pakistan	1960	1957	1974	Trinidad and Tobago	1970		
Panama	1970	1950	1974	Tunisia	1967	1956	1973
Papua New Guinea	1981	1982	1980	Turkey	1929	1950	1974
Paraguay	1933	S	1976	Uganda	1965		
Peru	1985	1960	1985	UK	1930	1970	1975
Philippines	1973	1950	1973	Ukraine		1954	1975
Poland	1929	1950	1973	United Arab Emirates			S
Portugal	1930		1975	Uruguay	1977	1967	1981
Qatar	1976		1975	USA	1975	1986**	1975
Romania	1929	1950	1979	USSR	1928	1954	1975
Rwanda	1964	1975	1975	Venezuela	1928	1960	1978
Saint Lucia			1986	Viet Nam	1980	1981	1980
Saint Vincent and the Grenadines		1981		Yemen Arab Republic	1971		S
				Yemen, People's Democratic Republic	1986	1987	1979
San Marino			1975				
Sao Tome and Principe			1979	Yugoslavia	1929	1950	1973
Saudi Arabia	1971	1950	1972	Zaire		1962	1977
Senegal	1977	1983	1975				
Seychelles			1979				

Notes: S = signed treaty.
* The Geneva Protocol, signed in 1929 in the name of China, is valid for Taiwan which is part of China.
+ The Genocide Convention was ratified in 1951 by Taiwan in the name of China. The People's Republic of China consider this ratification as null and void.
** The United States ratified the Genocide Convention in February 1986.
Source: SIPRI Yearbooks 1986 and 1988.

biological war, the US in 1983 had stockpiled only enough vaccine to protect 600 people against anthrax and 150,000 against Rift Valley Fever.[35] Given the fact that—at least until recently—anthrax could be ordered through the mail from some supply companies for as little as $35,[36] could anyone possibly feel defended by any government's defence programme?

If defence against attack is virtually impossible, and if some type of protection, like a vaccine, is necessary in order to initiate a biological warfare attack, then virtually all 'legal' defensive work done under the Biological Weapons Convention becomes suspect. The Convention cannot distinguish between offensive and defensive research and development except by the intent of the researcher. Who is to judge intent?

With biotechnology, the legal possession of even a minute quantity of disease or toxin for defensive research can be enough to multiply quickly for offensive purposes. This can be easily done since the Convention contains no provisions for verification.

Towards a real defence against biological warfare

In an excellent article in the book. *Biological and Toxin Weapons Today,* published by the Stockholm International Peace Research Institute, Richard Falk of Princeton University argues that we must work to restore trust in the Biological Weapons Convention. Signatory states, of which there are now over 100, must create a climate in which not only the letter but also the spirit of the Convention is observed.

> It is the underlying comprehensive prohibition of any capability to wage biological war, even in retaliation against prior use of biological weapons, that constitutes the special contribution of this Convention. Its very quality of extensiveness virtually dispenses with the need, in one sense, of any kind of precise monitoring, and in another, makes such monitoring a futile enterprise as it would seem easy to circumvent by a crafty violator. There is no way to rest confidence in the Convention on an assured capability to detect violations.[37]

Recognizing that in the age of biotechnology, no convention can provide complete assurance against the threat of biological warfare, our only hope lies in constructing a peace based on real, concrete expressions of trust predicated on mutual self-interest. (Since no other defence is possible anyway, what is there to lose?) Such a peace would begin with a new commitment to openness. Governments should offer full disclosure about their current biological warfare programmes. And in the future no such research should be classified—classified research only creates suspicions and thus only adds fuel to the arms race. (Recently the USSR, responding

to US charges that it had stockpiled 250,000 to 700,000 tons of chemical weapons, for the first time released an estimate of its own holdings—50,000 tons—approximately what the US is suspected of possessing. The statement called attention to the destabilization that would be caused if the US proceeded with its plans to produce binary chemical weapons.)

Were research programmes declassified and more information about them made available, governments could then begin to consider reducing funding for their biological warfare programmes. In November, 1987, we watched US delegates to the UN Food and Agriculture Organization argue that because of domestic budget problems, the US would be unable to pay perhaps $25 million of its assessment to the UN agency that helps feed the world's hungry. Set against America's one billion dollar CBW programme, their inability to meet their obligations to the UN can only be seen as a failure of priorities and common morality. Diverting money away from warfare and towards food, would help create stability and trust.

If nations' 'defence' programmes are truly defensive, then they should not be administered by the military, but by ministries of health and agriculture, where vaccines against other diseases are researched. As Jonathan King notes, 'The military is not in the business to alleviate suffering'.[38]

Countries could greatly add to an atmosphere of trust by opening their high-security biological laboratories to visits by scientists from other countries. Such 'inspections' would go a long way in allaying fears that deadly offensive weapons are being developed in these facilities. Exchanges of scientists as encouraged by the Convention, should be pursued. And information on any unusual disease outbreaks should be quickly supplied by the government involved. Progress in this area was made at the last review conference in 1986. Recently an anthrax outbreak in Sverdlovsk in the Soviet Union has prompted accusations that there must have been an accident with the development of anthrax weapons at a research lab in the city. This incident leads to the recommendation that governments become very, very careful in making such allegations, as false allegations only serve to heighten tensions and undermine trust in the Convention.

Article IV of the Convention requires all signatories to make sure that individuals within their borders abide by the Convention. Few countries have enacted laws requiring citizens to observe the terms of the Convention. Non-governmental organizations could help lobby for such laws —even laws more stringent and binding than the Convention itself. Borrowing a concept from the anti-nuclear movement, they might even push

for 'CBW-free zones'. In the US, Jeremy Rifkin of the Foundation on Economic Trends has taken the government to court to halt the construction of a high-containment aerosol testing laboratory. And he has consistently called for 'environmental impact statements' from the government's CBW programme.

In the US, the Committee for Responsible Genetics is circulating a petition amongst university biologists and chemists. Those who sign, pledge 'not to engage knowingly in research and teaching that will further the development of chemical and biological warfare agents' (see page 210). This is an important initiative which promises to create constructive peer pressure in universities. This effort could be duplicated elsewhere. With increasing amounts of money being offered to university scientists by the CBW programme, opportunities exist for students and faculty to educate themselves and others about the nature of biological warfare research being conducted at their own institutions.

Finally, provisions for periodic review conferences can be used to build trust and strengthen the Convention. Citizens can play an active role in pursuading their governments to participate constructively in these conferences.

In 1972, speaking to the Geneva Conference Committee on Disarmament, Nobel laureate Joshua Lederberg predicted that, 'Molecular biology might be exploited for military purposes and result in a biological weapons race whose aim could well become the most efficient means of removing man from the planet'.[39]

Today, Lederberg's fears edge closer and closer to reality. In the 1980s, developments in biotechnology have created big loopholes in the Biological Weapons Convention. Unless restraint and good judgement are applied, these developments will spark a biological arms race equally as dangerous as the nuclear arms race. Indeed such an arms race may now be underway. The likelihood of the use of these weapons would seem to be even greater than nuclear weapons, due to the ease of production, the sensitive targeting now possible and the difficulty of detection. Thus, as imperfect as it might be, the Biological Weapons Convention is humanity's best and only assurance against biological warfare. As such it deserves careful nurturing.

Notes

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35. Ibid., p. 234.
36. Douglass and Livingstone, op. cit., p. 25.
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November 5, 1987

COMMITTEE FOR RESPONSIBLE GENETICS

Dear Colleague,

We are writing to call your attention to ominous developments in the life sciences in this country. In spite of life enhancing potential, these fields are being used by a military establishment that, in the name of defending our population, actually threatens the initiation of a biological arms race. This is happening despite U.S. public renunciation of biological weapons and despite the strongest disarmament treaty in existence, the 1972 Biological Weapons Convention, which bans not only the deployment and stockpiling of these weapons, but their development as well.

As concerned individuals devoted to humane uses of science, we are writing to you on behalf of the Committee for Responsible Genetics (CRG), a group of scientists and other individuals committed to seeing the positive benefits of the life sciences instituted safely and responsibly in our society. Biological warfare--the use of deadly and debilitating disease as a weapon of war--has no place in responsible development of our field. We stand firmly opposed to the use of biological sciences for military purposes.

You may not have heard much about the build up in biological weapons research that has taken place during the current administration. Overshadowed by Star Wars and across-the-board increases in military funding, this issue has been largely overlooked by the press. Unfortunately, the threat is very real:

- Overall funding for biological warfare research has quadrupled in real dollars since Ronald Reagan took office.
- Funding in the so-called "basic research" category, much of it contracted out to universities and private firms, increased sixty-fold between 1981 and 1986. (BioScience, Vol. 37, No. 6, June 1987, p. 372)
- The Army is seeking a unique maximum containment facility which would permit studies of substantial volume of extremely hazardous viruses and other biomaterial in the form of aerosols, as used in warfare. This provocative action threatens to undermine the spirit of the treaty banning biological weapons, with concomitant danger of biological weapons proliferation and of escape, theft or deliberate release of the most dangerous agents of disease in existence.

(please continue)

- Even without the multi-million dollar Dugway facility, the U.S. is spending more on biological warfare research today than at the height of the Vietnam war when we had an acknowledged offensive program.

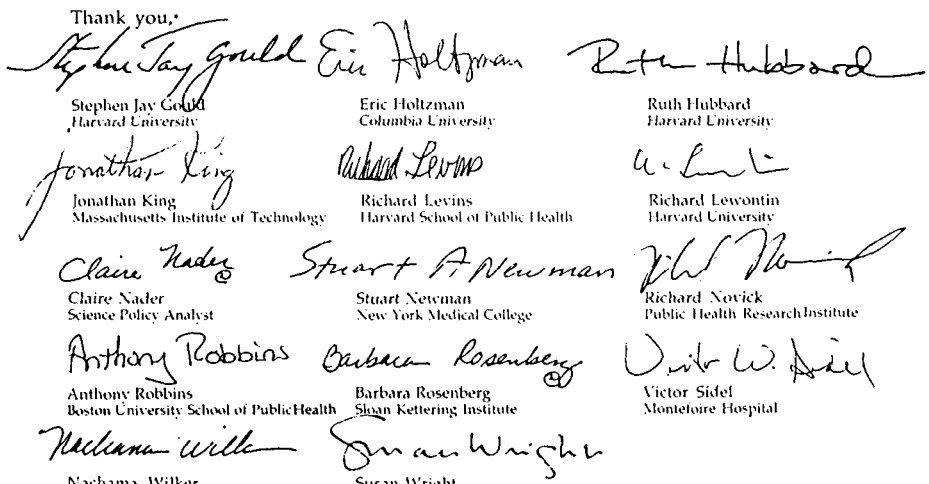
All of this research is taking place in the name of defense. "Defensive" biological weapons research, involving the growth of biological weapons agents for threat assessment and the design of defenses against them, is not easily distinguishable from an offensive research program. The spread of disease is so unpredictable and the range of biological agents that could be used is so large, that the very concept of defending against such agents is misleading. In particular, the defense of populations, even if theoretically possible would be far too expensive and prior immunization would be too observable and suggestive of offensive intention. Thus, military vaccine research is primarily useful for vaccination of troops in advance of launching an offensive attack.

The current program destabilizes the treaty and directly threatens the nation's health. This is why we are asking you to join our efforts to avert the prospect of a biological arms race by taking part in a nationwide pledge by biologists and chemists not to participate in military-sponsored biological research.

If you are involved in research or teaching in a university, medical or industrial institution, we ask you to: 1) sign and return the enclosed pledge to us, 2) make copies of the pledge and send them to your colleagues, 3) help fund the campaign using the enclosed card, and 4) stay in touch with the growing network of scientists opposed to the militarization of the biological and biomedical sciences. If you are not a scientific researcher, we still need your help to raise this issue with your friends and colleagues, and to financially support our goal of bringing the enclosed pledge to every biologist and chemist in the country.

We know that with your help we can make this campaign a success. We can help avert the threat of biological war and keep the life sciences supporting rather than threatening life.

Thank you,



Stephen Jay Gould, Harvard University
Eric Holtzman, Columbia University
Ruth Hubbard, Harvard University
Jonathan King, Massachusetts Institute of Technology
Richard Levins, Harvard School of Public Health
Richard Lewontin, Harvard University
Claire Nader, Science Policy Analyst
Stuart Newman, New York Medical College
Richard Novick, Public Health Research Institute
Anthony Robbins, Boston University School of Public Health
Barbara Rosenberg, Sloan Kettering Institute
Victor Sidel, Montefiore Hospital
Nachama Wilker, Committee for Responsible Genetics
Susan Wright, University of Michigan

(Affiliations for identification purposes only)

Regulating the Super 'Natural'

The Legal Challenge of Regulating Biotechnology

Introductions of exotic species from one locale to another have taken place since before recorded history. Such introductions form the backbone of plant and animal agriculture virtually the world over. But they are also responsible for many of the disease and pest problems that plague agriculture. Biotechnology's task is to introduce the good without unleashing the bad, a job complicated by the fact that unlike cows or cowpeas, biotech's introductions are often invisible to the naked eye. As critics have noted, 'you can't recall a micro-organism'. More troubling, the debate over regulation seems to pit the real and scientific need for regulation against the economic 'benefits' of introduction, making those who desire safety appear to be the enemies of progress. Many participants at Bogève expressed concern for the need to regulate the new technologies. In particular, Susantha Goonatilake, Pilar de Sevilla and Surendra Patel called for the creation of a model law for national governments and the United Nations system.

> Being able to handle matches easily and safely is not a general argument for the complete safety of fire.
>
> *P. J. Regal*[1]

> Bhopal at once conjures up an image of lakes, palaces, mosques and spacious gardens. Nature, too, has been kind to Bhopal and spreads its beauty to all quarters of the city...
>
> *from Air India's in-flight magazine, May, 1987*[2]

In the early Autumn of 1987, M.S. Swaminathan was probably wishing his retirement as Director-General of the International Rice Research Institute (IRRI) in the Philippines could come a little faster. Instead of being wined and dined in the predictable round of farewell parties, Swaminathan found himself penning open letters to the Philippine press defending IRRI against the most serious threat to its survival in more than a quarter century.[3] No fewer than three congressional initiatives were underway ranging from a probe into the technical competence of IRRI staff to legislation that could ultimately lead to the nationalization of the institute.[4]

The issue was an IRRI programme to study rice blast—a wide spread disease that causes substantial crop losses in Asia and elsewhere. In order to understand the highly variable pathogen, IRRI had arranged to bring in diverse samples from other countries—including from Du Pont in the United States.[5] Scientists at the University of the Philippines at Los Banos (UPLB) expressed concern that the research could lead to the release of the pathogen in the Philippines where blast has not been a major problem. Whether or not IRRI had applied for and obtained the correct permission under Philippine quarantine rules was also a matter of dispute.[6]

politicians nervous to the point of paranoia. The regulatory red tape —although not effective—is daunting, and many companies now find it attractive to test their new products offshore.

What better place to test than in the Third World where there are no laws or regulations to break? What better front to work through than a respected semi-UN institute such as an IRRI or CIMMYT? The IARC centres offer high-quality laboratories with international calibre scientists. They also have the necessary land, quarantine facilities, and diplomatic protection.

A pox on Wistar?

This may have been the thinking of the Wistar Institute in June, 1986, when the private Philadelphia group arranged with the Pan American Health Organization (PAHO) to test a new genetically-altered micro-organism as a rabies vaccine. Working from the same vaccinia, or cowpox, virus used by WHO in the war against smallpox, PAHO conducted tests in Azul, Argentina—a country without any biotech rules or regulations. Cows were injected with the new micro-organism in the field, unbeknownst to government officials. After three months of testing, a PAHO staffer inadvertently mentioned the experiment to national counterparts. Argentinians hit the roof.

In the ensuing furor, PAHO and Wistar claimed that their experiment could save the one million Latin American bovines that die each year from rabies. On the other side, 134 Argentine scientists charged that Wistar had acted irresponsibly and was merely looking for a cheap field test—one which would not have been permitted in the United States. The scientists argued that the labourers tending the tested herd had not been vaccinated against smallpox; that they were not properly monitored and that the workers and their families were allowed to drink unpasteurized milk from the injected cows. Wistar insisted that the workers had been vaccinated and were being watched for any adverse health problems.[11]

A year and a half after the experiment had been closed down, Wistar and Argentina were back in the news amid reports that blood samples from farmhands showed infection from the genetically-altered virus. Health officials in the United States were quick to insist that the infection—if it took place—was unlikely to cause a health problem for the workers involved.[12] Jeremy Rifkin, who released the news, warned that the real issue was not if the infection was dangerous but that it had happened at all. 'They said it couldn't be done', Rifkin asserted, 'but it could and was'.[13]

If Wistar claimed to be acting in the service of humanity, even its defenders in the American business establishment had their doubts. In an article decrying the unfairness of government regulation, *Forbes* magazine cited Wistar's Argentine adventure as one of two biotech examples where federal constraints forced the company to test overseas.[14]

On 'natural' and 'unnatural'

At the core of the debate over government regulation is the question of the potential danger in creating and releasing life forms the world has not known before. Will these life forms disrupt the environment? Will seemingly benign forms somehow mutate beyond their laboratory expectations when they reach the outside world? Rather than curing one problem, are we apt to create numerous new problems?

Confounding the discussion is the fact that the forms we are considering are 'natural'. Governments are accustomed to regulating 'unnatural' substances—chemicals and such. How does society monitor materials which are not synthetic?

The closest parallel to the challenge posed by biotechnology lies in the historic transfer of plant and animal species from one continent or island to another. The introduction of exotic natural species is exactly comparable to the release of genetically-engineered organisms into the environment. To understand this experience, the UN Environment Programme contracted Frances E. Sharpies. Sharpies' study—brilliant and fascinating—has yet to be published by UNEP.[15] Much of what follows is drawn from this study.

In the 12th century, Scandinavians hauled salmonoids to alpine lakes with apparent impunity. By the 1840s, the French had perfected a system of artificial propagation that made the impact of fish migration staggering in its volume. Today, Americans import more than 100 million fish a year to stock lakes and streams.[16]

Over 1,550 insect species have come to North America—almost all since 1800.[17] Dogs and pigs were off-loaded onto the Hawaiian islands long before the arrival of Europeans.[18] History records 788 successfully introduced mammals ranging from cats and cows to horses, sheep, and rabbits. Having ventured far from their original homes, these creatures are now common to every continent and most inhabited islands.[19] Two hundred and twelve bird species—including a wide assortment of chickens and doves—have been deliberately introduced into the environment of foreign lands.[20] Thirty to sixty per cent of the fish found west of the Rocky Moun-

Opposition to their research took IRRI by surprise. Breeding programmes normally test new varieties against major diseases and it is hardly unusual for a breeder to stockpile disease samples for these tests. That the stockpile would include exotic pathogens not found in the country is also not particularly surprising. After all, IRRI is an international centre developing rice for many countries and the tests were inside laboratories. Had opponents ventured to the Manila docks and monitored the pest hitchhikers on any ship, they might have found more exotic species than IRRI could provide. Some years ago, an entomologist on a rice ship from Trinidad to Manila whiled away his days by counting 41 non-paying exotic passengers—at least some of which disembarked with him.[7] With this in mind, officials at IRRI are convinced that the protest against their work is politically inspired and has nothing to do with the safety of the research.

That there is political opposition to IRRI in the Philippines is certainly true. Nevertheless, members of the Multi-sectoral Forum—the group of progressive scientists at UPLB[8] who uncovered the blast work—have valid grounds for concern. According to Pierre Benoit Joly at Bogève, one of IRRI's partners in the rice blast study, Du Pont, is one of the world's largest agricultural chemical companies and the world's largest investor in biotechnology. Du Pont launched its own rice blast study in the mid-eighties in order to develop new fungicides to combat what the company describes as 'the single most important fungal pathogen in the world'. The work involves the creation of avirulent fungal mutants and genetic transformation systems.[9] 'Avirulence' is in the eyes of the beholder. Philippine scientists are alarmed that genetically-engineered strains of blast may accidentally escape the IRRI labs and create a major new disease problem for farmers.

Along with the environmental concern comes a further and equally legitimate political concern that the IARC[10] centres may become cheap labour and 'safe' testing havens for biotech companies. Suffering under severe budget constraints and fearing being left behind in the explosive new biosciences, institutes such as IRRI might be susceptible to joint research ventures with private concerns that may give much more benefit to the company than to the Third World.

Almost single-handedly, Jeremy Rifkin of the Foundation for Economic Trends has awakened citizens in industrialized countries to the risks of introducing genetically-altered organisms into the environment. Rifkin has sued against every attempt by biotech firms to move their new life forms from the lab to the field. While he has lost a few protracted battles, the eclectic Rifkin has put the industry on alert and made both companies and

Table 19 Historic overview of exotic introductions: implications for genetically-engineered organisms

Summary of introductions	Examples	Comment
	Mammals	
788 examples for 118 species	Cats, cows, dogs, goats, horses, pigs, rabbits, rats, sheep	Comparatively low risk due to visibility
	Birds	
771 examples for 212 species	Chicken, goldfinch, doves, mynah, parrot, pheasant, sparrows	Nine species comprise 30 per cent of introductions
	Fish	
24 families, 250 species into USA	Carp, trout, salmon	Since Romans; now more than 100 million fish transfers per annum in the USA alone
	Insects	
Countless	Gypsy moth	40 per cent insect pests were introduced; insects account for 13 per cent of post harvest crop losses
	Plants	
12,000 species into Europe alone.	All major cereal and tuber crops widely dispersed	With 1500 native species, British Isles now have more introduced than indigenous species
	Micro-organisms	
Countless	Chestnut blight, Dutch elm disease, *Rhizobium japonica*	High risk due to invisibility

Note: In this table, an 'introduction' refers to the movement of a species or kind between continents or to islands. The exception to this definition is aquatic species. In this case, the introduction is from one water system to another.

tains are introduced species.[21] Forty per cent of North America's prime insect pests have also been introduced.[22] Not all accidentally. In an attempt to breed disease-resistant silk worms, a US astronomer brought the now infamous gypsy moth from Europe to Massachusetts in the late 1860s. A

mere century later, the offspring have chewed their way through five million acres of trees in the eastern United States.[23]

In comparison to higher-order animals, the impact of lowly plants is yet more substantial. Maize, rice, potatoes, wheat, soybeans, and half a dozen other crops occupy sufficient land area outside their native home to be seen from the Moon. Their environmental impact—together with cows, horses, pigs, chickens, and sheep—is literally incalculable. But without these thoughtless environmental releases, world history would have to be rewritten and there would be fewer of us around to do the writing.

Not all the transfers have been good news. Few in Florida would cheer the introduction of the Australian eucalypt, for example. Intended to dry up potholes and the like, the eucalypt seems now on its way to sopping up the Florida Everglades and endangering the deer and other mammals that forage in their vicinity.[24]

Still further down the food chain are the fungi, viruses and bacteria that we collectively refer to as micro-organisms. The negative introductions—as always—are the best known. Chestnut blight—a European fungus—has destroyed one of North America's most important trees in less than half a century. Another fungus typecast as Dutch elm disease is well on its way to eliminating another major tree. On the plus side of the equation is *Rhizobium japonica,* a bacterium brought to the USA from China that has introduced important nitrogen-fixing qualities for crop plants.[25]

The smaller they come, the easier they fail

Every year as birds and fish conduct their regular migrations, they bring to foreign shores the latest mutations in other micro-organisms.

The thing about micro-organisms is that you cannot see them. You do not know if they are there. Thus they are difficult to control. Still, very few introductions ever establish themselves. Of the survivors, far less than one per cent have left us with proof of their damage—and many have given us ample proof of their benefits.

A second concern applies especially to micro-organisms but also to the deliberate release of any product of recombinant DNA. The new products being inserted into the environment are not random mutations (which occur by the billions every day) but a genetic alteration designed to have a specific effect on, for example, a major crop or on human health. If the new organism mutates unexpectedly, exchanges genes with another organism or

does not perform as planned, the result may be immediate and serious. Many of the first products coming on stream include bioinsecticides and biofungicides—bacteria altered to be more toxic to plant pests. Some of these 'killer' bacteria have been designed to be 'auxotrophic'—constructed to debilitate over a brief time and space in the natural world. Recent studies show, however, that even 'suicidal' organisms have a tendency to seek out genes from neighbouring species that allow them to propagate and spread.[26]

In the laboratory, experiments are showing that the barriers restricting the exchange of DNA between higher and lower organisms may not be as strong as once thought. According to researchers Robert Grossmann and Bruce Koppel, 'The limitations appear to be the amount of genetic information that can be stably inherited and expressed'.[27] 'How', they ask, 'can one predict what the secondary transfer of genes is likely to be when so few micro-organisms are known?'[28] Given the complexity of interactions in the environment and our lack of knowledge, the most that could be asked of a regulatory process is that each introduction be studied on a case by case basis—a daunting prospect for any government and an inadequate response in any event.

It is difficult to construct tests that prove that a new organism has not escaped beyond its intended territory. Biotechnica International—one of the leading agbiotech companies—discovered this in July, 1987, as they prepared to test a nitrogen-fixing bacterium associated with alfalfa (lucerne). The firm had engineered *Rhizobiiim meliloti* to increase yields by 15 per cent in the laboratory. In order to monitor the spread of the bacterium, Biotechnica added a 'marker' gene that could be traceable in the surrounding environment. On the brink of the field trial, company scientists were shocked to discover that their marker gene was relatively common in the soils around the plot. There would have been no way to confirm the safety of the experiment.[29]

Biotechnica was at least more cautious than Montana State University pathologist, Gary Strobel. Also working with *Rhizobium meliloti,* Strobel field-tested his genetically-altered strains in Montana, South Dakota, Nebraska, and California in 1984—without seeking approval from anyone, and violating federal and university regulations in the process. Strobel's arrogant disregard for public safety became known a month after Biotechnica jettisoned its test proposal when the pathologist admitted to yet another release. In June of 1987, Strobel took on another exotic release —Dutch elm disease—by injecting 14 elm trees with genetically-altered *Pseudomonoas syringae.* To date, Strobel's only punishment has been in

the form of a reprimand and an order from the Federal Environmental Protection Agency (EPA) to conduct no more releases without a co-sponsor for one year. The 14 elm trees have been cut down and burned.[30] Close to a year after the incident, the National Institute of Health in the USA cleared Strobel of blame for the Dutch elm release on the grounds that the 'genetically-modified' bacteria was not covered under 'recombinant' DNA guidelines.[31]

Strobel's maverick act was not unique. Biotech companies frustrated by regulatory confusion and threatened by their venture capital funders have climbed to the rooftops of their labs and conducted open air experiments without permission.[32] Some scientists privately concede that the commercial pressure to market biotech products is so great that companies cannot afford to honour regulations. If they cannot legally conduct field tests in their own countries, they will move to unregulated countries—especially the Third World—and test there.[33]

Proving regulation-avoidance is not easy. In the first half of 1987, however, a number of American biotech firms have established either subsidiaries or joint-venture programmes in Singapore. Most of the research relates to human health care and there is legitimate concern that one contribution of the Singapore entity is to conduct tests that would be illegal back home.[34]

Recently, the Indian Government announced a cooperative research programme with a number of international biotech companies in the pharmaceuticals field. India has no regulations governing biotechnology.[35] Several transnational companies are launching joint ventures with the Indian Government with a view to developing aggressive research strategies for the subcontinent. Indian groups speculate that industry is looking for safe testing havens for its products.

Similar concerns attend the announcement by Novo Pharmaceuticals of Denmark to open up offices for biotech R&D in Sao Paulo, Brazil. Danish regulations virtually prohibit testing on home ground and Brazilian organizations fear that Novo is looking for a cheap and easy test route in Latin America.

While the Third World is not the only test site devoid of regulation, it is the most secure. Chastened by embarrassing test irregularities at home, Advanced Genetic Sciences of the USA hooked up with Montedison to try out its ice-minus bacterium in Sicily. First beset by rumours of Mafia connections and then attacked by environmentalists, the company now faces a test

injunction imposed by the Italian Government under a (genetically-altered?) fertilizer regulation.[36]

Not all regulation should relate to deliberate release. As Robert Goodman, a vice-president at Calgene, notes, 'If [a plant is] engineered to produce something toxic and it ends up in the food supply, then obviously the same kinds of concerns (about pesticide residues) would exist'.[37] Some governments are wondering whether or not transgenic food plants (plants containing inserted exotic genes) do not require special regulations.[38] Should the exotic gene be considered a food additive, for example? How will the body react to the foreign gene? Is nutrition affected? The introduction of a foreign gene generally tends to weaken the effectiveness of the host plant in one or more ways.[39] So, even if a herbicide-tolerant gene is safely introduced into wheat, will there be unexpected, negative consequences to other characteristics of the plant? The side-effects for consumers also require regulation. Research itself poses some dangers and must be regulated. And, of course, Socioeconomic impacts must be considered.

Bioregulation is a complicated exercise in any country. The United States has been hard at it for years. The result is still confusion and uncertainty. The Environmental Protection Agency, the US Department of Agriculture, the National Institute of Health, the Food and Drug Administration, the Congressional Office of Technology Assessment and the Office of Science and Technology Policy are only among the front-runners in a hodgepodge of federal and state agencies legitimately concerned with the most pervasive technological revolution in history. Some of the very agencies charged with regulating the technology are proponents and funders of the technology. No doubt, some scientists find the situation irritating, but how could it be otherwise? Efforts to streamline the regulatory maze inevitably lead to unacceptable and even dangerous shortcuts. Better, by far, to allow each scientific discipline and regulatory body to come to its own understanding and approach rather than to take unnecessary risks by jettisoning the experience and competence each has developed in its own field.

In the UNEP study, Frances E. Sharples identifies a number of constraints to safe regulation. Prominent among them is the 'extreme degree of specialization' in the biotech sciences.[40] Universities are producing biologists who would not recognize a Douglas Fir if it fell on them and students who know botany only by its proteins or plasmids. Doctoral degrees are being awarded to scholars who have bitten off such a tiny portion of life as to make humanity and human issues incomprehensible.

Further, scientists cannot agree on basic terms. The definition of 'plant' and 'animal' and 'gene' cause intense debate. EPA staffer, John Moore, claims that, 'Defining "pathogen" is like defining pornography: we all know what we are talking about but it's hard to define it'.[41] In such an academic environment, how can society gather together sufficient scientific expertise to determine the safety of a whole technology?

And then, of course, there remains the political environment. Consider the case of the US Biotechnology Science Coordinating Council (BSCC)—a sub-cabinet level body charged with bringing together and streamlining the regulatory structure. Internecine disputes between bureaucracies are common and any successful efforts to fast-track biotech 'regs' have been called into question. The head of BSCC, David Kingsbury, has been under investigation for conflict of interest. It seems he has continued as the director of a California biotech company, IGB Products, even as he worked as a public servant to set biotech standards.[42]

Today, the perceived need to remain competitive internationally threatens to obscure the debate over regulation in many countries. The industry argues that you cannot have both. In fact, the two issues must remain separate.

Grossmann and Koppel argue that, 'The key to risk assessment is prediction and, logically, the vast permutations of information that are constantly changing make comprehensive assessment questionable. It is, therefore, a question of trade-offs, for there will always be some risk. Still, there is the underlying question of whether economic pressures are principally controlling the regulation of this powerful technology.'[43] Clearly, biotechnology demands something more than 'fast-track' regulation by the companies and agencies who promote and profit from it.

> The other point worth remembering when one considers genetically altering these proteins is that they've evolved over millions of years in nature to have a specific structure... and probably the pressures that caused that evolutionary process to occur are very specific, but we don't have any knowledge of it. So it's likely there'll be some surprises that we'll find as we start modifying these proteins and looking at what effect they have in the seed.
>
> *Dr. Niels Nielsen, USDA/ARS at Purdue University.*[44]

Table 20 Biotechnology regulation and deliberate release in selected industrialized countries

Country	Status of regulation	Comment
Denmark	The 'Environment and Gene Technology Act' (June 1986) prohibits deliberate release of any rDNA product or organism including products involving gene deletion or cell hybridization without ministerial approval.	De Danske Sukkerfabrikker is seeking exemption to test somatic cell hybrids of mustard and rape. Novo Pharmaceuticals may be testing in Brazil.
Federal Republic of Germany	Central Committee for Biological Safety of Federal Health Office must approve publicly-funded deliberate release tests but industry compliance is voluntary. Parliament may soon approve a 5-year moratorium on deliberate release for micro-organisms but exempt plants.	University of Bayreuth in Bavaria conducted a field test in 1987 on Rhizobium that inhibited an antibiotic resistant gene. Green Party outcry against test has caused wide debate and political action. Industry is 'lying-low'.
France	Notification of use of rDNA technology is compulsory through Ministry of Research and Higher Education and subject to 'risk' classification although actually testing appears open and an advisory committee on deliberate release with Ministry of Agriculture has no teeth. National Assembly is considering legislation probably favourable to industry.	Ten deliberate release tests in 1987 including tests for Basta tolerant potato and tobacco for Plant Genetic System and antibiotic resistant tobacco. INRA Rhizobium field trials caused public opposition.
Italy	No regulations of any kind.	Ice-minus gene test blocked for Advanced Genetic Sciences because of a fertilizer regulation technicality. Government may be forced to act by Greens.
Sweden	Deliberate release is unregulated. Notification is voluntary. Parliament is expected to review situation and Ministry of Agriculture objects only to test on domestic animals.	Swedish companies may take part in drug testing in India as part of joint ventures. Biotech firms avoid releases in Sweden.
United Kingdom	Notification is compulsory but deliberate release is voluntary through the Health and Safety Commission's Advisory Committee on Genetic Manipulation. Commission, however, intends to make compliance compulsory and a pending Royal Commission on Environmental pollution may soon recommend further steps.	Three potato and Rhizobium releases and one baculovirus release in 1987. No public opposition or political awareness evident. UK is developing release standards with at least 8 firms including Ciba-Geigy in what they hope will be an EG model.

Country	Status of regulation	Comment
European Community	No policy directive as yet. Environmental Directorate has produced 7 unacceptable drafts and tension between divergent state views is considerable. European parliament could take a strong position against deliberate release.	Standards finally set by EC could make procedure slow and require extensive consultation among neighbouring states that will make tests difficult for biotech firms.
United States	Deliberate release is possible pending notification and approval by EPA. Overall policy is being developed by the Biotechnology Science Coordinating Committee. Numerous regulatory and legislative initiatives are underway to either block or streamline releases.	Two approved releases in 1987 for Advanced Genetic Science and a University. US firms may be testing through Singapore and Latin America.

Source: Data gathered from a variety of biotechnology journals and government press releases in the countries described.

Notes

1. Regal, P.J., 'Issues in Science and Technology', *Genetic Engineering,* 1985, Vol. l(4), p. 14-15.
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3. See, for example, letter dated 21 September, 1987, signed by M.S. Swaminathan to 'Editors of Major Philippine Media'.
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8. An informal gathering of scientists at UPLB who work closely with national NGOs and KMP (Philippine Peasant Movement) and who have been vocal critics of IRRI.
9. *Agricultural Biotechnology News,* January-February, 1987, p. 3.
10. International Agricultural Research Centres of the Consultative Group on International Agricultural Research (CGIAR) such as IRRI, CIMMYT, ICRISAT, ICARDA, ILCA, IITA, WARDA, CIAT, CIP and IBPGR.
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14. Huber, Peter, 'Who will protect us from our protectors?', *Forbes,* Vol. 140, July 13, 1987, p. 56. The other example is Oregon State University testing a vaccinia in New Zealand.
15. Sharples, Frances **E.,** *Evaluating the Effects of Introducing Novel Organisms into the Environment,* draft report in 1986-87, UNEP.
16. Ibid., p. 18.
17. Ibid., p. 2.
18. Ibid., p. 2.
19. Ibid., p. 10.
20. Ibid., p. 15.
21. Ibid., p. 19.
22. Ibid., p. 23.
23. Ibid., p. 24.
24. Ibid., p. 32.
25. Ibid., p. 36.
26. Ibid., p. 41-42.
27. Grossmann, Robert and Koppel, Bruce, 'The Release of Bioproducts for Agriculture: Environmental and Health Risks', Iowa State University, Bioethics Symposium, Nov. 2-4, 1987, Ames, Iowa, p. 4.
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32. Advanced Genetic Science did this with its ice-minus gene research.
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34. *Bio/Technology,* November, 1987.
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38. Fox, Jeffrey L., 'The US Regulatory Patchwork', *Bio/Technology,* Vol. 5, December, 1987, p. 1277.
39. Sharples, Frances E., op. cit., pp. 41-42.
40. Sharples, Frances E., op. cit., p. 88.
41. Fox, Jeffrey L., op. cit., p. 1276.
42. Fox, Jeffrey L., op. cit., p. 1274.
43. Grossmann and Koppel, op. cit., p. 9.
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Biopolicy: Ideas for Public Policy and Legislation on Biotechnology

The biotechnology revolution challenges society and its policy-making and regulatory processes in ways no other technology has done. Biotechnology raises questions about environmental and human safety, economic and social impact, and national priority-setting. New laws and regulations will be necessary. But how can these be made before the impact of the technology is known? Public policy must be forged. But how can this be done, when even the scientists are unsure of both the direction and impact of the new technologies?

> Only in the last few years have I come to accept that the [cost/benefit] model was totally wrong. The reason is that the benefits of technology are always immediate and obvious....The trouble is the costs are invariably hidden and unpredictable.
>
> *David Suzuki, geneticist*[1]

Most of humanity's great achievements and inventions have come with a downside. Even fire-making had, and continues to have, its costs. Health, Socioeconomic structures, culture and the environment are just a few of the areas that have been affected. Even if the consequences of past advances were predominantly positive, individuals, societies and nature needed time to adapt.

Biotechnology will bring about enormous changes in all areas of life at a rate we have never before experienced. There is not time to realize or understand the full consequences of one introduction before more introductions interfere, let alone time for people, societies, economies and the environment to adapt. This means that we will never be in a position to assess the overall impact of biotechnological innovations, be they in the area of tissue culture techniques, monoclonal antibodies, fermentation or genetic engineering. No doubt there will be irreversible synergistic effects which are not completely positive.

Biotechnology presents formidable challenges in public policy formation. The technology is complex. The effects may not be felt for years after the technology is employed. Because biotechnology has the potential to touch every aspect of life, virtually every legal jurisdiction and government agency might claim some interest in regulation. Without coordination and a rational planning process, society runs the risk of over-regulation sacrificing the possible benefits of the technology or under-regulation allowing misuse and possible disaster.

Public policy is formulated with laws, regulations, administrative policy, etc. Below, we outline public policy considerations, some of which could be realized in legislation, some of which would require other means. Following these basic observations, we offer a modest 'model law' as a starting point for legislation.

I. Possible objectives of public policy:

- To protect health and safety of society.
- To protect Socioeconomic and cultural welfare of society.
- To protect the environment.
- To protect against diversion of resources for basic needs.
- To protect the national economy.
- To protect against dumping of products, processes and production plants.
- To protect against mis- and disinformation to the public.
- To protect against industrialization, commercialization and monopolization of environment and life.
- To protect against monopolization of major foods and crucial products.
- To protect against the homogenization of the world and the destruction of cultures and traditions.
- To protect against dangerous research and technology.

II. Some basic guidelines for an approach

All risks emerging after risk assessment (see below) must be carefully weighed against potential benefits, giving due consideration to all the policy objectives and in particular to the following guidelines:

- Biotechnology shall always be regarded as a tool, not an aim in itself, which means that other possibilities to reach a certain aim should be surveyed, the various risks compared and the biotechnological method ruled out if another method turns out to be more efficacious.
- If the potential impact of a biotechnological innovation turns out to be detrimental to society or the environment, other measures should be sought.
- If impact assessment of a biotechnological innovation does not reveal any grave problems, society must still determine if the innovation will divert resources and expertise from more important tasks.
- In case of doubt it is part of industry's responsibility to prove that the biotechnological innovation is needed and will not have detrimental effects, or that no safer or better alternative is available.

- In addition to the above precautions, the release of genetically engineered or otherwise genetically altered or manipulated organisms. especially micro-organisms, into the environment should be regarded as a serious measure and be carried out only after diverse impact assessments.
- Genetic manipulations of higher organisms, including the production of transgenic and chimeric creatures, should not be regarded as methods of first choice. For example, especially in the case of animals, the resulting organisms are often not robust and need intensive and costly care.
- Certain biotechnologies involving human beings and interfering in substantial ways with life itself should be subject to a broad public debate, ethical discussion and possible regulation or restriction. Relevant regulatory bodies should closely monitor the use of the technology to avoid abuse, in particular, discriminatory and racist application.
- Reproductive technologies in humans must also undergo similar procedures, keeping in mind cultural and religious feelings prevalent in the nation and the necessity of not exploiting women.
- Biotechnological diagnostic methods for humans, in particular gene diagnostics, should be monitored to avoid abuse, discrimination, and racist application.
- The conservation, utilization and improvement of genetic resources and genetic diversity must not be hindered or endangered by a biotechnological innovation.
- 'Uniformism' and homogenization of life and culture should be avoided as far as possible.

III. Orientation of biotechnological research and projects

Any biotechnological research or projects have to keep the benefit of the people as its ultimate aim in mind and should employ the guidelines outlined above. Other guidelines should include:

- Biotech research or projects that result in unnecessary or significant torment of animals should not be allowed.
- Biotech research or projects imported from another country shall not be carried out if banned in the country of origin.
- A person or company who proposes to carry out biotechnological research or projects, especially when public money is involved, should prove that the aim is to benefit the majority of the people, and that the research or project set-up will not harm the people or the environment in the vicinity.
- Researchers must abide by laboratory and experimentation safety regu-

lations to be worked out on the basis of international recommendations, such as the respective recommendations of OECD.

IV. Risk and impact assessment

1. General impact on society

Before the introduction of a new biotechnological product or licensing of a new biotechnological production plant, its impact on the general welfare, health, economy, labour situation, culture and socioeconomic structures, etc. should be studied. This should include the following:

- Ideally, society needs to assess whether major investments in a biotechnological product, production, research, marketing, etc. constitute a real necessity in view of available resources to satisfy the immediate needs of the majority of the population.
- The safety of research, laboratory or production equipment should be checked.
- The safety of workers in a laboratory or a production or test plant as well as that of the people and the environment in the vicinity needs to be ensured.
- The Socioeconomic impact on poor people, small farmers and small business should be given special consideration, including the study of possible replacement of products, the production or marketing of which is important for people's economic survival; the affordability of an agricultural innovation for small farmers; the risk of losing competitiveness if they cannot afford it; the risk of people losing jobs due to the innovation; the possibility of increased urbanization due to the innovation; etc.
- The potential effects of the innovation on women, their role in society, their status, workload, job-possibilities, health, etc. should be studied.
- The potential effects of the innovation on the life and health of children should be considered.
- The possibility of noise and air pollution and other factors that reduce the quality of living in the vicinity of a laboratory or a production or test plant or an experimental area should be determined.

2. *General impact on the environment*

Before the introduction of a biotechnological innovation (in particular a new organism, be it genetically manipulated or new for other reasons, and also a new biotechnological production plant) into the environment, its impact on the environment as a whole and at the site of the introduction and

its vicinity, the nation's natural resources and genetic resources and diversity, its wildlife, etc., ought to be studied. This should begin with an assessment of the status quo, which has to be well known before any forecasting with respect to the introduction can be attempted.

This would include the following:

- The immediate environment of the introduction site has to be thoroughly studied as to soil composition, wild life, plant life, microbiological life, soil biology, climatic conditions, water situation, factors already disturbing the ecological balance, etc. and the interaction of all the factors.
- In particular, in preparation for cases of releases of micro-organisms into the soil (for agricultural purposes) the soil biology has to be thoroughly studied, including a complete assessment of all micro-organisms and small animals in the soil and their interactions and needs. Equally necessary is the study of any occurrence of organisms related to the soil organisms (for example) and found elsewhere in the vicinity.
- The possibility of pollution of air, water, soil, etc., as well as of noise pollution should be checked.

3. Specific assessments should include:

- Assessment of monitoring possibilities of the biotechnological innovation, experimentation or the use or release of new organisms in the environment.
- Assessment of possibilities to stop the application of the innovation, the experimentation, research or marketing of a biotechnological product or to remove new organisms already released in the environment in case of negative effects.
- Assessment of possibilities of any kind of contamination of a product produced by a biotechnological production method, especially if the product has to be isolated from living organisms, living tissues or cell or tissue cultures.
- In case of a release of new organisms, in particular micro-organisms into the environment, environmentally specific assessments should be carried out including assessment of:
  - long-term survival chances of new organisms in the environment;
  - possibility of genetic exchange with other organisms in the particular environment;
  - genetic flexibility, i.e. changeability and adaptability of the new organism;
  - degrees of interference and interrelationships with organisms already in the environment;

- biogenetic waste, the potential to spread disease or undergo genetic exchange and how this new form of industrial waste will be regulated and treated;
- impact of large-scale release, for example, of a cloned plant variety, on the genetic resources in the particular environment.

V. Further considerations:

- Following their introduction, biotechnological innovations need to be closely monitored over an adequate length of time, which should be determined on the basis of the impact and risk assessment and the degree of interference with life. Some innovations, in particular those directly pertaining to human health, should be continuously monitored. Even if they do not show serious detrimental effects, the monitoring system must not be loosened within the set time, since the impacts on society, environment and a country's economy may only gradually become apparent. If there is reason for concern the monitoring period could be extended.
- No product, research project, trial test, production process, production plant or any other biotechnological innovation should be exported to another country if it is banned or not approved in the country of origin.
- Correspondingly, a country should not import any biotechnological innovation banned or not approved in the country of origin. In case it is banned in a country other than the country of origin, the country considering import would be wise to study the reasons for the decision in order to decide whether these reasons are valid.
- Any safety precaution stipulated in the country of origin for a biotechnological innovation should probably be adhered to by the exporting company or agency and the importing country.
- Patenting of biotechnological inventions should not be allowed if it results in restricting research in plant and animal breeding or in restricting small farmers' control over their production system.

VI. Specific areas of biotechnology

In the specific areas of biotechnology regarding products and technology, very concrete regulations should be formulated. The areas include:

1. Products

The guidelines on products shall include regulations concerning the products themselves and their distribution or release, their specific risks, research, product tests and trials, safety of production plants, safe disposal

or treatment of biogenetic waste, workers' safety, effects on people, animals, plants and the whole environment, marketing methods, promotion, export and import behaviour of industry, pricing and monopoly policies and in particular industry's behaviour in and towards the Third World.

(a) *Pharmaceutical products.* These include medicines, vaccines and diagnostics. Apart from the general stipulations above, an International Code on Pharmaceuticals drawing, *inter alia,* on the work of HAI and on the contributions to the 1985 Dag Hammarskjöld Seminar on 'Another Development in Pharmaceuticals' *(Development Dialogue* 1985:2) should serve as a minimum guideline in this area. In addition, all pharmaceuticals produced by biotechnological methods should be so labelled.

(b) *Pesticides and agrochemicals.* These include any substances used in agriculture, be they chemicals produced by biotechnological methods, biological substances or even living organisms. Apart from the general stipulations, an adapted version of the International Code of Conduct on the Distribution and Use of Pesticides adopted by FAO 1985, including the clause on Prior Informed Consent, should serve as a minimum guideline in this area.

(c) *Food.* This includes raw products and processed foods, additives, flavours, fragrances, colours and spices. In the area of milk products, the International Code of Marketing of Breastmilk Substitutes, adopted by the World Health Assembly in 1981, can serve as a guideline with respect to children. For other foods, particular consideration should be given to:
- labelling and full disclosure of food ingredients and production method, possible risks and shelf life;
- adequate testing for possible contamination;
- effects on culture, in particular food culture, and tradition and Socioeconomic structures;
- risks of products produced by the help of gene technology;
- marketing practices and promotion, including dumping in the Third World;
- registration;
- security of production workers;
- possible environmental factors.

(d) *Household products.* Guidelines should provide for the safety of people using household products or being likely to have access to them; for the safety of the production workers; for the safety of the environment; and for the quality of a product, adequate pricing, fair marketing methods including labelling.

(e) *Cosmetic products.* The code on pharmaceuticals should serve as a model to develop guidelines in this area.

2. *Military applications*

The 1972 Biological Weapons Convention signed by over 100 countries outlaws research on and development and possession of biological weapons for offensive use. The Convention requires all signatory states to pass laws making violations illegal within their borders. Such laws and regulations still need to be passed in some countries.

VII. Damage

In the case of damage arising from the use of a biotechnological product or method, research trial, production process, etc., the person, company or agency responsible for the introduction of it should be legally responsible for the damage. Guidelines for the identification of damage and how to assess the damage should be developed.

What follows is a rudimentary, draft model law for the national regulation of biotechnological research and the environmental release of genetically-engineered organisms. It is not meant to include all the points made above, but is offered instead as a starting point and a tool for discussion.

Note

1. Quoted in 'AFC and Biotechnology: A Discussion Outline', August, 1987, p. 14.

Draft Model Law

THE BIOTECHNOLOGY PUBLIC SAFETY AND ENVIRONMENTAL PROTECTION ACT

An Act to Regulate Biotechnology
and the Release and Use of Genetically
Engineered Organisms in the Environment

Be It Enacted by the [Assembly, Congress, Parliament] of ...

1. FINDINGS

The [Assembly, Congress, Parliament] finds and declares that the new biotechnologies, including genetic engineering, have an enormous potential to benefit many fields of human endeavour by providing new services and products for human health, crop and livestock production, veterinary medicine and pollution control; that the health care, pharmaceutical, chemical, and food processing industries of this Nation may benefit from, and will increasingly be affected by, advances in biotechnology.

The [Assembly, Congress, Parliament] further finds that while the potential benefits of biotechnology are great, there is legitimate concern for the effect that the release of genetically engineered organisms, as they move from contained research laboratories into the outdoor environment, may have on the health, safety, and welfare of the public.

The [Assembly, Congress, Parliament] also recognizes that much of the initial research in biotechnologies, including genetic engineering is taking place in a few major countries where public concern for the release of genetically engineered organisms into the outdoor environment has significantly restricted such releases, and, that some commercial and semi-governmental enterprises have sometimes selected to undertake releases in other countries where regulation is either non-existent or insufficient.

The [Assembly, Congress, Parliament], therefore, determines that it is incumbent upon the Nation to take responsible and timely measures to ensure that the Nation's sovereignty, the public health and safety, and the environment are protected, and that societal concerns about the impact of biotechnology are promptly addressed while allowing research to advance; and

that these important interests may be balanced through creation of a Biotechnology Review Board acting as an agency of the Office of the [President, Prime Minister] with the cooperation of the Ministries of Agriculture, Health, and the Environment; and

that such Board will be empowered to review all proposed experimentation related to advanced techniques in the biosciences, both in the laboratory and in the outer environment, with particular attention to the release of genetically engineered organisms into the environment, whether for purposes of research or commercialization; and

that this review mechanism will permit the Nation to assess the potential risks or benefits to the public welfare including the social, economic and environmental impact of the experimentation or commercialization.

2. DEFINITIONS (as used in this Act)

(a) 'Biotechnology' includes, but is not limited to, recombinant DNA technology, monoclonal antibody technology and bioprocess technology.
(b) 'Genetically engineered organism' means any plant, animal, insect, or micro-organism (including but not limited to bacteria and viruses), whose genes and/or genetic structure have been artificially altered for scientific or commercial purposes.
(c) 'Outdoor environment' means any area outside of the confines of an approved laboratory designated for recombinant DNA work, including but not limited to forests, fields, soil, wells, mines, waste dumps, streams, rivers, lakes, underground aquifers, or other bodies of water and the atmosphere.
(d) 'Board' means the Biotechnology Review Board created under section 3 of this Act.
(e) 'Person' means, in addition to the usual meanings, all political subdivisions of this Nation or any agencies or instrumentalities thereof.

3. BIOTECHNOLOGY REVIEW BOARD

(a) There is created under the Office of the [Presi-

dent, Prime Minister] a Biotechnology Review Board, which shall consist of nine members appointed as follows:

an employee with special responsibility for animal health who shall be appointed by the Minister of Agriculture;

an employee with special responsibility for crop protection who shall be appointed by the Minister of Agriculture;

an employee with special responsibility for workplace health and safety who shall be appointed by the Minister of Health;

an employee with special responsibility for community health who shall be appointed by the Minister of Health;

an employee with special responsibility for quarantine who shall be appointed by the Minister of the Environment;

an employee with special responsibility for soil and water pollution who shall be appointed by the Minister of the Environment;

three representatives of the scientific community who are knowledgeable about the techniques and applications of genetic engineering as well as the principles of ecology and environmental science, none of whom has financial or contractual interest in either a biotechnology enterprise or any commercial enterprise likely to be affected directly by biotechnology or its products, and each of whom shall be appointed by the [President, Prime Minister]; and

three representatives of the general public who have no commercial or other financial interests in biotechnology or enterprises that may be directly affected by biotechnology; one representative of the agricultural community, one representative of the consumer organizations and one representative of environmental organizations, each of whom shall be appointed by the [President, Prime Minister].

(b) The members of the Board shall serve three-year terms, except for those members first appointed to the Board, of whom four shall serve for one year, four shall serve for two years, and four shall serve for three years. The initial terms of office of the members of the Board shall be determined by lot among the Ministers and the [President, Prime Minister]. The members of the Board shall be appointed within 60 days after the date that this Act becomes effective.

(c) The members of the Board shall serve without compensation, except that they shall be compensated for expenses incurred in the performance of their duties.

(d) The [President, Prime Minister] shall appoint the chairperson of the Board from among the twelve members of the Board. The Board shall, as soon as practicable after the appointment of its members, select a vice chairperson from among its members and a secretary who need not be a member of the Board.

(e) All decisions of the Board shall be deemed final, subject only to judicial review in accordance with the Rules of the Court.

4. BOARD REVIEW OF EXISTING LAWS AND REPORT TO THE [ASSEMBLY, CONGRESS, PARLIAMENT]

It shall be the duty of the Biotechnology Review Board to study, analyse, and review any laws, rules and regulations that may be applicable for governing experimentation in biotechnology and, in particular, the environmental release of genetically engineered organisms.

It shall also be the duty of the Biotechnology Review Board to determine the safety standards necessary for laboratories undertaking experimentation in biotechnology and, in particular, the release of genetically engineered organisms.

Within 18 months of the appointment of its members, the Board shall prepare and transmit to the [President, Prime Minister] and the [Assembly, Congress, Parliament], a report concerning the potential impact of experimentation in biotechnology and, in particular, of the environmental release of genetically engineered organisms on the Nation's economy, its public health and safety, and its environment. This report will include an assessment of whether existing laws and regulations, by themselves, are adequate to protect the economy, public health, and environment of this Nation from any untoward side effects or economic impacts from the experimental and/or commercial release of genetically engineered organisms or other products of the new biotechnologies. Further,

in this report, the Board shall make any recommendations of law and regulation it may find necessary and prudent for the Nation for review and oversight of biotechnology activities, including those for governing the environmental release of genetically altered organisms.

The Board shall also submit an annual report to the [President, Prime Minister] and the [Assembly, Congress, Parliament] concerning the review activities of the Board and the progress of the Nation's biotechnology industry during the preceding calendar year.

5. NOTIFICATION AND APPROVALS

A person who proposes to undertake experimentation or commercialization in biotechnology and, in particular, release genetically engineered organisms into the outdoor environment of this Nation shall, not later than six months prior to the date of the proposed release, notify the Biotechnology Review Board of the proposed release date and location. At the same time, the person shall notify the public officials of the local jurisdiction in which the proposed research or release is to occur. The notices to both state and local officials shall be accompanied by documentation that applications for all applicable permits have been made.

Within the six month period, the Board and/or local government officials may request that a public hearing be held for informational purposes on the proposed release, providing opportunity for general public comment on the proposed research or release.

Within 30 days of receipt of final documentation from the person proposing the research or release that all required permits have been issued, and in the absence of any outstanding request for a public hearing by local authorities affected by the proposed release, the Board shall authorize the research or release; except that, if during the six-month period, the Board finds that the information submitted by the applicant is incomplete or unclear as to the proposed research or release, or finds that more information is warranted for public health or environmental reasons, it may request further information from the applicant, and may, if necessary, postpone the research or release date by order until such information has been obtained and reviewed to the Board's satisfaction; and except in the event that a public hearing is required in which case the Board must make a final decision within 15 days following that hearing if the hearing takes place after the initial 30 day examination period.

A person shall not undertake research or release any genetically-engineered organism into the outdoor environment of this Nation if the research or release is prohibited by the Board. A person shall not violate any order of the Board to postpone any release.

6. PENALTIES

(a) A person who violates this Act is liable to a civil penalty of not less than [US $50,000.00], nor more than [US $500,000.00], to be collected in accordance with the provisions of the [penalty enforcement] law. If the violation is of a continuing nature, each day during which it continues constitutes an additional, separate and distinct offence.

(b) In addition to the penalty provided above, if a person violates this Act, or if the Minister of Justice has reason to believe that a person is about to violate this Act, the Minister of Justice may seek injunctive relief to prohibit and prevent the violation.

7. EMPLOYEES AND EXPENSES

The Board is entitled to call to its assistance and use the services of the employees of any government department, board, bureau, commission, or agency as it may require and as may be available to it for the purposes of carrying out its duties under this Act, and to employ such stenographic and clerical assistants and incur such travelling and other miscellaneous expenses as it may deem necessary in order to perform its duties, and as may be within the limits of funds appropriated or otherwise made available to it for those purposes.

8. ADOPTION OF RULES.

The Board shall adopt rules and regulations concerning the implementation of the Act according to the provisions of the [Administration Procedure Act].

9. LOCAL COOPERATION.

(a) No [municipality or county or local] [board, committee, commission] shall enact any law, ordinance, or regulation prohibiting the release of genetically engineered organisms; except that no provision of this section or Act shall limit the authority of any local government in the enforcement or administration of any provision of law which it is permitted or required to enforce and administer, including local land use regulation.

(b) The Board shall hold a public hearing if any public officials or citizens in a [municipality or county] request a hearing on a proposed release designated for that locality. Such a hearing, if requested, shall be held in that local jurisdiction, with the Board giving the citizens of that jurisdiction 30 days' public notice through published notice in at least two general circulation newspapers.

10. APPROPRIATIONS.

There is appropriated from the General Fund to the Biotechnology Review Board the initial sum of [US $40,000.00] to carry out the purposes of this Act.

11. EFFECTIVE DATE,

This Act shall take effect immediately.

From Cabbages to Kings?

Patents, Politics and the Poor

What began early in this century with the patenting of roses and chrysanthemums spread by mid-century to the patenting of food crops ... and may end the millennium with the patenting of ourselves. While lawyers and scientists debate the efficacy of property rights over plants compared to the patenting of genes or cows, few are looking at the rights of those who first gave us wheat or cows. The international battlefield lies in Geneva—at WIPO and UNCTAD and GATT—but the battle will be won or lost in the fields and forests and parliaments of the Third World. At Bogève, Karim Ahmed, Calestous Juma and Henk Hobbelink helped to steer the discussion of the implications of patent monopolies and potential strategies to counter the threat.

> The decision says higher life forms will be considered and it could be extrapolated to human beings. But for the time being we are not going to consider applications involving human life.
>
> *Charles E. Van Horn, director for organic chemistry and biotechnology, US Patent and Trademarks Office, 1987, referring to the decision to allow the patenting of animals*[1]

> We have to look at the bucks to ethics ratio.
>
> *George Cahill, Howard Hughes Memorial Foundation, 1987*[2]

> 'The time has come', the Walrus said,
> 'To talk of many things:
> Of shoes—and ships—and sealing-wax
> Of cabbages—and kings
> And why the sea is boiling hot
> And whether pigs have wings.'
>
> 'But wait a bit', the Oyster cried,
> 'Before we have our chat;
> For some of us are out of breath,
> And all of us are fat!'
>
> *Lewis Carroll,* Through the Looking Glass

United States: from oysters to supermouse

On April 16,1987 (just a few short weeks after Bogève), the US Patent and Trademark Office, following an Appeals Court decision, won a Pyrrhic victory over an oyster. Its 'inventor' claimed that his little animal, developed at the University of Washington to enable the shellfish to be eaten all year-round, would make a real contribution to the Pacific coast seafoods industry.[3] The Appeals Court agreed but contended that the polyploid oyster still did not meet patent criteria—but not because it was a higher life

form. The Appeals Court went on to say, for the first time, that animals including livestock and pets are patentable.[4] Asked what could not be patented, one of the examiners told Keith Schneider of the *New York Times* that the door was open to everything except the patenting of human beings. But, in the case of people, the official hinted that certain human characteristics may be patentable.[5]

You win some—you lose some. The effect of the Appeals Court decision was immediate. When scientists gathered in Washington on June 26,1987, to discuss the problems of sequencing and then mapping the three billion 'base pairs' in the human genome, they had one particular problem in mind: Walter Gilbert announced he was going to copyright us.[6]

The Harvard biologist is starting up a new company, Genome Corporation, and is putting together the venture capital needed to employ about 200 people in the multi-year project. By slapping a copyright on each base pair as he finds it, Gilbert is hoping to get the edge on a massive federal government drive also intended to map the human genome. The Department of Energy initiative is floundering, in part, because of the complex corporate interests at stake and because many of the potential scientists/ collaborators are already contractually linked to biotech companies.[7]

In fact, Walter Gilbert is in a run for our life with at least one other company. Collaborative Research, which has announced a kind of crude human map already.[8] The scale of the Collaborative map leaves the genetic markers about nine million base pairs apart while the American government's map would have a marker every 50,000 pairs.[9] If this sounds like gobbledygook, it is a bit like using Magellan's map of Africa to find Harare instead of a Michelin road atlas.

Does Collaborative intend to patent or copyright the genetic sequences? No one is certain. The company has already invested US $12 million in the project and the full bill may run to between US $50 and $100 million over the next five years.[10] Some returns can come from the development of diagnostic kits but this is an uncertain market and probably not too profitable in the longer run.[11] Some form of intellectual property right may prove a surer route to riches.

The question still remains as to whether 'we' are patentable. Many lawyers think not. Others are uncertain. Over the last few decades, patentability has progressed from cabbages to shellfish. Maybe kings will be next. Clearly, the opposition to patenting human characteristics or copyrighting genetic

maps is more ethical than technical. But patents mean monopoly and monopoly is a great way to make money. As one co-sponsor of the Human Genome study told Leslie Roberts of *Science,* 'We have to look at the bucks to ethics ratio'.[12] Indeed we do!

We also have to look at how we got ourselves into this mess.

'It seems a shame',
the Walrus said,
'To play them such a trick;
After we've brought them out so far,
And made them trot so quick!'
Lewis Carroll, Through the Looking Glass

The flower's children

When US Patent Attorney Benton Duffett was invited to address a conference on plant gene patenting in March, 1987, he prefaced his speech with the announcement that Luther Burbank had been inducted into the Inventors' Hall of Fame for his July Elberta peach—plant patent number 15, issued 55 years earlier.[13] For the first time, a plant breeder was recognized in the Hall of Fame as a true 'inventor'.

It was a peculiar launch for an argument advocating the right of inventors to extend patents to all forms and levels of life. The famed Burbank had worked his genius and died years before the US Plant Patent Act was signed into law. He himself was ambiguous about the propriety of patents[14] and it is hard to suggest that patents were an incentive to his own incredibly diverse breeding efforts since his fame had been won long before patents were a gleam in a lawyer's eye. Indeed, five of the first sixteen patents were issued to Burbank posthumously and assigned to Stark Brothers Nursery.[15] The gold medallion awarded by the Hall of Fame did not pass to the heirs and descendants of Luther Burbank but to Stark Brothers—still, thanks to the great breeder, a major force in the nursery trade today.

But, then, patent rights and human rights have never had very much in common. The century-long battle over the merits of intellectual property systems has shown that patent monopolies tend to work against the interests of the small in favour of the large. By starting off with Burbank and the monopoly of plant varieties, Benton Duffett at least got us off on the right foot in coming to an understanding of how the world has moved from the seemingly harmless patenting of flowers to the monopolization of life.

The drive to patent living things began in France at the turn of the century

when rose breeders wanted the same recognition as the inventors of steam engines and light bulbs. Their efforts led to a special international convention at the beginning of the 1960s when a meeting in Paris created the International Union for the Protection of New Varieties of Plants (UPOV). But 'flower power' really took hold in the late sixties and early seventies when most Western European countries, the USA, New Zealand and Japan adopted seed patenting (PBR) legislation.

By then, flowers were no longer the issue. Major companies were patenting cereals and vegetables. After all, God created life but we were allowed to name life. A rose by any other name could be wheat or rice. Once the technical and political concept of patenting flowers was acceptable, there was no intellectual basis for preventing the patenting of food plants. Once food was patentable under PBR, it only remained to patent the rest of life under stronger industrial monopolies.

Life—as a non-tariff barrier

Historically, biological products and processes have not been eligible for intellectual property protection. Current discussion within the European Communities, the OECD, the World Intellectual Property Organization (WIPO) and, most significantly, the General Agreement on Tariffs and Trade (GATT) are leading to a change in international conventions that would 'industrialize' biology and make manipulated genes and altered species patentable. In effect, the vast biological diversity of the Third World—whether discovered or adjusted—could be rendered the intellectual property of private interests. 'Gene' patents are already permitted in health and agriculture in the United States and similar moves are under way in Japan and Europe. The inevitable losers in this development will be the countries who have (or had) the biological diversity in the first place.

The most important new initiative is in GATT. The September 29th 1986 Declaration of Punta Del Este, Uruguay, where the 96 GATT member nations pledged their solidarity, peace and friendship in world trade fooled no one. The current GATT round will be the toughest ever.[16] During the Uruguay encounter, the EEC, the USA and Japan made it clear that they want an extension of the GATT rules into trade services—including patents.[17]

Via a 1984 amendment to their Trade Act, the American Government now considers a lack of patent protection to be an unfair trading practice.[18] The US Administration is arguing that the absence of patent laws in one country amounts to a non-tariff trade barrier for countries that have patent laws.[19] In

pursuit of this view, the Americans have charged South Korea with unfair practices related to patents for chemicals and foodstuffs[20] and gone after the Brazilians on pharmaceutical patents.[21] The United States has also demanded that Canada adopt patent laws similar to those in the US for pharmaceuticals and plant varieties.[22]

It is a challenging concept. Lawyers concur that a patent is a form of government intervention in the marketplace—a practice seemingly at odds with strict capitalist economic thinking. Economists agree that patents should be seen as a form of government subsidy—not unlike tax credits, export incentives, and post-secondary education.[23] Thus, the US is asking GATT not to lower trade barriers or reduce export subsidies but to force other states to meet the level of subsidy offered in the USA. The Republican Administration takes the view that it is unfair for other countries not to subsidize American companies in the manner to which they have grown accustomed at home. Any government denying these sacred rights violates GATT and is downright un-American.

But if the most dangerous battleground is in Uruguay, important skirmishes will also be fought in Geneva—at WIPO, UNCTAD and UPOV.

Latin American governments and breeders heard the warning bell —appropriately—in Uruguay in November 1987 during the XIIth Seminario Panamericano de Semillas. Speaking in Montevideo, M.H. Thiele-Wittig —a lawyer with UPOV—summarized new proposals for the plant-patenting convention before the assembled delegates.[24]

From the beginning of the eighties, the plant-patenting folk and the industrial-patent folk have been squabbling over biotechnology. Member states of WIPO (from industrialized countries) have tended to take the view that the 'definitions' used in industrial patenting should be adjusted so that plants, animals and micro-organisms could come under the WIPO mandate. On the other hand, the industrialized-country members of UPOV have found their ranks divided between the small seed houses, who fear gene patenting, and the large, integrated genetics supply companies that like the idea of the tougher industrial patent approach.

Thiele-Wittig's report made it clear that the genetics supply corporations had won out. UPOV is now preparing for a new international convention. The final form of a new convention is unclear, of course, but logic suggests that UPOV is going to be relegated to the 'attic' of intellectual property agreements. UPOV signatory states such as the United States, Japan, the

UK, France and the German Federal Republic want very little from UPOV other than it should not interfere. Provisions in the existing convention make it difficult for the big biotech countries to move comfortably from the system of plant breeders' 'rights' of UPOV to industrial plant patents. Those restrictions will now be removed. In other words, UPOV will make it possible for countries to use WIPO and/or UPOV for plant variety protection and UPOV will be flexible enough that its convention could be used for animals as well. Nothing in UPOV's rules will mitigate against gene patents on a plant that also has variety rights.

WIPO hopes to absorb biotechnology patents without a change in its international convention—a complex, painful and politically dangerous exercise at the best of times. Neither it nor its Northern member states want to see a broad public debate on the patenting of life. In this, the attitude of patent offices and politicians in the North amounts to gross indecency and a quite shocking abrogation of democratic principles.

National laws and international conventions that were first passed to exclude specifically the patenting of life's essentials such as food and drugs —and which explicitly ruled out monopoly over biological processes—are now being altered to incorporate these very essentials without referral back to society. These are not technical issues.

For the remainder of the eighties and into the early nineties, the battle over life patents in Geneva will be one of the most important North-South and moral battles of this century. It is a battle which the South—organized and certain of its strengths—could win.

> Patents that restrict the flow and utilization of this [germplasm] material could have serious consequences in the years ahead. For example, patenting of specific genes for disease resistance could restrict deployment of these genes and render crops more vulnerable in the event of a major disease epidemic. Patenting the expression of a high protein trait in wheat could make access to this material too expensive for those who need it most.
>
> *Ian Edwards, Pioneer Hi-Bred, September, 1987*[25]

The great intellectual scavenger hunt

In the late seventies and early eighties, the debate on intellectual property was over plant varieties and the combatants were farmers, consumers and non-governmental organizations (NGOs) on one side against seed companies on the other side. Today, the debate is over biotech patents with the

seed industry squaring off against the biotech houses. The issues are the same.

Ten years ago, non-governmental organizations warned that the move to monopolize plant varieties would inevitably lead to the patenting of other life forms. Once society accepted the patenting of a plant, law-makers and regulators would have no theoretical or intellectual basis for rejecting the patenting of micro-organisms and livestock. In its wisdom, the industry demurred. No connection, they claimed.

A decade ago, seed patenting opponents warned that monopoly legislation would slow scientific innovation by reducing the exchange of plant germplasm among breeders. Writing in a major biotech industry publication, a top executive with Pioneer Hi-Bred—one of the strongest advocates of plant breeders' 'rights' in the seventies—warned, 'At a recent meeting of the National Wheat Improvement Committee ... some very real concerns were raised that, in both the public and private sectors, administrators are becoming reluctant to permit the exchange of plant germplasm pending a determination of patent possibilities'.[26]

A decade ago, NGOs also warned that the scope of patent protection could extend from the seed to the final food products. The seed industry disagreed. In resisting gene patenting today, Pioneer Hi-Bred's Ian Edwards now warns, 'Similarly, attempts to patent the expression of a high quality oil in sunflowers could make the resultant products more expensive for consumers'.[27] Indeed, several states now permit what is known as 'end product' patenting—the fruits or cut flowers of patented material.

Although the philosophical implications of life patenting dominate the mind, the practical consequences are also profound, especially for farmers:

1. *Patent stacking:* Since a patented gene retains protection in any combination of genes, it is probable that a new variety could end up with more patents in it than a Boeing 747. Each gene could be 'owned' by a different company and come with a royalty charge.

2. *Gene monopoly:* The right to prevent others from using a patented gene could cut off the traditional method of variety improvement building on other's research. And, it could allow one patent holder to monopolize the future of a crop that requires a specific gene, for example, to resist a major disease or to meet a crucial processing standard.

A lone sample of *Oryza nivara* (a form of rice) from Uttar Pradesh State in India contained the only gene in the world known to fend off grassy stunt virus. That gene is now incorporated into rice sown over 20 million hectares of Asia.[28] Should such a gene become anyone's monopoly property?

3. *Characteristics monopoly:* A recent patent has been granted to Sungene for a sunflower variety with very high oleic acid content. The claim allowed was for the characteristic (i.e., high oleic acid), and not just the genes producing the characteristic. Sungene has notified others involved in sunflower breeding that the development of any variety high in oleic acid will be considered an infringement. If this stands up in the courts, it means that a patent holder could prevent others from completing research even using totally different genetic systems.[29] Why not a patent for 'tasty' bread or 'high-yielding' rice or for 'good' kids?

4. *'Original sin':* On February 6th, 1988, the *New York Times* gave page one attention to a long-expected US patent office announcement that the offspring of patented livestock would also be subject to royalty charges throughout the 17 years of patent protection.[30]

This patent version of the old 'original sin' will soon be visited upon plants as well. Several years ago, Hans Leenders, Secretary-General of FIS/ASSINSEL (the federations of world seed houses and their breeders) proposed to abolish the farmers' right to save seed. Said Leenders, 'Even though it has been a tradition in most countries that a farmer can save seed from his own crop, it is under the changing circumstances not equitable that a farmer can use this seed and grow a commercial crop out of it without payment of a royalty ... the seed industry will have to fight hard for a better kind of protection'.[31]

Agricultural biotechnology companies are also fearful of the farmers' traditional right to save seed. 'The use of biotechnology to create novel crop varieties is generally not a business with an attractive return on investment', Peter Carlson of Crop Genetics claims. '... the farmer's field is a genetic Xerox machine. The one-time sale by the biotechnology breeder of a new variety will never support a price structure adequate to cover the research costs.' What about developing cytoplasmic male sterile (hybrid) plants? Carlson is sceptical: 'The extra effort to hybridize a new variety to create a "repeat sales" opportunity is substantial, and adds no value'.[32]

While there is pressure to amend the so-called plant breeders' 'rights' legislation to force farmers to pay for bin-saved seed, biotech companies

Table 21 The United States: comparison of utility patents and plant breeders' rights

	Plant variety protection	Plant patent act	Industry utility patent
Complete written description required			x
Sexually reproduced varieties protectible	x		x
Asexually reproduced varieties protectible	*	x	x
Protect hybrids		x	x
Novelty required	x	x	x
Requires standard of unobviousness			x
Provide generic coverage			x
Provides protection for genes and other parts			x
Doctrine of equivalents available	?	x	x
Sexually reproduced varieties infringe	x		x
Asexually reproduced varieties infringe	x		x

* However, asexual reproduction infringes the certificate except when applicant is in pursuit of a plant patent.
Source; Adapted from S.B. Williams, Jr. 'Features: Utility Product Patent Protection for Plant Varieties', *Trends in Biotechnology,* The Upjohn Co., February, 1986, Vol. 4, No. 2, p. 34.

would generally prefer to use the industrial patent system. The WIPO approach has a few disadvantages: a complete written description of the plant (or gene or cow) is required and the invention is not supposed to be 'obvious'—there should be what lawyers call an 'inventive step'. But the rewards are great. Not only must farmers pay for the offspring of their cows and maize but 'generic' patents are available (e.g. characteristics) and even hybrids can be patented. The table above compares the different intellectual property regimes available for plants in the United States.

One of the prominent features of patents is the ability of such legislation to encourage fighting within industry. Industrial patents are daunting enough, but life patents pose incredibly complex legal problems. How do you prove that a living, changing thing is really yours? Someone once said that the beauty of hanging is that it wonderfully concentrates the mind. So it is with patents. The mind of the inventor and the mind of the lawyer are concentrated—not solely on creative innovation—but on patentability and legal defences.

During the summer of 1987 alone: Monoclonal Antibodies lost a biotech patent suit to Hybritech and had to pay US $2.25 million and a stiff royalty fee.[33] Hybritech then turned around and got into the same litigation battle

with Abbott Laboratories in a dispute over a US $50 million market for sandwich assay kits related to Hepatitis-B and other diseases.[34] Meanwhile, Minntech settled its claim against Endotronics for US $325,000 in cash. In return Minntech reinstated a non-exclusive licence allowing Endotronics and Celanese to use its hollow fibre technology.[35] The Hormone Research Foundation and Hoffmann-La Roche sued Genentech in the UK over the control of a human growth hormone (t-PA).[36] Applied Protein Technologies sued Millipore Corp. for US $90 million claiming breach of licensing contract.[37] Beckman Instruments was awarded US $1 million from Pharmacia LKB AB (Sweden) for patent infringement of its scintillation technology and Genex and Searle settled a lawsuit which included proprietary rights.[38] The only folks we know who made money for sure that summer were the lawyers!

Cetus and Hoffmann-La Roche together with Ajinomoto are now engaging in a giant legal battle over the patent rights to the promising anti-cancer drug, interleukin-2. Hoffmann-La Roche and Ajinomoto expect to get a patent that will cover IL-2's DNA sequence and the genetic engineering techniques employed to produce it. But Cetus says it has made important changes to the molecule and has beaten Hoffmann-La Roche in the lab and in the clinics. If, however, Hoffmann-La Roche's expected patent covers the molecule's natural sequence, it may supersede Cetus's protection for the work it has done. According to Michael Ostrach, senior vice-president and general counsel at Cetus, such broad patents could drain the creativity and vigour from the industry. 'It would be unfortunate if patents of a very large scope are granted', he said. 'There's going to be a very severe chill on innovation.'[39] As the *San Francisco Examiner* noted, 'for Cetus, litigation may precede medication'.

Patent battles and intellectual property monopolization can seriously erode innovation. 'The difficulty will be to find a way', Johannes Schmekel of Alfa-Laval says, 'so scientists can protect their ideas, but still keep the information channels to their colleagues open. Exchange of ideas, view points, etc., is the only way to bring science forward. Today it is very common that companies apply for patents and "gag" the scientists. Good for the companies, but maybe of less interest ... in the long run.'[40]

Not only can life patents constrain the flow of information and hamstring the ability of breeders to innovate, but there is also good reason to doubt that the availability of patents encourages investment in biotechnology. Linda Greenhouse of the *New York Times* surveyed some industry representatives at the time of the five-four US Supreme Court decision that made

life patenting of micro-organisms possible. She found that more than a dozen companies had already been long at work on products they had no reason to believe would ever win a patent. 'They have already created, in the laboratory at least', Greenhouse wrote, 'new strains of bacteria that can make such diverse things as insulin, hormones, the virus-fighting drug called interferon, commercial chemicals, the simple form of sugar known as fructose, protein, and a variety of liquid fuels'.[41] Less than a year after the US patent office announcement that it would entertain animal patents, 17 applications were on the desk.[42] The research on each one of these applications would have been launched years before the Patent Office's decision.

There are two reasons why patents are not essential to innovation. First, with a new technology, the pace of innovation outstrips the value of any individual patent. Thus it was with micro-electronics and computer software. Industry fretted that it did not have protection for software but, in fact, developments moved so quickly that any form of protection became irrelevant. Now we have micro-organisms. Greenhouse reports that 'Stephen Turner, president of the Bethesda Research Laboratory, said he doubted that the ability to patent would have more than moderate impact on the field because advances in molecular biology were coming so fast. The substance or technique that might be worth patenting today may be out of date in only a few years'.[43]

Second, there is money to be made. Would Ciba-Geigy turn away from research on a plant variety that likes atrazine herbicide because there was no patent? Would Kirin Brewery of Japan ignore the opportunity to market its waste products? Would Campbell Soup rather not have a high-solids tomato because no monopoly was available?

There is a warning in all of this for little companies that think that patents can help them fend off the big transnationals. Burke Zimmerman of the National Institute of Health (US) told the *New York Times* when the US Court decision was handed down, 'If someone hits on something really hot, you can bet the pharmaceutical companies are going to look for some way to duplicate it, and it's not that hard to do'.[44]

Neither are the transnationals impressive innovators. The *Wall Street Journal* records that Hoffmann-La Roche almost overdosed on its valium patent. 'Eighteen years of living on Valium made Hoffmann-La Roche Inc. prosperous—and more than a little sluggish.' In order 'to shake the company out of its torpor', Gail Bronson wrote, Roche had to furiously rekindle its R&D programme before the Valium patent expired in 1986.[45]

There is an old story about a toad on a lily leaf. It seems the toad and leaf are placed in an uncovered pot. Ever so gradually, the water is heated. Finally, the water is brought to a boil. The toad dies without ever having thought of leaping to safety. Today, both the lily and the toad are patentable and we are the ones sitting on the lily leaf. Perhaps it is time we took a good look around. Barely a year after the US patent office ruled on oysters, Du Pont won a patent on its supermouse—a mouse containing a human gene that increases the little rodent's susceptibility to cancer. In line for the next patents are another mouse with human genes developed by Integrated Genetics that secretes t-PA from its mammary glands and a human gene bearing chicken bred by Transgenic Sciences that lays medically-useful eggs.[46] About 21 animals are in the US patent pipeline.[47] But it may remain for the European Communities to turn the patent world into a transnational's oyster.

> 'I like the Walrus best', said Alice, 'because he was a little sorry for the poor oysters'. 'He ate more than the Carpenter, though', said Tweedledee. 'You see he held his handkerchief in front, so that the Carpenter couldn't count how many he took: contrariwise'.
>
> *Lewis Carroll,* Through the Looking Glass

Europe: turtle dove-tailing?

If many in the South have watched with amazement the machinations of the US patent system, they have generally failed to observe parallel—and sometimes earlier—developments in Europe. In 1922, long before Washington contemplated the passing of a patent law for fruits and flowers, the German *Reichsgericht* allowed a process patent on bacterium derived from a turtle. Deemed useful in the treatment of tuberculosis, the Court held that while the patent was a little unorthodox, it met the spirit of German law and was offering society something important. And, in 1969, one year before the US passed its Plant Variety Protection Act, the Bonn Government decided the 'Red Dove' case determining that a breeding process for animals was patentable.

Europe's attitude toward life patents specializes in inconsistencies. Consider Switzerland—the bastion of transnational chemical, pharmaceutical, seed and food companies. The Swiss legislature has a long history of patent battles. During the last half of the 19th century, Switzerland rejected numerous attempts to pass patent laws and, in 1863, described the principle of patents as 'pernicious and indefensible'. In 1887, however, Switzerland capitulated to international pressure and passed its first bill. Until 1907,

however, chemicals and textiles were excluded from protection. Further revisions made almost everything patentable. Until Christmas of 1977, Swiss courts allowed the patenting of micro-organisms and were, at least theoretically, open to the patenting of plant varieties. Following the introduction of new patent laws that season, both micro-organisms and plant varieties were stricken from the list. After further revisions in mid-1984, man-made micro-organisms and plant varieties were again patentable material. By the Spring of 1986, ninety-nine years after the first patent law, naturally-occurring micro-organisms, pure cultures and even animal inventions are, at least theoretically, patentable. What next?

If not for Switzerland, for the Common Market what next is already what now. Thanks to the work of Henk Hobbelink and national participants in the Seeds Action Network in Europe, a draft directive on 'the legal protection of biotechnological inventions' prepared by the Commission of the European Communities has come to light.[48]

As Hobbelink and his colleagues outline, the proposed 'law' goes beyond US proposals by declining to place an upper limit on what life is patentable. Theoretically, as well, the EEC rule would end the free exchange of germplasm between scientists and would make 'original sin' patents possible for plants and animals. Most disturbingly, the onus of proof would rest upon those accused of infringing on another's patent. Guilty of violating a monopoly until proven innocent.

Despite plans to push the directive through in 1988, such a leap in legislation is a long way from becoming law. More likely, political and public opinion will force patent attorneys to pull in their horns. More sophisticated strategists within the larger biotech companies have probably been more horrified by the EEC draft than the NGOs. Not that they do not want all that the directive offers, but they want it gradually—as societal sensitivities are muted by the pace of product introductions.

With the situation changing monthly, at the time of this writing, four countries appear to permit the patenting of higher life forms (i.e. animals): Greece, Hungary, the USA and the USSR. Another five countries (Argentina, Australia, Brazil, Japan and Turkey) appear to have patent laws that at least do not expressly exclude the patenting of animals. As many as 14 countries allow protection for plant and animal cell cultures while another 11 states again may not specifically exclude this possibility. The table over leaf has been compiled by RAFI based upon confidential data gleaned from 37 countries.

Table 22 The status of life form patenting in 37 selected countries

Country	Plant breeders' rights	Plant patents	UPOV member	Macro molecules/ viral particles	Plant cell culture		Animal varie-ties	Engineered organisms	
					Mic-robes	Plant/ animal		Mic-robes	Plant/ animal
Industrialized market economy countries									
Australia	×	×	×	×	×	×	?	×	?
Austria					×	?		×	?
Belgium	×	×	×	×	×	?		×	×
Canada				×	×	?		×	?
FR Germany	×	×	×	×	×	×		×	×
France	×	×	×	×	×	×		×	×
Greece	×	×		×	×	×	×	×	×
Ireland	×		×	×	×	×		×	
Israel	×		×	×		?		×	
Italy	×	×	×	×	×	?		×	?
Japan	×		×	×	×	×	?	×	?
Luxemburg				×	?	?		?	
Netherlands	×		×	×	×	?		×	?
New Zealand	×		×	×		?		×	?
Portugal									
South Africa	×		×	×	×	×		×	
Spain	×	?	×	?	?	?		×	?
Switzerland	×		×	×	×	×		×	×
Turkey		?		?	?	?	?	?	?
UK	×		×	×	×	×		×	
USA	×	×	×	×	×	×	×	×	×
(Scandinavian countries)									
Denmark	×		×	×	×	×		×	
Finland				×	×	×		×	
Norway				?					
Sweden	×		×	×	×	×		×	
Industrialized centrally planned economy countries									
Czechoslovakia				×	×			×	
DR Germany	×								
Hungary		×	×			×	×	×	
Poland									
USSR		×		×	×	×	×	×	
Third World countries									
Argentina	×			×			?	×	?
Brazil							?		
Chile	×								
China				×	×	?		×	
Mexico									
Rep of Korea		×		×	×	×		×	×
Taiwan									

A Brief Chronology of the Patent Debate in the North

Early History

7th Century BC The Syberites of Greater Greece grant cooks with new recipes exclusive monopoly over the use of their recipes for one year;

480 Emperor Zeno of Rome rejects the concept of monopoly;

1474 City State of Venice establishes first patent law—but adds rule that patent must be 'worked' or be forfeited;

1623 Article Six of the English Statute of Monopolies establishes patent law;

1790 First US Patent Act to comply with Article 8 of the Constitution; concept of a 'compulsory license' is proposed in the Senate but rejected;

1791 France passes patent legislation affirming that inventor has monopoly as a 'natural right';

1794 Austrian Royal Decree accepts patents but rejects 'natural right' and describes patents as 'exception' to the 'natural right of citizens' to have access to inventions;

1819 Sweden adopts a patent system.

The Patent Push

1825-50 Companies press for stronger patent monopolies in the UK and among the states of Germany; Petitioners in Switzerland ask for patents there; the US Patent Act revised —monopoly powers increased; Spain adopts patents;

1838 The US patent office launches first formal government expedition to collect germplasm overseas.

Patent Resistance

1851 The Swiss legislature rejects another attempt to establish a patent system;

1851-2 British Parliament investigates complaints against patent system; 'Compulsory licence' concept is raised;

1852 Portugal enacts patent law;

1853 A German official calls for 'compulsory licences';

1854 Swiss reject patent laws once again; Patent law is adopted in Belgium;

1858 British scientists call for 'compulsory licences';

1862-5 British Parliament attacks abuses of patent system;

1863 German *Kongress Deutscher Volkswirte* condemns patents as 'injurious to public welfare' while German chambers of commerce call for abolition of all patent monopolies; Swiss legislature describes the principle of patents as 'pernicious and indefensible'; UK scientific organizations repeat call for 'compulsory licences';

1864 Italy undertakes a patent scheme;

1865 A patent law is passed in New Zealand;

1868 Bismarck announces his opposition to the principle of patents;

1869 Dutch parliament repeals patent law claiming that a good law of patents is an impossibility'; Canada adopts a patent law.

1869-72 UK House of Lords passes bill calling for 'compulsory licences' and applies other tough restrictions on the monopoly; prominent British politicians call for abolition of patents altogether;

1870 US Patent Act amended—monopoly powers strengthened;

1872 Japan passes first patent law.

The Capitulation

1873 Patent Congress at the Vienna World's Fair adopts 'compulsory licences' as solution to the monopoly dispute—opposition crumbles with compromise and due to economic depression; Japan repeals its patent law;

1874 Patent reform bill passed in British House of Lords is withdrawn in the House of Commons;

1877 Germany accepts a new patent law;
1882 Switzerland continues to reject patent referendum;
1883 Paris Union establishes a global patent regime;
1885 Term 'industrial property'defined to include agricultural products including grain, fruit and cattle;
1885 Japan reintroduces its patent law; Norway accepts a patent law;
1887 Switzerland finally adopts a patent law—but excludes chemicals and textiles;
1894 Denmark accepts a patent law;
1898 Finland adopts a patent regime;
1900 Paris Union is amended and strengthened in Brussels;
1903 Australia adopts first patent law;
1907 Under pressure from Germany, Switzerland amends patent law to include chemicals and textiles;
1910 The Netherlands reintroduces a patent system.

Strengthening Monopoly

1911 Paris Union is amended and strengthened in Washington;
1920 Greece adopts a patent law;
1922 German *Reichsgericht* (Supreme Court) upholds process patent on bacterium derived from a turtle useful in tuberculosis treatment; London meeting of industrial patent lawyers discusses need for protection of plant varieties;
1925 Paris Union is amended and strengthened in The Hague;
1927 Ireland takes on patent laws;
1930 The US Congress passes a unique Plant Patent Act allowing the monopolization of asexually produced fruits, trees and ornamentals. Potatoes and other asexually produced vegetables are excluded.
1934 Paris Union is amended in London and 'industrial property definition' is broadened to also include 'flowers and flour';
1948 Italian High Court declares plant varieties patentable but legal confusion leads to call for special plant variety law;
1952 US Patent Act amended—monopoly powers improved; Vienna session of the International Association for the Protection of Industrial Property (AIPPI) fails to act on German proposal on plant patenting;
1957 In Paris, ASSINSEL (International Association of Plant Breeders for the Protection of Plant Varieties) accepts French invitation to host a conference on Plant Breeders' Rights in order to circumvent industrial patent system apathy;
1958 Fritz Matchlup's study for the US Senate gives landmark position rejecting the 'natural right' concept for patenting; Seymour Melman's study for the US Senate claims that innovation would continue in the public and private sectors 'with or without a patent system'; Paris Union is amended and strengthened in Lisbon;
1959 New breeds of agricultural animals as well as some industrial plants are declared subject to certificates of invention in the USSR;
1960 Canada's Isley Royal Commission affirms Matchlup view that there is no economic evidence that the patent system is justifiable—and adds that patents should not be extended to plants;
1961 Brazil challenges the fairness of the Paris Union in the UN General Assembly; International Union for the Protection of New Varieties of Plants (UPOV) is established in Paris;
1962 The Rahl study of the patent system notes: 'It is not freedom of competition which requires apology. It is interference with freedom which must always be explained';

1963	The Strasbourg Convention attempts to unify the patent system among western European states;
1966	US Presidential Commission unanimously affirms the value of the patent system;
1967	The Banks Committee in the UK affirms the value of patents through an 'innocent by association' argument that patents and industrial development appear to share a common history; Committee concedes that no empirical data exists on the merits of patents; Paris Union is amended and strengthened in Stockholm;
1969	In landmark 'Red Dove' decision, German Federal Supreme Court rules that a process for breeding animals may be patentable; New Hungarian patent law expressly permits the patenting of animal breeds under criteria similar to UPOV rules;
1970	In Washington, 35 states sign Patent Cooperation Treaty to ease the application work of companies by adopting a still more uniform approach among industrialized countries; The US Plant Variety Protection Act is passed during the Christmas season of a dying Congress. For the first time, cereals and vegetables are patentable. Major processing vegetables remain excluded.
1971	Strasbourg Agreement strengthens patent system in Western Europe;
1972	UPOV Convention is amended.
	Reconsiderations
1974	UNCTAD study rejects the 'natural right' concept; Fur-bearing animals become subject to certificates of invention in the Soviet Union;
1975	Micro-organisms are ruled patentable in German Bakers' Yeast case;
1976	Canadian Working Paper on Patent Law Revision rejects validity of patent system and calls for a new Act with a ten year 'sunset' clause; Micro-organisms deemed patentable in Australia;
1978	UPOV is amended to allow entry of the USA;
1979	Japan's patent office guidelines allow the patenting of micro-organisms;
1980	By a 5-4 decision, the US Supreme Court allows General Electric to obtain a patent on a micro-organism under the regular industrial ('utility') patent law; In another Christmas battle, another dying Congress amends the 1970 Act to include six major vegetables previously excluded;
1986	Molecular Genetics is granted the first utility product patent for a plant variety giving companies a choice of patenting through the 1970 PVPA or via industrial patents; Sungene is granted a patent for the high-quality characteristic of the oil in a sun-flower and warns other companies not to develop high-quality oils;
1987	US Patent Office announces it will allow the industrial patenting of higher life forms including pets and livestock; A Patent office official leaves open the possibility of patenting human 'traits'; Genome Inc. announces it will try to copyright base pairs of the human genome; UPOV announces intention to remodel Convention to accommodate biotechnology interests;
1988	The US Patent Commissioner reveals a new policy that will allow those holding livestock patents to charge royalties on the offspring for the full life of the patent; Du Pont obtains a US patent on the first transgenic mouse (containing human genes) valued for its susceptibility to cancer; A Commission of the European Communities drafts a decree of the 'legal protection of biotechnological inventions' which would go beyond US decisions to leave the patenting of all life forms possible including subsequent generations of patented plants or animals and which reverses the burden of proof in order to better protect inventors from infringement.

Source: Obtained by RAFI from numerous legal and historical documents including the Canadian Government's 1976 'Working Paper on Patent Law Revision'.

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Bio-Battles at the UN

Plants and Politics at FAO

The battle over the international control of the flow and use of biological diversity has largely been waged at FAO. Many of those at Bogève—including Annelies Allain, Cary Fowler, Henk Hobbelink, Pierre Benoit Joly, Pat Mooney and Daniel Querol are veterans of Rome battles and were able to offer a clear overview of the issues at stake. Despite major progress during the 1980s, the nineties still threaten to see a US end-run around the FAO via a UNEP/IUCN 'treaty'. Meanwhile, the position and purpose of the International Board for Plant Genetic Resources (IBPGR) remains in doubt and is still causing consternation. On the horizon, too, biotechnology may forge a revised FAO Commission for Biological Diversity. Hopes for the International Fund are improving although some still debate the importance of the South's germplasm for the North.

> Germplasm represents the raw material for plant breeders. Patents that restrict the flow and utilization of this material could have serious consequences in the years to come.... The issue of patenting germplasm is also a very sensitive issue in developing countries, a number of which were the original sources of our major crop species and still represent key areas for germplasm collection. We need to remain sensitive to this issue and not jeopardize our future capacity to obtain vital germplasm with new sources of resistance to pests and disease.
>
> *Ian Edwards, Pioneer Hi-Bred, 1987*

Accompanying the creation of the biotechnology industry in the 1980s has been a fierce debate waged at the United Nations over the conservation and use of plant genetic resources. 'Genetic resources', the genes that code for the characteristics of all living things from the drought tolerance of a sorghum to a baby's brown eyes, are the raw materials for the new biotech industry as well as for today's plant and animal breeding industries. Determining who will collect, save, and document these resources and determining how they will be exchanged—in other words, who is to control and benefit from genetic resources—has become a question of immense importance.

Most of the world's important food crops were domesticated in Asia, Africa, and Latin America thousands of years ago. It is in these areas that the greatest amount of genetic diversity can be found. Historically, scientists from industrialized countries have ventured southward in search of exotic plants for new medicines, ornamentals and on behalf of their plant breeders, keen on developing new varieties of wheat or tomatoes, for example. Thus, much of the collected (and easily accessible) diversity came

to be housed in the North. For a variety of good and not so good reasons, institutions perpetuated this movement of genes from South to North. Today, only some 14 per cent of the germplasm in storage (not including that in the international agricultural research centres) is located in the South.

The first three rounds: 1981-85

At the end of the 1970s, several Third World countries, most notably Mexico, began to express concern about the implications of this history. Specifically they wanted simple guarantees that they would not be denied access to genetic resources originating in the South but now stored in the North. They envisaged an 'international genebank' under the auspices of the UN'S Food and Agriculture Organization (FAO). It would be a bank where any *bona fide* researcher or breeder could gain access to genetic materials regardless of the person's politics. (Already concerns were being expressed about politics dictating exchange policies, both at genebanks in the North and South.) And they also envisaged an 'international convention', spelling out guidelines to promote the full and free exchange of genetic materials.

At FAO conferences in 1981,1983, and 1985, Third World delegates fought for and passed resolutions creating:

1. The framework for an international system of genebanks funded and operated by national governments under guidelines (regarding access and exchange, etc.) established by the FAO.
2. An 'International Undertaking', specifying voluntary guidelines for the conservation and exchange of genetic resources.
3. A Commission on Plant Genetic Resources, as the first and only intergovernmental body where governments, as governments, can assemble to talk about this topic. (The Commission meets every other year. In the interim a 'working group' of the Commission is authorized to meet.)

All of these measures met stiff opposition from industrialized countries, especially the US, Canada, the UK and Australia. Even the more progressive Northern states such as Sweden allowed their foreign policy to be dictated by their seed industries and worked actively against the Third World. Among Third World nations, the 'leaders' tended to be Mexico, Cuba, Colombia, Costa Rica, Venezuela, India, Pakistan, the Philippines, Senegal, and the Congo, though support was broad and enthusiastic particularly in Latin America. Among the states in the North, Spain was alone in playing a highly constructive role.

A detailed history of these 'seed wars' at the FAO (through 1985) can be found in *Development Dialogue,* 1983:1-2 and 1985:1.

Progress and lingering problems

While the Third World had won significant victories in an amazingly brief time, several troubling problems lingered on as 1985 drew to a close. One problem concerned the International Board for Plant Genetic Resources (IBPGR), another concerned a proposal to establish an 'international gene fund', and yet another involved continuing disagreements over the scope of the Undertaking and the 'rights' plant breeders and farmers should be granted.

Over the years, the IBPGR, a quasi-independent, quasi-UN organization (but technically an NGO) had come to take over FAO's historic role in germplasm conservation. Operating out of FAO headquarters, but without real FAO supervision, IBPGR had come to be seen by some in the Third World as the 'traffic cop' overseeing the movement of genetic resources in ways advantageous to industrialized countries. As a self-proclaimed 'technical and scientific body', IBPGR appeared rudderless. Who was to make policy decisions in this scientific institution? While denying it had any involvement in politics, it became increasingly evident that IBPGR was up to its stamen in politics. Behind the scenes it joined industrialized countries in opposing all Third World initiatives at the FAO. Fearing supervision (by the FAO Commission), IBPGR made plans to pack its bags and leave FAO. But a series of events led to today's uneasy arrangement. IBPGR remains at FAO—officially the two are working their differences through. Meanwhile, the Commission is recognized as the policy making body and is enjoined to work in 'complimentarity' with IBPGR. But does this mean that the Commission sets or even influences IBPGR policy? Does it even preclude IBPGR working at cross-purposes to FAO? While a 1987 'Memorandum of Understanding' clarifies some problems—the IBPGR Board will determine its programme of work, but FAO will continue to exercise a veto over the appointment of the IBPGR Chair—clearly, major difficulties remain to be solved.

The International Undertaking continues to be controversial, because it sets as a goal the full and free exchange of all categories of genetic resources from the wild relatives of agricultural crops to the advanced breeding lines and patented varieties of Northern corporations. Industrialized countries argued passionately, but ineffectively, that the Undertaking recognizes the legitimate 'rights' of plant breeders and confine its turf to the exchange of the 'raw' material originating in the Third World.

The debate over plant breeders' rights spawned a broader discussion in the March 1987 meeting of the Commission on Plant Genetic Resources. There, Third World delegates argued that if plant breeders had 'rights' of ownership, control, and compensation by virtue of labouring for a decade (often with 'donated' Third World genetic resources) to develop a new variety, then Third World farmers as a group also deserved some rights and recognition. Was it not Third World farmers who domesticated our important agricultural crops, observed, developed, and safeguarded the tremendous genetic diversity used by the modern plant breeder? Were not Third World farmers actually plant breeders themselves in the constant process of selecting for characteristics to meet their particular needs?

How then could 'farmers' rights' be observed? This was the question Commission delegates grappled with in FAO's Green room that March. They rejected the simple 'pat on the back' suggested by industrialized countries and instead opted for the creation of an 'international gene fund' for the conservation and utilization of plant genetic resources (first suggested by France and the Netherlands in 1985). Such a fund—needed in any case to bolster anaemic conservation budgets—would make farmers' rights concrete. Administered by the Commission and thus indirectly by the international community, it would 'reward' farmers with programmes beneficial to all.

The argument seemed logical enough. But the US was having none of it. The US had opposed the creation of the Undertaking, the international system of genebanks and the Commission. It was not about to be party to the creation of an international fund that might challenge the hegemony of IBPGR in dishing out genetic conservation favours to the Third World and industrialized country institutions. But of course the US could not phrase it quite so bluntly. So it simply declared that funding for conservation programmes was already adequate. Another fund, more money, was unnecessary—so unnecessary in fact that the US even opposed a study of the feasibility of establishing the fund. The transparency of the argument was greeted with derision among scientists in the US who, themselves, felt underfunded. The absurdity of the US position became painfully obvious when, in 1988, the US National Research Council reported that the country's key gene bank was 'antiquated' and that it posed 'difficulties for assuring safe, secure storage' of germplasm. More funding and major renovations were called for.[1] And in an off-camera discussion after a TV debate, a high-ranking State Department official confided that the real reason had to do with the fact that the UN could not be trusted. It was, in the

words of this official, a 'super-democracy', an institution where everyone got to vote.[2]

Nevertheless, the Commission requested that the Director-General of FAO move to establish the fund. During the summer, the Director-General oversaw the preparation of the necessary legal documents and declared the fund a reality. Soon thereafter the fund's first donation arrived—to the chagrin of the US delegation and the delight of Third World ambassadors —from a private American foundation, the CS Fund.

Round four: 1987

The November 1987 FAO Conference was dominated by the re-election of the organization's director-general. Nevertheless, genetic resources remained on the front burner as new announcements in the Opening Plenary debate brought the total number of countries adhering to the Undertaking, the Commission or both to an impressive 114. In a surprising and encouraging move, both Norway and Ethiopia announced their support for FAO's initiatives. Norway's move signalled a thaw among the Scandinavian states and gave hope that traditional Nordic empathy for the concerns of the South would prevail. For the South, Ethiopia's participation was equally significant since that country has, by far, the best and most important gene bank controlled by a Third World country and has—with Nicaragua—done more than any other country in the South to conserve and utilize crop germplasm.

American attempts to scuttle the Undertaking and Commission had clearly failed. A US attempt to organize a boycott of the Commission's 1985 meeting met with so little success that the US itself finally showed up searching for seats at the back with fellow observers from the NGOs. In the Commission's second round in March, 1987, the US observers found themselves shoulder to shoulder with a Soviet delegation. The USSR is not a member of FAO and American diplomats had challenged the viability of the Commission/Undertaking partly on the grounds that it would be useless without Russian involvement. To have Soviet officials present and active —as fellow observers—was downright embarrassing. All signs indicated that the international community accepted and endorsed the FAO initiatives. But while important issues remained—strengthening the voluntary Undertaking and establishing mechanisms for the Fund (so that recognition of farmers' rights would not simply be 'voluntary')—the Conference faced more pressing concerns.

The US arrived with its budget axe. Repeatedly it called for massive budget

cuts, hinting at 30 per cent. It revealed that FAO income projections were inflated, because the US did not intend to meet its own obligations. This stance, others noted, would take the US from being the biggest contributor to being the biggest debtor to FAO.

The American budget proposal, tacitly supported by a number of other industrialized countries, was accompanied by only one specific budget-cutting suggestion, made repeatedly: to reduce the budget, the US called for the demolishing of the Commission on Plant Genetic Resources.

Third World delegates were alarmed, and irritated. The USA, which had consistently opposed the creation of the Commission, was attempting to destroy the Commission under the guise of budget-cutting. Were the entire budget of the Commission eliminated, the FAO would realize a savings of less than 0.0004 per cent. Reaganomics at its most incisive!

A broad range of delegations felt compelled to support specifically the Commission, the Undertaking, and FAO's work on genetic resources in general. Supportive statements were offered by Mexico, Venezuela, Norway, Spain, Costa Rica, Trinidad and Tobago, Pakistan, Poland, Ethiopia, Angola, and Peru. No nation stepped forward to support the US position against the Commission.

Given the threat posed by US budget proposals, Third World nations were put on the defensive. In the end they had to settle for protecting the gains they had made during previous conferences. While no new gains were made, the groundwork was laid for advances in 1989.

The Commission is developing its programme. According to its Secretariat, it is an ambitious one:

> This programme covers technical and legal matters and in particular the establishment of an international fund to promote the preservation (collecting, conservation, evaluation, and documentation) and utilization (plant breeding as well as seed production and distribution) of plant genetic resources, mainly in developing countries; the legal situation of base and active collections in the world; legal arrangements for the establishment of an international network of base collections of germplasm in gene banks under the auspices of FAO; measures to assure complementarity between IBPGR and the Commission; assessment of countries' capabilities of using their plant genetic resources; development of an international information system on plant genetic resources; and professional training on plant genetic resources in developing countries.[3]

Table 23 FAO member states score card

Member States	Under-taking	Com-mission	Working Group	Seed Donor	Seed Recipient	IBPGR Base	IBPGR Board	IBPGR Grant	IBPGR Fund
Africa									
Algeria				x					
Angola									
Benin		x		x					
Botswana		x		x				x	
Burkina Faso	x	x		x	x			x	
Burundi									
Cameroon	x	x		x	x	x			
Cape Verde	x	x							
Central African Rep.	x	x							
Chad	x	x		x					
Comoros									
Congo		x	x						
Djibouti									
Egypt	x	x	x	x				x	
Equatorial Guinea									
Ethiopia#	x	x		x	x	(x)		x	
Gabon	x	x							
Gambia		x							
Ghana				x	x			x	
Guinea	x	x		x					
Guinea-Bissau		x							
Ivory Coast	x			x	x			x	
Kenya	x	x	x	x			/x/	x	
Lesotho									
Liberia#	x	x		x					
Libya	x	x	x	x					
Madagascar	x	x						x	
Malawi	x			x					
Mali	x	x		x				x	
Mauritania	x	x							
Mauritius	x	x						x	
Morocco		x							
Mozambique	x			x				x	
Namibia									
Niger		x		x				x	
Nigeria#				x	x	(x)		[x]	
Rwanda		x							
Sao Tome & Principe									
Senegal	x	x	x		x	x			
Seychelles									
Sierra Leone		x							
Somalia				x					
Sudan		x		x	x			x	
Swaziland									
Tanzania				x				x	
Togo		x		x				x	
Tunisia	x	x	x	x					
Uganda		x						x	
Zaire									
Zambia	x	x	x	x				x	
Zimbabwe	x			x				x	
Total(51 states)	23	31	7	26	8	4	1	19	

Member States	Under-taking	Com-mission	Working Group	Seed Donor	Seed Recipient	IBPGR Base	IBPGR Board	IBPGR Grant	IBPGR Fund
Asia and the Pacific									
Afghanistan		x							
Bahrain	x								
Bangladesh	x	x	x	x				x	
Bhutan				x					
Burma				x					
China				x		x	x	x	x
Cook Islands									
Dem. Kampuchea									
Dem. PR Korea	x	x							
Fiji	x							x	
India#	x	x	x	x	x	(x)	x	[x]	x
Indonesia		x	x	x	x			x	
Iran	x	x							
Iraq	x								
Jordan								x	
Korea Republic	x	x		x				x	
Kuwait	x								
Laos									
Lebanon	x							x	
Malaysia				x	x	x	x	x	
Maldives									
Mongolia									
Nepal	x			x				x	
Oman	x								
Pakistan		x		x			x	x	
Papua New Guinea				x				x	
Philippines#	x	x	x	x	x	x	x	[x]	
Qatar									
Samoa									
Saudi Arabia									
Solomon Islands	x							x	
Sri Lanka	x	x		x				x	
Syria	x	x						x	
Thailand		x		x	x	x		x	
Tonga	x								
Turkey	x	x							
United Arab Emirates									
Vanuatu									
Viet Nam									
Yemen Arab Rep.		x		x					
Yemen PDR	x								
Total (41 states)	19	14	4	15	5	5	5	17	2

Member States	Under-taking	Com-mission	Working Group	Seed Donor	Seed Recipient	IBPGR Base	IBPGR Board	IBPGR Grant	IBPGR Fund
Latin America and the Caribbean									
Antigua & Barbuda	x								
Argentina	x	x				x			
Bahamas									
Barbados	x	x							
Belize		x							
Bolivia	x	x							
Brazil		x				x	x		
Chile	x	x							
Colombia#	x	x				(x)			
Costa Rica	x	x	x	x		x		x	
Cuba	x	x						x	
Dominica	x	x							
Dominican Rep.	x	x						x	
Ecuador		x							
El Salvador	x	x	x						
Grenada	x								
Guatemala		x		x				x	
Guyana		x							
Haiti	x	x							
Honduras	x	x		x					
Jamaica	x					x		x	
Mexico#	x	x	x	x	x	x		[x]	
Nicaragua	x							x	
Panama	x	x	x						
Paraguay	x								
Peru#	x	x	x			(x)		[x]	
St. Christopher & Nevis		x							
St. Lucia		x							
St. Vincent/Grenadin		x							
Suriname									
Trinidad & Tobago						x			
Uruguay		x							
Venezuela		x							
Total (33 states)	20	25	5	4	1	8	1	8	

Member States	Under-taking	Com-mission	Working Group	Seed Donor	Seed Recipient	IBPGR Base	IBPGR Board	IBPGR Grant	IBPGR Fund
Europe									
Albania									
Austria	x	x	x					x	x
Belgium	x					x		x	x
Bulgaria	x								
Cyprus	x	x		x			x	x	x
Czechoslovakia		x				x			x
Denmark*	x	x	x		x	x			x
Finland*	x	x				x		x	x
France	x	x	x	x	x	x	x	x	x
Germany FR	x	x			x	x	x	x	x
Greece	x	x		x	x	x		x	x
Hungary	x	x				x			
Iceland*	x	x				x			
Ireland	x	x						x	x
Italy#		x			x	x	x	x	x
Lichtenstein	x								
Luxembourg									
Malta									
Netherlands#	x	x			x	x		x	x
Norway*	x	x				x			x
Poland	x	x	x			x			
Portugal		x		x	x	x		x	
Romania									
Spain	x	x	x	x	x	x		x	x
Sweden*	x	x		x	x	x		x	x
Switzerland	x	x						x	x
United Kingdom	x	x			x	x	x	x	x
Yugoslavia		x						x	
Total (28 states)	20	21	5	6	10	17	5	16	17
North America/Others									
Canada					x	x	x	x	x
USA#					x	x	x	x	x
Australia		x	x	x	x	x	x	x	x
Israel	x	x		x	x	x		x	x
Japan					x	x	x	x	x
New Zealand	x								
Total (6 states)	2	2	1	2	5	5	4	5	5
Grand total (159 states)	84	93	22	53	29	39	16	65	24

Notes: * Scandinavian countries share the Nordic Gene Bank near Lund, Sweden, and in a remote island mine in Norway.
Country is host to an International Agricultural Research Centre (IARC) or another member Institute of the Consultative Group on International Agricultural Research (CGIAR)
(x) Base collection(s) are held by an International Agricultural Research Centre (IARC) situated in the country.
[x] All or part of IBPGR grants may have gone to the IARC in the country.
/x/ Board membership is not related to country.

Round five

The fifth round of the on-going battle at FAO takes place in 1989 when both the Commission and the full FAO Conference host their biennial bouts in Rome. Among the major points of combat—not all formally on the agendas—are the following:

Tricks or treaties?

In April, 1989, the FAO Commission will face the question of how to put the International Fund on a more firm financial footing. To most delegates, the Fund is not only a practical mechanism for financing the programme of the Commission, but also the practical manifestation of 'farmers' rights'—the principle that if corporate plant breeders are given legal rights and rewards (through patents on new varieties), then farmers as a class require consideration and safeguards for the very real contributions they have made and continue to make in developing and conserving genetic material.

In the 1987 round, Peru suggested that support for the fund might come from levies on exports (presumably seed) and development projects. A tax on seed exports which went to support the Fund would be a tax on those who financially benefit the most from the conservation of genetic resources. It could easily be argued that the work of the Fund, insofar as it supports conservation, in fact serves as a subsidy to those corporations who need genetic resources for their breeding programmes.

Nevertheless, this idea will meet with stiff opposition from the US, for example, who would rather finance the work of the IBPGR, a more controllable and less internationally accountable body. However, compromises may be possible, since it will be in the long-term interest of the US to promote friendlier relations with Third World nations which possess so much valuable genetic diversity. Already some countries are asking why they should be obliged to freely exchange genetic resources with the US if the US will not sign the Undertaking pledging to freely exchange with them. And why should countries regard US plant patent laws as sacred, if the US is so hostile towards establishing a conservation-oriented fund in symbolic recognition of farmers' rights?

Even as FAO and its member states get their act together, however, the International Union for the Conservation of Nature and Natural Resources (IUCN) with strong backing from the American State Department, is promulgating their own version of a 'Treaty' for the in situ conservation of genetic resources. The treaty would also include a funding mechanism by which governments and NGOs could contribute to national and local conservation groups in the South. Although not totally overlapping the work in Rome, where both in situ and ex situ strategies are on the

agenda, IUCN's initiative could gut the political thrust of the exercise at FAO—much to the benefit of the North.[4]

First aired at an IUCN gathering in February, 1988, a final text is hoped ready for signatures within two years—wherein 'the United States will be actively involved in the negotiation process at all stages of treaty development'.[5]

Despite its intense opposition to FAO's low level Undertaking and its rejection of the need for any more funding, US State Department officials have thrown their support behind a very broad approach to the UNEP/IUCN counter treaty.

During 1988, US State Department Mandarins gave public support to the notion of a legally-binding treaty that would include a system of financial compensation to national governments and indigenous peoples for germplasm conservation. Senior American officials even left open the door to providing compensation through taxation.

At a specially convened meeting in Geneva in November, 1988, a large US delegation pushed hard to ensure that the draft treaty would also 'bind' the South into surrendering its germplasm.

This is 'bacon and eggs' treaty-making. The US (the chicken) is saying to the South (the pig), 'Let's get together and make bacon and eggs. You provide the bacon and we'll provide the eggs.' Somehow, the 'binding' commitment required is different!

> There is a relation between the amount a country donates *to* IBPGR and the number of collections designated to that country *by* IBPGR.[7]
>
> *David Wood, Head, Genetic Resources Unit, CIAT, 1987*

Not all of the bio-battles will take place inside the FAO. Still trying to avoid the clutches of 'super-democracy' at FAO, IBPGR continues to cast about for a new home. Enthusiastic about capturing a larger slice of the germplasm pie, some officials at the UN Environment Programme in Nairobi may offer the Board a new base. IUCN has also offered a home in Gland. Whether IBPGR will be free to accept is yet another question. For the moment, the Consultative Group on International Agricultural Research has told the Board to lie low and stay in Rome. Nevertheless, a conference in Nairobi at the end of September, 1988, gave IBPGR the opportunity to negotiate a new address.

On the other hand, Rome may prove safer than Nairobi. IBPGR—which is participating in a major germplasm programme with the nine SADCC states of Southern Africa—is also contemplating some quiet diplomacy in South Africa itself. According to Board Minutes reporting on the work of the Executive Committee, the Committee sought a 'clarification of the CGIAR position on links with South Africa; (the Chairman of CGIAR suggests that IBPGR, if the work is considered to be of importance, could carry out a low key programme in that country).'[8] This says as much or more about CGIAR than it does about IBPGR.

The CGIAR Chair's reply to IBPGR on South Africa emphasizes that the dispute over IBPGR must shift to the whole of the Consultative Group on International Agricultural Research (CGIAR) and its International Agricultural Research Centres (IARCs) such as IITA and ILCA—both in Africa.

CGIAR's defense of IBPGR has been tepid, at best, but it has still insulated one of its member institutions from the slings and arrows of outraged democracy at FAO.

Three questions dominate: Who controls IARC germplasm? Is IBPGR technically competent? Is IBPGR trustworthy? That all is not well between the crop-oriented IARCs and the gene-oriented IBPGR is hardly news. But the tension became public in October 1986 at an international symposium hosted by the Plant Genetic Resources Centre in Addis Ababa, Ethiopia. Speaking as head of the Genetic Resources Unit of CIAT (International Centre for Tropical Agriculture at Cali, Colombia), Dr. David Wood outlined the constructive and creative relationship his Unit is attempting to establish with farmers in the area. Wood stepped aside from his presentation, however, to take a broad swipe at IBPGR, staff of which were sitting stunned in the room. Wood stated that CIAT was disassociating itself from IBPGR and was refusing to be part of the IBPGR network. He went on to attack the biases in the IBPGR funding programme and asserted that the role of gene banks in the IARC system is to serve the Third World.[9]

GTZ officials—the technical aid agency of the Bonn Government—virtually imploded, having paid for much of the symposium, and retired to the toilets while IBPGR staff looked longingly at the windows. The Ethiopians took note. By comparison, NGO criticisms of IBPGR—which followed later in the day—appeared muted and reserved.

While Wood is undoubtedly an independent and outspoken individualist,

he properly reflects the seldom-voiced frustration of many gene bank directors with the competence and political insensitivity of IBPGR.

Some of the frustration has to do with accuracy. An internal review of the IBPGR collection data undertaken in 1986 showed huge information gaps and argued that the record on collection missions was out by anywhere from a quarter to a third and that, sometimes, regional food crop priorities had been neglected by IBPGR which had funded industrial crop collections in the same territories instead. Outsiders familiar with IBPGR claimed, however, that this study, too, was riddled with errors—for and against the International Board.

Of much greater concern is the safety of the genebank network put in place by the Board. Another internal study—this time of 17 key genebanks —revealed that at least seven were substandard, some dangerously so. A RAFI Case Study summarizes the situation as of mid-1987 (see pages 281-86).

The news of the registry survey sent a mild shock wave through the CGIAR and related national genebanks. At a seed conference in Montevideo in early November, 1987, Dr K.L.Tao—the IBPGR staffer leading the on-site bank evaluations—was critical of RAFI for having exposed the IBPGR study. It was 'undiplomatic'. Nevertheless, Tao went on to tear apart the Argentine genebank and, in a public forum, turned his guns on CIAT's bank in Colombia. With most of the front row composed of CIAT officials, this might have been a fair return for the abuse IBPGR received in Addis but it was also suicidal. Subsequently, Dr Tao and his colleagues have completed evaluations of 33 of 38 base collections—but the details of the additional surveys have not been disclosed.[10]

CIAT—and many of the other international centres—are further dismayed by IBPGR's political clumsiness. There is a widespread feeling that IBPGR has been the architect of its own problems. Leading up to a meeting at CIMMYT in late 1987, David Wood penned a letter to fellow genebank directors that scored the board harshly for its distribution of key base collections. Of the 127 base collections, Wood wrote, '81 are in industrial-ized countries, 29 in the International Agricultural Research Centres, and 17 in national collections of developing countries...'[11]

Of the 81 base collections held by the North, 70 are in the hands of the 13 countries that fund IBPGR. Wood pointed out, 'There is a relation between the amount a country donates to IBPGR and the number of collections

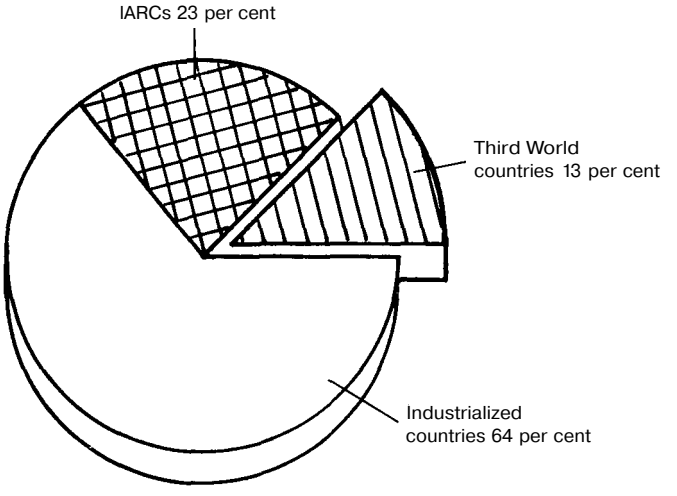


Figure 18 IBPGR base collections

designated to that country by IBPGR'.[12] Wood reckoned that a donation figure just under US $65,000 equalled one base collection. It may be that the Howard Hughes Foundation in the USA and IBPGR in Rome share a similar ethical philosophy...

Nevertheless, not all the political embarrassment lies with IBPGR. The International Centres also have cause to blush. When asked by FAO to indicate the ownership of the germplasm the centres hold in their genebanks, most of them haughtily replied that they were 'custodians' on behalf of the world community. Romantic idealists to the core! Yet, it is still hard to see 'Cigar' (as CGIAR is often known) as such a bunch of old softies. In the corporate world, high-sounding phrases are only used when the facts are either missing or uncomplimentary. If the Centres are 'custodians' then they must be answerable to someone. Who?

More than other Centres, IRRI has come under attack for its rice genebank. But of all Centres, IRRI has done more to articulate the legal status of the bank by making it institutionally separate from the rest of the organization. Despite this, the recently-retired Director-General of IRRI, M.S. Swaminathan, says that the 'ownership' of IRRI and of the genebank is based upon an exchange of letters between the IRRI Board and the Philippine Government. Either party can end the arrangement with a simple letter. Once ended, all the physical property of IRRI—excluding only the personal possessions of IRRI employees—reverts to the Philippine Government and is assigned to the keeping of the University of the Philippines at Los Banos.[13]

The Philippine Government—whether in good times or in bad—is not the

world community. It may be of little consolation to Indian or Chinese breeders to know that their traditional rice material is the property of the Philippines rather than the property of IRRI.

As it is with IRRI it may also be with the other international centres. Third World governments meeting at FAO are not content with high-sounding phrases and declarations of love and peace. They want a technically and politically responsible system for the conservation of one of the world's most valuable treasures.

Fittingly, the delegation of Pakistan, which often plays a prophetic role in these conferences, has been the first to introduce the subject of biotechnology. In the midst of one of the biggest agricultural 'revolutions' in history, it was left to Pakistan and Venezuela to raise the question of how this might affect the FAO. Pakistan stated that it could 'foresee in the near future the need for an international code of conduct on biotechnology'. Indeed, countries now aware of the importance of genetic resources may well turn their attention to the consequences of the uses of those resources. The 'seed wars' at FAO, as they have been described, may become 'gene wars'.

If so, IBPGR will still be in the thick of things. The Board is well aware that the genes it works with are the building blocks of genetic engineering. In the Spring of 1983, the Board's director, Trevor Williams, attended COGENE—the Committee on Genetic Engineering of the International Council of Scientific Unions gathering in Cologne. Following the sessions, Williams wrote (April 12) to Judith Lyman at the Rockefeller Foundation in New York proposing the creation of a 'gene library' for DNA workers. In closing, Williams added:

I've marked this letter confidential because you will have heard the member states of FAO have asked for more consideration for an international convention and genebank and the question of germplasm is rapidly becoming political. It is spearheaded by the Latin American countries especially Mexico, Colombia, and Peru. Against this background, if the IBPGR seems to be moving towards a gene library we could be accused of taking countries' 'valuable' materials and putting in a form only immediately useful to developed country breeders; hence the need for confidentiality at this stage. (After all, the breakthroughs are likely to come in USA, FRG or Australia).

Now, a gene that would let a leopard change its spots—that would be useful!

As a result of the joint Pakistan/Venezuela initiative, biotechnology has a prominent place on the Commission agenda and resolutions are bound to be carried to FAO's November 1989 Conference as well. A truly effective

approach to biotechnology in the context of biological diversity, however, requires that FAO consolidate its own conservation efforts. At the moment, plant (generally meaning 'crop') genetic resources are treated separately from animal, forest and aquatic genetic diversity. Only if the Commission has oversight over all of these activities can its members deal intelligently with the problem/potential of biotechnology. In a new world where wild and weedy relatives of crops (found in forests and fields) are increasingly valuable—and in a world of transgenic species where genes from the animal kingdom are becoming routinely transferred to the plant kingdom, it is time for the FAO Commission on Plant Genetic Resources to become the FAO Commission on Biological Diversity.

> AID supports the work in Oregon through a research contract and at CIMMYT through its regular contribution. The overall purpose is to develop improved varieties for the less developed nations, but the varieties should also be of considerable interest and potential value to the United States.
>
> *Dana G. Dalrymple, USAID, 1980*[14]

Dependence and interdependence

Following the Third World's victories at FAO in the first half of the eighties, the American Association for the Advancement of Science held a symposium titled 'Seeds and Sovereignty' during its 1986 sessions. This began a popular move among industrialized countries to downplay the importance of Third World germplasm. A key theme arising from the US meeting was that all regions of the world are 'interdependent' in their germplasm needs. Each of the modified Vavilov Centres (modified to meet modern political boundaries and more recent information on the origin of species) would starve without access to breeding material from the others.

This kind of reasoning was music to the ears of Northern politicians anxious to break down the North-South environment prevailing at the UN. Much of the material for this view arose from research by Dr Jack Kloppenburg and Daniel Lee Kleinman at the University of Wisconsin.[15] David Wood helped with the technical data.[16] Kloppenburg and his colleague are keenly sympathetic to the South's concerns, it should be stressed, and it is not their intention to have good research distorted for the North's ends.

According to the 'interdependence' view, Australia, Europe and North America are about as dependent on other regions as is Africa. Ergo, the diplomats argue, Africa and the North have common cause to make against Asia and Latin America for their food security. Even the most independent regions in Asia still look elsewhere for a third or more of their food crop germplasm.

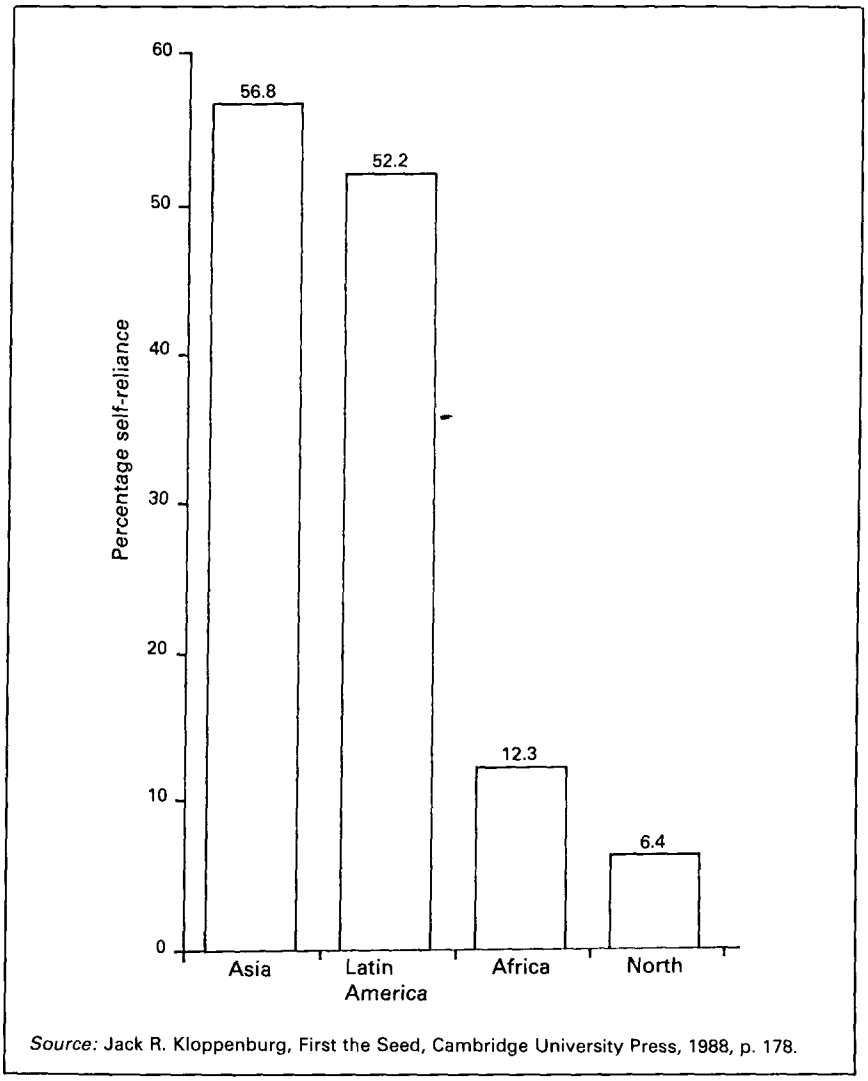


Figure 19 Food crop independence: percentage of major food crops from within each region or continent of origin

Southern scientists such as Dr Melaku Worede of Ethiopia (who was with us at Bogeve) find these global generalizations far removed from their reality. The interdependence theory hangs upon twenty food crops. Ethiopia's most important crop—Teff—is not among them. Nor is Ethiopia credited for its thousands of years of durum wheat and barley breeding. As we have already discussed, the Bonn Government is fighting to get its hands on Ethiopia's barley; the Ethiopians are now looking anxiously to the Near East (the Vavilov Centre) for more breeding stock.

In fact, the theory of the twenty crops hangs on a Western concept of what

crops are important. Poor people's crops are not always present. Thai villagers obtain as much as a third of their nutritive requirements from wild plants.

Undoubtedly, the South—over time—could be sorely hurt by extensive germplasm embargoes. But, with exceptions, many of the imported crops important to the South have long histories and substantial genetic diversity and adaptability in their adopted homes. Further, those closest to hunger in the South have recourse to many other local crops outside the macro-calculations of the North. On the other hand, the past decades of monoculture in the North make Australia, Europe, and North America heavily dependent upon the core group of twenty crops. Not only is the crop base narrow but so is the genetic base within each crop. Additionally, the requirements of both producers and processors combine to increase the 'felt' demand for germplasm.

Nevertheless, in his excellent book, *First the Seed,* Jack Kloppenburg both makes the point that the polemics at FAO should not obscure the world view that humanity must work together to conserve and utilize genetic diversity and also that, 'there is empirical justification for the characterization of the North as a rich but "gene-poor", recipient of genetic largess from the poor but "gene-rich" South'.[17]

Quixotically, the same US Government that was applauding the notion of genetic 'interdependence' at FAO was also arguing the need for improved germplasm from the IARCs. Hearing the beat of a different drummer (the US Congress), State Department officials, in 1986, were under heavy pressure to defend their aid grants to IRRI and CIMMYT in a world where American farmers were competing with Third World farmers for rice and wheat markets.

Subsequently, a USAID study showed that a quarter of a million hectares of American rice land are sown to semi-dwarf rice. Semi-dwarfs amount to a little more than a fifth (21.9 per cent) of all US rice and IRRI semi-dwarf material accounts for 73 per cent of all semi-dwarfs. Further, the study showed that IRRI's semi-dwarfs are growing rapidly in popularity.[18] Indeed, CB-801—euphemistically described in the USAID publication as an IR8 'derivative'—was patented in the United States by the Farms of Texas Co.[19]

In 1984—the year for which the USAID had the most recent figures—the farmgate value of the American rice harvest was approximately US $1.1

billion. The farmgate value of the crop sown to IRRI-based germplasm was US $176 million. In 1984, the USAID gave IRRI a grant of US $6 million. Not a bad return on an investment.[20]

The situation for wheat is rather more spectacular than for rice. By the mid-eighties, semi-dwarf strains accounted for almost 19 million hectares (close to 60 per cent) of the US crop. This was far more than double the acreage of ten years earlier. Of this, the USAID conservatively estimated that 36 per cent of the semi-dwarf (21 per cent of all wheat) contained germplasm from CIMMYT-Mexico.[21] With a farmgate value of US $8.8 billion in 1984, germplasm from CIMMYT-Mexico contributed to more than US $1.8 billion of the crop value. Once again, USAID's 1984 grant to CIMMYT was US $6 million.[22]

Yet another study gives some insight into the direct value of tropical germplasm to the American maize crop. In 1985, Dr M.M. (Major) Goodman, reported on a survey he did of the use of exotic maize germplasm in US breeding programmes. Goodman concluded that only about 4 per cent of the current US crop included any exotic germplasm. In fact, he estimated that the contribution of exotic material equals only one per cent of the US maize germplasm base.[23]

Not impressive. However, companies surveyed by Goodman suggested that between five and ten per cent of 'Corn Belt' hybrids would contain exotic maize over the next fifty years and many companies thought the figures would run between 15 and 30 per cent. Ciba-Geigy calculates that all of their southern (US) hybrids would use exotic maize.[24]

In 1984, the farmgate value of the US maize crop stood at US $20.1 billion. A lowly one per cent of this value is still $201 million. If the tropical exotic material is ranked at one-tenth of all exotic material, its contribution is still in the range of US $20 million. If biotechnology has the impact expected in allowing the use of exotic germplasm, then the company estimates of 30 per cent of the US crop would mean that exotic material would support as much as US $6 billion of the farmgate value. Much of this material comes to the United States from or through CIMMYT.

In summary, germplasm drawn from just two of the International Centres —IRRI and CIMMYT—contribute hundreds of millions of dollars every year to the US farm economy. Jack Kloppenburg offers other figures that show the value of specific genes. A Turkish barley landrace, for example, codes for resistance to barley yellow dwarf virus. The landrace—donated

freely—saves US farmers US $150 million a year. Kloppenburg adds that new soybean varieties from Korea could save food and feed companies from US $100 to 500 million a year in processing costs.[25] Late in 1985, scientists at Cornell were developing clones of a Bolivian variety known as 'Polo' in order to confer resistance to Golden Nematode—a major disease and economic threat to growers.[26] The savings for US farmers could be tremendous.

Aware of its crop dependence, the US has cast about for bargaining chips. In a special issue of the *Iowa State Journal of Research* including major studies by T.T. Chang of IRRI on rice and Major Goodman on maize —where all the news (for US germplasm consumers) was bad—space was left at the very end for Stanley Krugman to sound a note of political optimism.

Reviewing the state of international politicking around genetic resources, Krugman offered, 'In most cases, however, these genetic programmes have been directed to safe-guarding of agricultural crops of major importance to the developed nations. This was perfectly natural at the time the programmes were initiated. Presently, however, the emerging developing nations are seriously challenging the established agricultural germplasm management systems insisting that they play a greater role, that their agricultural needs be considered, and that they receive a greater portion of the benefits from the use of their germplasm.'

On the bright side, Krugman adds, 'Biologically, US woody species have the broad genetic base to fit many different environmental niches around the world. It is thus not surprising that eventually forest genetics would have a role to play in foreign policy.' Not to beat about the bush, Krugman proposes that the Americans exploit germplasm in ways flatly opposed by State Department officials in Rome: 'There are commercial and trade opportunities that can be developed and exploited that involve the selling and exchanging of forest germplasm'.[27] This is a far cry from the US insistence at FAO that genetic resources should be seen as 'the common heritage of all humanity'.

There is little risk, however, that US politicians will be unable to see the forage for the trees. The economics of American food crop dependence are overwhelming. The following tables offer a calculation of the importance of foreign germplasm to the US economy.

In recognition of the importance of exotic germplasm, the flow of acces-

Table 24 The billion dollar crops: US crop germplasm security and the IBPGR network

Crop	Average annual value of crop; US farm sales/ imports (US$ million)	Centre of diversity	US IBPGR 'network' mandate[1]	US world storage rank[2]
Soybean	11,278.4	Chinese	Global	3
Maize*	10,412.4	Meso-American	Regional	4
Wheat	6,475.1	Near Eastern	Global	1
Cotton	4,233.0	African/Andean	(Greece)	3
Coffee (import)	3,925.3	African	Import	–
Tobacco	2,851.4	Andean	(Greece)	–
Sugarcane	1,722.5	South East Asian	Global	1
Grape**	1,524.9	Central Asian/Med.	——	–
Potato	1,206.0	Andean	CGIAR	6
Rice	1,163.1	Indo-Burma	Regional	2
Sweet Orange+	1,150.3	South East Asian	Regional	3
Sorghum	1,146.5	African	Global	1
Alfalfa**	1,053.7	Central Asian/Euro-Sib.	——	1
Tomato	1,051.0	Andean	Global	1
Cacao (import)	1,016.0	Andean	Import	4
Total	50,209.6			

* Many authorities consider the US collection to be the largest and most diverse. Although the USSR and Yugoslavia both claim to have extremely large collections, some believe they are no longer viable.

** As of 1987, IBPGR has no network base for this crop.

\+ IBPGR information ls for citrus.

* No information available.

[1] From IBPGR Annual Report–1987, pages 29-32 and 35. In most cases, the US shares 'global' status with one or more other states. 'Regional' implies a mandate for any region of the world, (i.e. 'New World').

[2] Data for this column is interpreted from Donald L. Plucknett, Nigel J.H. Smith, J.T. Williams and N. Murthi Anishetty, *Gene Banks and the World's Food,* Princeton University Press, 1987, Chapter 6 or, if crop data was unavailable from this source, from the appropriate IBPGR 'Directory of Germplasm Collections' wherein RAFI has tallied the crop collections.

sions to the US National Seed Storage Laboratory has more than doubled since the formation of IBPGR and tripled since the passage of the US Plant Breeders' Rights bill in 1970.[28] Beyond the seed from farmers' fields, Christine and Robert Prescott-Allen have recently showed us that between 1976 and 1980, wild—not cultivated—genetic material contributed US $340 million per year in yield and disease resistance to the US farm economy.[29] Wild material, too, is part of the sovereign territory of states and is also protected in its habitats by local people. According to the Prescott-Allens, wild germplasm has contributed US $66 billion to the American economy

Table 25 US participation in IBPGR's global network of base collections

Crop	Species	IBPGR network mandate
Allium		Global
Amaranthus		Global
Cucurbit et al.		Global
Eggplant		Global
Grasses	Cynodon	Global
Grasses	Paspalum	Global
Grasses	Pennisetum	Global
Legumes	Zornia	Global
Legumes	Leucaena	Global
Millets	Pennisetum	Global
Okra		Global
Phaseolus	Cultivated	Global
Sorghum		Global
Soybean		Global
Sugarcane	Vegetative	Global
Sugarcane	Seed	Global
Sweet Potato	Seed	Global
Tomato		Global
Vigna		Global
Wheat	Cultivated	Global
Citrus	Vegetative	Nth America
Maize		New World
Rice		Regional

Source: IBPGR Annual Report, 1987, p. 29-35

—or more than the total international debt of Mexico and the Philippines combined.[30] In fact, the comparison of the South's financial debt to the North's 'gene debt' is valid and worth further exploration. The FAO Fund could and should be seen as another way for the North to pay off its very sizable debt to the South.

For RAFI and the Seeds Action Network and its member NGOs who have observed and acted in the bio-battles at FAO, it is clear that round five will not be the last. This fight has at least ten rounds.

Notes

1. National Research Council, 'Expansion of the US National Seed Storage Laboratory: Program and Design Considerations', 1988, p. 1.
2. Cary Fowler of RAFI participated in the television debate in Washington and talked afterwards with the official in question.

3. Esquinas-Alcazar, Jose T., 'Plant Genetic Resources: A Base for Food Security', *Ceres,* Vol. 20, No. 4, July-August, 1987, p. 44.
4. Discussion with Ann Fitzgerald of the CS Fund and Pat Mooney, RAFI, 18 May, 1988.
5. William A. Nitze, Deputy Assistant Secretary, United States Department of State, in an 11 April, 1988 letter to Theodore M. Smith, Consultative Group on Biological Diversity, Rockefeller Brothers Fund, New York.
6. Ibid.
7. Underlining is in the original document.
8. Minutes, 15th Meeting of Board of Trustees, Rome, 24-26 February, 1988, p. 5, IBPGR/88/46.
9. Pat Mooney of RAFI was a guest speaker at the same symposium and was present for Wood's extemporaneous remarks.
10. Minutes, 15th Meeting of the Board of Trustees, Rome, 24-26 February, 1988, p. 5, IBPGR 88/46.
11. From the annex to a letter dated September 15, 1987 to the Heads of IARC Genetic Resources Units from David Wood at CIAT, Colombia. Pat Mooney of RAFI was handed this material in Montevideo on 6 November, 1987.
12. Underlining is in the original document.
13. From a conversation between M.S. Swaminathan and Pat Mooney of RAFI at IRRI in August, 1986 while Mooney was a guest lecturer at an IRRI sponsored training programme for genebank staff.
14. Dalrymple, Dana G., 'Development and Spread of Semi-Dwarf Varieties of Wheat and Rice in the United States: An International Perspective', *Agricultural Economics Report,* 455, USDA, June, 1980, p. 132.
15. Summaries of their research have appeared in many publications including *Diversity,* Issue 10, 1987, p. 29-33.
16. Wood showed Pat Mooney of RAFI his draft work for Kloppenburg on a flight from Addis to Rome in October, 1986.
17. Kloppenburg Jr., Jack, *First the seed: The Political Economy of Plant Biotechnology* 1492-2000, Cambridge University Press, 1988, p. 181.
18. Dalrymple, Dana G., 'Development and Spread of High-Yielding Rice Varieties in Developing Countries', USAID, 1986, p. 115.
19. Ibid., p. 115-116. The USA Plant Variety Protection Office confirmed patent issued October 31,1985 in a telephone conversation with Pat Mooney of RAFI on February 6, 1988.
20. Farmgate data was provided by Dana G. Dalrymple in correspondence with Hope Shand of RAFI. Figures for the IRRI material were derived by RAFI from Dalrymple's crop data as described in these paragraphs.
21. Dalrymple, Dana **G.,** 'Development and Spread of High-Yielding Wheat Varieties in Developing Countries', USAID, 1986, p. 96.
22. Farmgate data was provided by Dana G. Dalrymple in correspondence with Hope Shand of RAFI. Figures for the IRRI material were derived by RAFI from Dalrymple's crop data as described in these paragraphs.
23. Goodman M.M., 'Exotic Maize Germplasm: Status, Prospects and Remedies', *Iowa State Journal of Research,* Vol. 59, No. 4, May, 1985, p. 501.

24. Ibid. p. 504.
25. Kloppenburg Jr., Jack, & Kleinman, Daniel Lee, 'Seeds and Sovereignty', *Diversity,* 10, 1987, p. 31.
26. 'Scientists Aid Potato Industry', *Agricultural Biotechnology News,* November/ December, 1985, p. 1.
27. Krugman, Stanley L., 'Forest Genetics and Foreign Policy', *Iowa State Journal of Research,* Vol. 59, No.4, May, 1985, p. 529-531.
28. US National Research Council, 1988, 'Expansion of the US National Seed Storage Laboratory: Programme Design Considerations', p. 4.
29. Prescott-Allen, Robert and Christine, *The First Resource: Wild Species in the North American Economy,* Yale University Press 1986, as reviewed by Ed Wolf in *Diversity,* Issue No. 13, 1988, p. 31.
30. Culpeper, Roy, 'The Debt Matrix', The North-South Institute, Ottawa, April, 1988, p. 8.

Case Study

The Security of the World's Major Gene Banks

Issue: The International Board for Plant Genetic Resources is undertaking an evaluation of each gene bank which it previously designated as a 'base' for plant germplasm storage. A partial report covering the first 17 banks was submitted to the Board in February, 1987, exposing major security problems.
Countries affected: All countries—but immediately—Australia, Canada, Greece, Spain, the USA, and ICARDA (International Centre for Agricultural Research in Dry Areas). Other implications are noted for Ethiopia, the Philippines and the Federal Republic of Germany.
Impact: The majority of the world's collected crop germplasm is not securely stored and some of it has been lost due to financial and technical shortcomings.

According to the report restricted to IBPGR's Board of Trustees, seven of the 17 evaluated 'designated base' gene banks in the IBPGR network do not meet the Board's standards for registration. The substantial—possibly overwhelming—majority of the IBPGR network may fall below acceptable safety standards. Four other 'designated base' banks asked that the evaluation be delayed and, in a concluding comment to the confidential study, the secretariat notes:

It would be highly beneficial also to evaluate the other twelve designated genebanks which did not respond to earlier invitation letters. It is likely that these genebanks have relatively poor conditions.

Although only seven of the 17 banks so far evaluated fall below IBPGR standards, these represent exactly half of the available storage space (in the survey) and 60 per cent of the surveyed germplasm. Thirty-seven out of 64 'designated base' crop collections are affected in the evaluation report. Among those found wanting are major gene banks in Australia and Canada as well as the world's largest and most commercially important bank—the National Seed Storage Laboratory in the United States. The following table reports on the 13 banks discussed in detail in the IBPGR staff paper. Again, four others have delayed their evaluation in order to upgrade their facilities.

Among important national banks still awaiting evaluation are those in Kyoto and Sendai, Japan, the German Democratic Republic's bank at Gaterslaben and the huge facilities at Leningrad and Krasnador in the Soviet Union. Among International Agricultural Research Centres, ICRISAT (with important sorghum and millet collections) has not replied to an invitation to be evaluated and CIMMYT (with wheat and maize) was not invited at all—a sign of strained relations between CIMMYT and IBPGR.

Table 26 IBPGR secretariat evaluation of first 17 gene banks

Country	Institution	Status
Australia	CSIRO-Canberra	Unacceptable
Australia	CSIRO-Samford	Unacceptable
CGIAR/IARC	ICARDA-Syria	Unacceptable
USA	NSSL-Ft. Collins	Unacceptable
Greece	GCB-Thessalonika	Unacceptable
Spain	Polytech-Madrid	Unacceptable
Canada	PGRC-Ottawa	Unacceptable
CGIAR/IARC	IRRI-Los Banos	Acceptable
Taiwan	AVRDC-Taiwan	Acceptable
Italy	CNR-Bari	Acceptable
Thailand	TISTR-Bangkok	Acceptable
F.R. Germany	FAL-Braunschweig	Acceptable
Nordic	NGR-Lund	Acceptable

Notes from the evaluation

Unless otherwise indicated, all quotes used in this case study are taken from *Progress on the Development of the Register of Genebanks,* Provisional Agenda Item 10, International Board for Plant Genetic Resources, 14th Meeting of the Board of Trustees, Rome, February 25-27, 1987.

Even those gene banks found acceptable by the secretariat may have severe faults. The Italian gene bank at Bari is a case in point. In the past, IBPGR has placed appropriate importance on banks having back up

generators in case of power failures. Yet, the Bari facility was registered as responsible for globally-important wheat germplasm despite the absence of a back up generator, because 'there is an agreement with the electricity company for a continuous supply of power'.

Lowest on the scale is the Greek gene bank which is cited for a long list of failures both administrative and mechanical. In the document's summary, the secretariat says, 'The evaluator states that this genebank is the poorest of all those he has visited'.

The Universidad Politecnica in Madrid, Spain (not the bank Spain has placed under the auspices of the FAO Commission which was favourably surveyed by FAO itself), is scored for both poor storage conditions and poorer monitoring of the germination level of accessions. Some germplasm, according to the evaluator, may be beyond recovery: 'The genebank is designated for wild *Brassica* and wild *Cruciferae*. Some accessions are 20 years old and cannot be recollected.'

The problem of personnel and management are recurring themes in the report. The Australian gene bank at Samford (Brisbane) managed by the prestigious CSIRO is shown to be far from immune to these problems:

> The material in the genebank involves seed dormancy and empty seed problems. Besides the genebank manager ... there is only one technician to handle the sample registration, seed testing, drying, packing, storage and exchange, therefore the genebank is unable to conduct initial germinations test and monitoring viability test for all accessions ... Currently regeneration is carried out on the priority materials, that is accessions with some agronomic value...

IBPGR's evaluation levels a similar criticism at the CSIRO gene bank in Canberra. The report notes, 'however, many management standards as listed below are unsatisfactory'.

Although the United States has received almost US $2.8 million from IBPGR over the years (amounting to 22 per cent of all grants given by the Board) and has gained (directly) more than 23,000 seed accessions (28 per cent) covering a dozen economically important crops, the IBPGR staff evaluation found the Fort Collins National Seed Storage Laboratory below registration standards.

Regarding personnel and management, the evaluation noted: 'The genebank is understaffed. There are ca. 210,000 accessions but only 13 staff (including part-time and vacant posts). In addition, there is currently no seed physiologist,' In the evaluator's concluding comments, he added, 'information promised to be mailed to me (unavailable during visit) wasn't' and 'subsequent correspondence not replied to'.

Most serious, however, are the technical shortcomings of the world's most important gene bank. The staff study reports, 'The regeneration standard is low (60 per cent of initial viability). Arrangements need to be established for regeneration of tropical species,'

The following graph offers an overview of the security of the 17 evaluated banks in the IBPGR gene bank system. In summary, the seven unacceptable banks thus far evaluated account for about 13 per cent of global germplasm in storage and have received (or their countries have received) 29 per cent of all grants from IBPGR.

Urgent problems

The conflict between FR Germany and Ethiopia

The IBPGR evaluation gives passing grades to both the FAL gene bank at Braunschweig, Federal Republic of Germany, and to the Plant Genetic Resources Centre/Ethiopia. Expressing mild concern for germination standards in Germany, the secretariat makes particular note of FAL's failure to provide full duplicate samples of IBPGR material to other gene banks as per its commitment. The summary report states, 'With the exception of the *Beta* collection received from the Greek Gene Bank, almost all the accessions of the IBPGR designated crops are not duplicated elsewhere'.

The same study also records that Ethiopia has not

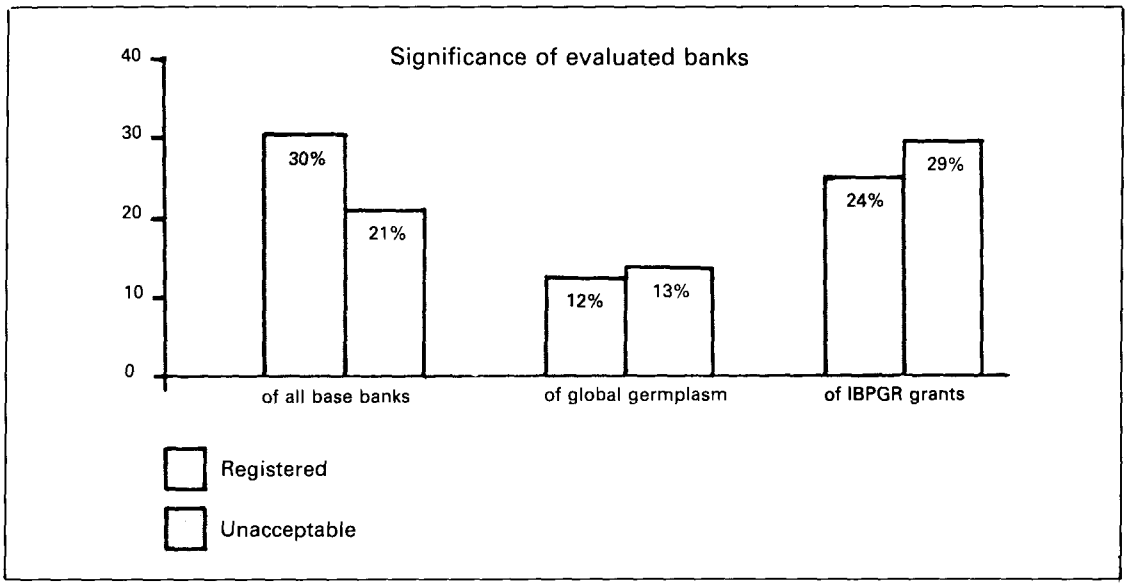


Figure 20 IBPGR bank register evaluation: registered and unacceptable bases

duplicated its germplasm elsewhere. The differences, however, is that Ethiopia has not committed itself to do this through IBPGR and, further, that the germplasm originates in Ethiopia and has not been sent to it for safekeeping from elsewhere. In fact, the evaluation offers Ethiopia the only direct compliment given to any gene bank elsewhere in the report:

> This bank is extremely well run and a credit to all the staff I met. There are some deficiencies in seed laboratory equipment, but the staff work hard to overcome such difficulties. Particularly impressive was the fact that the conservation unit manager had taught himself seed physiology (partly from IBPGR publications), and the ability of the documentation unit to provide detailed answers to my questions. All concerned with PGRC-E should be heartily congratulated for their excellent work.

Although outside the boundaries of the IBPGR evaluation, the crucial issue here is the dispute between the Federal Republic of Germany and the Ethiopian Government over the future of the Ethiopian bank and the duplication of barley germplasm. The Ethiopian bank was originally constructed and financially supported by GTZ (the German development agency). Control and management of the bank has been in the hands of Ethiopia for several years but GTZ funds have continued to provide the hard currency necessary to maintain equipment. In return for the bank, Germany has demanded a duplicate sample of Ethiopia's germplasm—especially barley. Ethiopia agreed to this request more than a decade ago but has not provided the material. Now Germany refused to continue crucial financial support to the bank until it gets its barley. The last GTZ official left Ethiopia June 15, 1987, after two years of failed negotiation.

Technically, Ethiopia is prepared to make duplicates available but points out that its accessions are in 'populations' making it scientifically impossible to provide duplicates. Any division of seed samples would leave each party with genetically different material rather than duplicates. Behind the dispute is Germany's economic interest in Ethiopia's barley and Ethiopia's right to retain sovereignty over its botanical treasures.

At risk is one of the best gene banks anywhere in the world. Also at risk is unique seed of barley, sorghum, durum wheat, millets, oats, etc. from one of the world's most important Vavilov Centres of Genetic Diversity—Ethiopia itself.

The Federal Republic of Germany appears prepared to risk the loss of this resource in order to extract the barley seed it values. Its argument is that it is not safe to have all the seed stored in one bank. They are right. But the IBPGR evaluation shows that the Germans should—at least—take their own advice.

Following RAFI's circulation of the IBPGR paper and RAFI's comments on the position of the GTZ, officials of the Agency wrote to Ethiopia seeking some accommodation and referring directly to the negative publicity GTZ had received. Limited financial support is now flowing again from Germany although the situation remains precarious.

More happily, as a result of discussions with the FAO Commission on Plant Genetic Resources, Ethiopia has agreed to place a cold storage unit in the PGRC/E under the auspices of the FAO Commission. In fact, germplasm from farmers in Zimbabwe has already been placed in storage at Addis.

The Canadian bank

If the Greek bank is ranked the worst by its evaluator, the Plant Genetic Resources Centre, Ottawa, Canada, did not even warrant its data sheets. The detailed evaluation sheets were omitted from Appendix I of the report and the Ottawa bank was given its own special Appendix II. The five page appendix could hardly be more critical. Regarding the database documentation, the evaluator notes, 'the CGB is handicapped in having to rely on the TAXIR software programme long discarded elsewhere. This...places a severe restraint on the effectiveness of the curator...(in) meeting modern requirements...'

More embarrassingly, the Ottawa bank had a filing problem: 'The curator does not have copies of the original letters of agreement between IBPGR and the Canadian authorities and requests copies from Rome'.

On the ability of the Canadian government to meet its international obligations, the evaluator commented on Canada's responsibility as a designated base for barley, millets, and oats. Concerning barley, the Nordic gene bank is to give a duplicate sample to Canada but the evaluator warns, '...there are no facilities for storing them if and when they do'.

On millets: 'Canada undertook in 1977 to provide long-term storage for duplicate samples of ICRISAT material. (The gene bank Director of) ICRISAT visited CGB in March, 1986, to arrange details of transfer of 14.000 accessions, saw the storage facilities and departed to look for an alternative genebank capable of meeting requirements.' Other material received from Kew Gardens has been safely stored but, the evaluator comments, 'Arrangements for multiplication in Canada have failed due to inability to accept financial support from IBPGR'.

The most severe problem, however, lies with Canada's commitment to store oat material. Some 12,600 samples were received in 1980.

They have been lying, as received, in paper bags and cardboard boxes, for *six* years, in an annex to the medium-term storage. Lack of personnel and storage space had prevented their germination testing, drying, packaging to acceptable standards and low temperature storage. The accessions have been subjected to widely fluctuating temperatures—(up to 25 degrees Centigrade)—and much of this material must be considered a write-off. Three points emerge:

1. Whether to rescue the surviving materials which seems impossible with present resources at CGB—or replace from USDA at another centre capable of such storage.
2. Present arrangements constitute a threat to germplasm in generating a false sense of security.
3. This is a classic case of erosion of germplasm in a genebank and provides valuable ammunition to critics of the IBPGR and the international system.

We concur.

Since RAFI's original disclosure of the internal IBPGR study, the Canadian bank has been publicly embarrassed into action. Officials now claim that the endangered germplasm has been moved to safe storage and that other steps are being taken to upgrade the bank. Canadian curators also claim that the rejuvenation rate of the seed is higher than expected.

Conclusion

We believe the following points can be drawn from the IBPGR evaluation:

1. The problems of gene bank security continue. Although more gene banks in the North were evaluated than in the South, the banks in Ethiopia, Taiwan and Thailand fared much better than their larger

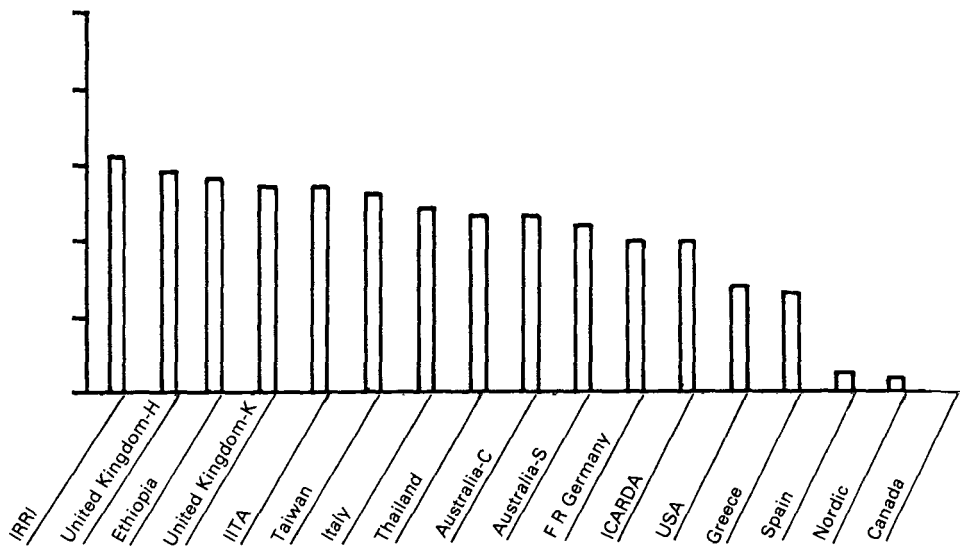


Figure 21 IBPGR bank registered evaluation: ranking of base banks RAFI interpretation of evaluation.

counterparts in Australia, Canada, the USA, or Italy.
2. Aside from the risk of 'putting all our eggs in one basket', there is evidence to suggest that the high cost of personnel and administration in the North may be a greater risk than that of equipment failure in the South. Of the two, the issue of equipment is more solvable and less expensive than personnel. There is a strong financial case to be made for focusing an FAO germplasm network in the South.
3. Although only partly addressed in the evaluation (note the US and Canadian banks discussion above), a second major problem relates to the financial and scientific problems of regenerating exotic germplasm. Thus, there is also a powerful scientific case for developing an FAO network in the South.
4. The IBPGR 'network' includes many banks which do not meet its own standards. There is no positive correlation between the quality of a gene bank and the responsibility it receives for 'safeguarding' designated base collection.
5. The IBPGR does not make the problems of its bank network public or available to governments. National governments who are contributing germplasm to substandard banks at the advice of IBPGR are not aware of the risks they are taking with their botanical treasures.

Recommended action

1. The development of an FAO Network for Genetic Resources Conservation anchored in the South with the redeployment of endangered germplasm from substandard banks to existing superior or new facilities in the South.
2. National governments (particularly those in the North holding international collections) should identify specific collections of exotic germplasm in their keeping and, while agreeing to maintain the collections, place them under the auspices of the FAO Commission on Plant Genetic Resources.
3. The development of complimentary conservation strategies to the gene bank system which would include biosphere reserves and community seed conservation.
4. The early implementation of the International Gene Fund via the FAO Commission on Plant Genetic Resources so that, beyond voluntary contributions, one per cent of the retail price of seeds, plants, and bulbs as sold in the North be rebated by governments to the Fund for allocation in the collection, conservation, and utilization of genetic resources.

The ranking of gene banks

The graph indicates RAFI's interpretation of the surveys undertaken by IBPGR's evaluators. This evaluation may appear to judge the Nordic Gene Bank at Lund rather harshly. The bank is well-run but heavily dependent upon other institutes for key services. The Nordic bank (operated on behalf of all Nordic countries) is also unduly dependent on traditional kitchen freezers. In RAFI's opinion this dependence is unacceptable and poses some risks for the long-term security of the bank. But the survey neglects to evaluate the back-up gene bank at Spitsbergen, which provides unique additional support to the Nordic system. In general, while the Nordic bank would benefit with improvements, it is probably one of the better-run banks in the world and this is not adequately reflected in the graph.

(The graph compares the gene banks surveyed in ratio to the IRRI gene bank in the Philippines, which is generally considered to be the best gene bank in the world.)

Part Four

Towards a People-oriented Biotechnology

The Bogève Declaration

Towards a People-oriented Biotechnology

Twenty-eight participants from 19 countries met at La Soleillette, Bogève, France, March 7—12, for the 1987 Dag Hammarskjöld Seminar on 'The Socioeconomic Impact of New Biotechnologies on Basic Health and Agriculture in the Third World'. The seminar was organized and sponsored by the Dag Hammarskjöld Foundation, Uppsala, Sweden, and the Rural Advancement Fund International (RAFI), Pittsboro, USA, and Brandon, Canada, in cooperation with the International Organization of Consumers Unions (IOCU), Penang, Malaysia, the Seeds Campaign of the International Coalition for Development Action, Barcelona, Spain, and the United Nations Non-Governmental Liaison Service (NGLS) in Geneva.

We, the seminar participants, met at Bogève, France, to discuss the impact of new biotechnologies on health and agriculture in the Third World, where the vast majority of the world's people live. In discussing the nature of the new biotechnologies, and their significance for humanity, we recognize that:

Biotechnology is a global issue. It cannot be assigned such attributes as positive, negative, or neutral. Like any other technology, it is inextricably linked to the society in which it is created and used, and will be as socially just or unjust as its milieu. Therefore, we conclude that in today's world this most powerful new technology is more likely to serve the interests of the rich and powerful than the needs of the poor and powerless.

We fully recognize the potential of biotechnology to improve the quality of life of humanity. But it is important to emphasize the risks and hazards associated with biotechnology, including serious and possibly irreversible health, safety, environmental and Socioeconomic consequences, as well as the use of such technology in biological warfare.

In agriculture, for instance, while biotechnology may promise to increase production and reduce costs, it is more likely to accentuate inequalities in the farm population, aggravate the problem of genetic erosion and uniformity, undermine life-support systems, increase the vulnerability and dependence of farmers and further concentrate the power of transnational agribusiness.

In health, for instance, biotechnology promises more effective diagnostic tools and new ways of preventing and curing diseases. However, the pharmaceutical industry is more likely to focus on the most profitable opportunities and divert attention from basic health requirements.

In view of the above, we make the following recommendations.

At the Citizen Level:

- that we accept a major role in the development of public discussion and policy related to biotechnology;
- that we monitor industry activities in this field;
- that we commit ourselves to taking action in this field with the relevant UN bodies including FAO, GATT, ILO, UNCTAD, UNEP, UNIDO, WHO and WIPO;
- that we agree to carry our concerns back to the network with whom we are engaged, such as Health Action International (HAI), International Baby Food Action Network (IBFAN), Pesticide Action Network (PAN) and Seeds Action Network (SAN) in order to facilitate cooperation;
- that we seek to promote appropriate technologies that are socially just and ecologically sustainable, including regenerative agriculture, alternative crop protection strategies, preventive medicine, recycling of resources and wastes etc.

At the National Level:

- that a dialogue be established to determine the real needs of society and the main requirements for a national biotechnology strategy based on these needs;
- that the Socioeconomic and environmental implications of such a strategy be fully considered;
- that the regulatory requirements for the safe testing and introduction of the technology be established and stringently enforced;
- that the control over the technology be assigned to the public sector and that the monopolization of the technology by private interests be resisted.

At the International Level:

- that, as at the national level, a wide-ranging international discussion of the impact of biotechnologies be encouraged and begun as soon as possible, noting particularly the initiatives begun in UNIDO/ICGEB (The International Centre for Genetic Engineering and Biotechnology), UNCSTD/ATAS (The Advance Technology Alert System) and other international bodies;

- that Third World governments take measures to develop appropriate biotechnologies and further explore the opportunities for South-South cooperation in all aspects of the development and use of biotechnology, in particular with regard to the utilization of genetic raw materials;
- that the evolution of research and development of biotechnology be closely monitored so that the interests and rights of the Third World are kept foremost in institutions working on these issues;
- that changes in existing intellectual property rights discussed in WIPO, which deny the rights of the Third World, be closely monitored and that a major revision of the Paris Convention be encouraged in order to safeguard the interests of the Third World.

In conclusion we wish to reaffirm that a rational biotechnology policy must be geared to meet the real needs of the majority of the world's people and the creation of more equitable and self-reliant societies while in harmony with the environment.

Participants (names of countries in the following list are given for identification purposes only): Martin Abraham, IOCU (Malaysia); Karim Ahmed, Natural Resources Defense Council (USA); Annelies Allain, IOCU/IBFAN (Malaysia); Erna Bennett (Italy); Pierre Benoit Joly, SOLAGRAL (France); Praful Bidwai (India); Tim Brodhead (Canada); Anwar Fazal, IOCU (Malaysia); Cary Fowler, RAFI (USA); Daniel J. Goldstein (USA); Susantha Goonatilake (Sri Lanka); Kwaku Haligah, PAFATU (Togo); Henk Hobbelink, ICDA (Spain); Calestous Juma (Kenya); Martin Kenney (USA); Eva Lachkovics, RAFI/IIZ (Austria); Thierry Lemaresquier, NGLS (Switzerland); Jiraporn Limpananont, The Drug Study Group (Thailand); José Lutzenberger, Technologia Convival (Brazil); Camila Montecinos, CET (Chile); Pat Mooney, RAFI (Canada); Olle Nordberg, DHF (Sweden); Surendra Patel (India); Daniel Querol (Peru); René Salazar, SIBAT (The Philippines); Pilar de Sevilla, Fundación Natura (Ecuador); Hope Shand, RAFI (USA); Mira Shiva, VHAI (India); Vandana Shiva, Research Foundation for Science Technology and Natural Resource Policy (India); Melaku Worede (Ethiopia).

Climbing the DNA Ladder

The Third System: Perspective from the South

By Anwar Fazal

Anwar Fazal, Past President of the International Organization of Consumers Unions, chaired the Geneva Symposium on the impact of the new biotechnologies, which followed the Bogève Workshop. A summary of his presentation of the discussions at Bogève is reproduced here.

The Bogève meeting was a very important beginning, whose participants accepted that they were meeting one of the greatest challenges to humanity—biotechnology. It has two major areas that concern us: the first is the structural transformations accompanying the biotechnology revolution. This includes structural transformation in the areas of science, economics and politics.

While the structure of science is changing significantly, substantial changes in the field of economics will also take place. Pat Mooney reminded us that some 40 per cent of the world's manufacturing is based on biological materials. This 40 per cent is bound to be seriously affected by the technology transformation. Whole industries are involved, and millions of human beings will have to experience the effects.

Concomitantly power structures will be transformed and the rules of the power game are being changed. We already experience new systems of blackmail and corruption done at the global level by governments in order to get their way. Biotechnology is a new, powerful tool on the way to controlling the world.

The second area of concern is safety, which involves two main issues. On the one hand human health, the environment, the food chain, which can be endangered by accidents and mismanagement of the new biotechnologies. On the other hand the deliberate use of them for biological warfare—or what used to be called germ warfare— which is a very real and imminent threat.

We looked at these two clusters and tried to work out a common response to them. We realized that biotechnology is a global issue—not a Third World issue only, or a link-with-the-North-issue, but an all-comprising one. So we have to deal with it at the global level.

It is global for a variety of reasons, which emerged throughout our meeting, including that the actors are working in the global arena and that the technology itself, the products and manipulated organisms will not be

respecting borders. The speed at which the technology and the scope of application are moving is again a common threat to which we have to adapt the style and strategies of our response.

Another frightening aspect is that the biotechnology industry is rather invisible. A nuclear power station you can see; you can see when it blows up. But biotechnology does not have distinctive plants. And if an accident happens, such as the inadvertent escape of a manipulated organism, it could easily be hidden from the public and nobody would be able to predict the scope and entirety of its effects, nor the borders of the area affected. It is frightening that we might have to wonder about the possibility of being surrounded by insidious germs not knowing where they are, where they come from, where they will go, where they have already gone and whether they are here at all.

And this technology is in the clutches of those who are hungry for profits, those whose main goals are trying to make money out of it rather than working for the public good. This fact together with the previous three points becomes extremely important for us.

There are, from the interventions at our meeting, several things we should keep in mind. Jiraporn Limpananont reminded us of three very simple 'Ds' which are useful for us to remember as specific concerns that we shall have. The first D was 'Dependency', the second was 'Dumping'—the way in which the Third World can become the dumping ground for biotechnological products and pay high prices for them while they displace our own products, and the dumping of the technology itself, such as testing processes that will be involved—the third D is the 'Dominance' of transnational corporations, the dominance of the powers, who are managing, controlling, and bargaining in the market place.

Annelies Allain talked about the experiences of one campaign, including three points that would also be useful for us in trying to deal with biotechnology: first we must have some kind of 'Vision', where we are going, what kind of structure we want to see and what the alternatives are. Without alternatives there is no vision. It is like trying to focus a camera with no film in it. It is no point trying to focus if you do not know where you want to go.

Annelies' second point is 'Visibility'. How do we make a campaign like this public? We talked about various strategies, both in terms of information in the media, and how to get it on the UN agenda. The issue has to become as visible as possible. If we cannot make it visible, if we cannot translate it into

the lives of ordinary people in such a way that the media and the governments are going to be interested, we are not going to move anything or anyone. The issue will be considered rather remote.

The third point is that 'Victims' have to get together, which means we have to identify them and help them to speak up and be heard.

These three 'Vs', Vision, Visibility, and Victims, are going to be important ingredients in our campaign. So the campaign will have to have proactive forces looking at the alternatives we want, active ones and reactive ones certainly, because of the world that we live in. If we cannot react sufficiently, we have to seek those solutions that give us the power to do things our own way. And those alternatives must be concurrently developed.

It was also useful that Martin Abraham reminded us that there was a Green Revolution, which, as a lot of people will certify, has gone wrong, and that there are still people celebrating it as a victory—amazingly. (I suppose it takes time to communicate these kinds of things.) We must not forget the lessons of the Green Revolution, as this new revolution—'gene revolution'—is about to begin.

But more important than that, the revolution we should be concerned with is our own revolution—you can say the peoples' revolution—and our ability to organize and respond to the biorevolution. It is a revolution that will have to bring not only the PhDs together. It will also have to bring together what I call the BSTs, the 'Blood, Sweat and Tears people', the farmers, the peasants and ordinary people, who don't have PhDs but have their blood, sweat and tears to contribute. It will also have to bring together what you may call the YOSs, the 'Your Obedient Servants'. These are the people who, in fact, control institutions—international or national ones—the public servants, who are there paid by the structure in order to serve humanity as 'obedient servants'.

Can we get all the elements together to start our peoples' revolution? I think we can. We have a vision, the Bogève Declaration demonstrates that. It has a very important ingredient in being rooted in people and being rooted in the environment. We also have a symbol. Vandana Shiva contributed the symbol—the Seed. We think of the seed, in all its forms, including the seed for our work, for our own revolution. We also have an organization, considering the four major global citizens' networks represented at Bogève (PAN, HAI, SAN and IBFAN) and the issues they are concerned with: pesticides, pharmaceuticals, seeds and babyfood, which are all affected by

the biotechnology issue. So we have a structure with hundreds, maybe thousands of other groups that are working in these areas.

We have developed out of Bogève a personally linked solidarity and a light participatory support structure that will help, we hope, get this revolution going. This is what we have begun. I hope out of this action we will see biotechnology used as a tool only with caution and in a critical, rational and people-oriented way. Then perhaps it may be able to make some contribution to people's well-being.

Tomorrow Has No Fixed Address

The Third System: Perspective from the North

By Tim Brodhead

Tim Brodhead, Executive Director of the Canadian Council for International Cooperation, spoke about the role of the third system faced with the challenges of the new biotechnologies in the workshop at Bogève. A summary of his views are reproduced here.

One of the most striking features of the Bogève meeting was the effort of participants drawn from the scientific and NGO communities to find a common language and a shared frame of reference. A concern for scientific rigour and exactitude in discussing complex issues struggled with a need for popular understanding as a basis for action. In the words of the architect Raymond Moriyama, 'the building of a bridge begins not from one side, but from each side'. At the end of much impassioned debate there was indeed considerable agreement—beginning with the acceptance that blanket opposition to technological advance closes off avenues which have the potential to improve the human condition, but also that the 'technological imperative' (any technology which can be developed, should be developed) inverts the proper relationship between science and society.

Such an agreement is important because it signals an awareness of people's capacity and right to participate in decisions which will determine their collective future, rather than leaving them to the experts and technicians —or to the powerful. The complexity and inter-relatedness of present-day problems are frequently advanced as reasons for ceding control to the 'specialist'. Science and technology, which have increased our ability to control our world, paradoxically have lessened our capacity to predict our future and thereby weakened our trust in tomorrow. The solution to every problem, it sometimes seems, leads into a new dilemma: improved health results in rapid population increase and pressure on the environment, nuclear power promises cheap energy and unleashes the Bomb, new seed varieties have the capacity to boost agricultural production but also contribute to the erosion of our genetic heritage. A sense of powerlessness develops when every problem which we can solve is part of a larger problem which we cannot. But, as the Club of Rome pointed out in its report *No Limits to Learning,* 'individuals learn by participating in interactions with society; and society learns from the participation of groups and individuals in its activities. One measure of the potential for innovative learning in a society is its degree of effective participation. And, from a global point of view, the potential for learning in the world system as a whole hinges on the extent of participation at international as well as national and local levels,'

There are other barriers to such involvement than just an uncritical reliance on experts: a sense of powerlessness, repressive social and political systems, individual alienation and isolation. At Bogève we encountered some of these, but we also drew strength from earlier experiences in campaigns focusing on pesticides, toxic exports and genetic resources, and from the sheer richness and diversity of the individuals who were present.

It is instructive to consider the emerging role of people's organizations—to use a more positive term than merely 'non-governmental'; for years they have been active mainly at community and national level, providing services and channels of participation as well as fulfilling a corrective function. Their international activities have mainly been in welfare and, more recently, as channels for the North-South transfer of aid. Over the past decade, however, people's organizations have begun to forge international networks which reflect both the interrelatedness of the issues we confront and the inadequacies of governments trapped in the fiction of national sovereignty to deal with them.

Those quintessentially transnational phenomena—capital, corporations and communications—mock the myth of sovereignty. The UN system offers one means for developing a coordinated strategy, but in the face of its in-built contradictions—so long as it is hostage to powerful countries and interests—the international network of people's organizations is increasingly offering an alternative. Like the white corpuscles in the body, NGOs alert and mobilize society's defence mechanisms against decay and malfunction. In their contemporary forms—Physicians for Social Responsibility, Friends of the Earth, Amnesty International, with their networks of national affiliates and equivalents—the women's movement, environmental, peace and social justice movements are a living refutation of the adage 'there is no constituency for the future'.

Much of the work to date of these spreading networks has been reactive: serving as an early warning system of destructive policies and practices, policing the powerful, curbing the wilful disregard of the common good for private advantage. But people's organizations have a prophetic function as well, as the Bogève Declaration attests, reasserting the primacy of human values in determining public policies.

It is because they embody and articulate values shared by millions that people's organizations have a countervailing power to that of corporations and governments. The babyfood campaign could not have forced giant corporations to modify their marketing practices without the force and

appeal of their simple message concerning the immorality of maximizing profit without regard to human well-being. But for those values to prevail requires an efficient and strong network of organizations and individuals in North and South, as well as strategic alliances with particular national governments and the UN system in order to legislate a code of conduct.

We stand at a moment of profound change, in which the values of a production-centred model of development compete with those of people-centred development, and western technology-driven progress with a new paradigm which is both more sustainable and more tolerant of cultural particularities. Tomorrow has no fixed address; the role of people's organizations, as always, is to champion pluralism, the capacity of individuals to create the future they wish for themselves and their children.

Part Five

Appendix

Glossary of Terms

? - *Interferon:* a protein effective against viruses. It is part of the immune system. When a virus infects the (human) body, it triggers off the production of ? - interferon, which then mediates further immune reactions, ? - interferon is also active against certain types of cancer.

Amino acid: A building block of proteins.

Anthrax: a contagious disease of cattle which may be transmitted to humans causing malignant pustules and gastrointestinal disorders. It can be fatal in humans. The causative bacterium is *Bacillus anthracis.*

Antibiotics: antibacterial drugs in human and veterinary medicine. The first antibiotics were derived from fungi and bacteria. Later antibiotic generations involved also chemical synthesis.

Antibody: Specific protein produced by the immune system of higher animals and humans as part of the immune response to the presence of a specific antigen.

Antigen: Substance or well defined part of a substance which is recognized and bound by a matching antibody.

Assay: test

Auxotrophy: dependence of organisms on organic matter for food (auxotrophic organisms)—also called heterotrophy—as opposed to autotrophy, the ability to feed on carbondioxid. A specific auxotrophy refers to the inability of an organism to produce itself a specific essential substance such as an amino acid or a vitamin. The organism has to take up this particular substance with its food.

Avirulent mutants: mutants of a disease causing organism which due to the mutation lost their virulence.

Bacillus thuringiensis (Bt): a common soil bacterium which produces a protein toxic to insects.

Bacterium: a single-celled micro-organism with a relatively simple cell structure which differs in various ways from higher organisms—from fungi onward. (There exists an enormous diversity of varieties including bacteria able to feed on carbondioxid in the air—autotrophic and bacteria feeding as parasites in living organisms or some feeding on decaying matter—both auxotrophic.)

Base: in this context it is a component of the nucleotides which make up the DNA. Four different organic bases are involved in the structure of the DNA: adenine, guanine, cytosine and thymine. Their sequence is responsible for the genetic information in the **DNA.**

Base pair: a unit of the DNA double helix consisting of a base of each DNA strand losely connected to each other. Only two pair combinations are possible: adenine-thymine and guanine-cytosin.

Biological warfare (BW): the use of weapons of biological or biotechnological origin.

Biopesticides: a term used for pesticides derived from biological substances or organisms. It may also be used for pesticides derived from biotechnologically (including gene technologically) produced substances or organisms.

Biotechnology: development of products by exploiting biological processes or substances. Production may be carried out by using intact original or modified organisms, such as yeasts and bacteria, or by using active cell components, such as enzymes from organisms.

Botulism: poisoning with the toxin of *Clostridium botulinum,* an anaerobic bacterium, i.e. a bacterium that lives under exclusion of air. *Clostridium botulinum* can infect food cans as it is able to live under air tight conditions.

Bovine leukaemia virus (blv): virus that causes leukaemia in cattle.

Callus: a cluster of undifferentiated plant cells that can, in some species, be induced to form the whole plant.

Cell: the smallest structural unit of living organisms that is able to grow and reproduce.

Cell culture: growth of cells under laboratory conditions.

Cell culture technology: technology using cell cultures.

Chemical warfare: use of chemicals as weapons.

Chimera: the Greek word was originally used for a fabulous creature made of three different animals. In the context of biotechnology it is used for animals derived through the fusion of two embryo cells from animals of two different species, but not too distantly related.

Chromosomes: longish bodies in the nucleus of a cell of organisms higher than bacteria. They are composed of DNA and proteins. (A bacterial chromosome is of much simpler structure.) Genes are carried in the DNA of the chromosomes.

Clinical assay: test in clinical medicine.

Clone: a group of cells or organisms derived from a single common ancestor —mostly a single cell or a tiny piece of tissue—through asexual multiplication. Due to the single ancestor and the asexual propagation, the members of the clone are next to genetically identical to each other and the parent. Substances, such as genes or proteins that are multiplied via cloning of cells are also called cloned substances.

Cloning: multiplication method via clones.

Culture: cultivation of living organisms in prepared medium.

Culture medium: a mixture containing nutrients needed for cell growth.

Dengue fever: tropical viral disease transmitted by mosquitoes. It is characterized by rheumatic pains, fever and skin eruption. Dengue haemorragic fever is characterized by intestinal haemorrhage.

Deoxyribonucleic acid (DNA): the molecule that carries the genetic information for almost all organisms. The DNA molecule consists of a long succession of nucleotides (see nucleotide), the sequence of whose base-components is the actual carrier of the genetic information. At times when the DNA is not being used in an organism it exists as the so-called double helix—two intertwined strands of DNA linked together through the base pairs.

Diagnostics: agents used as a help to diagnose diseases or disorders, i.e. identify a disease or disorder and distinguish one from another.

DNA sequence: the sequence of bases of a DNA molecule. The sequence makes up the genetic information.

Encapsulated embryos: plant embryos derived from somatic cells (somatic embryogenesis) artificially encapsulated together with nutrients and possibly also growth enhancers and pesticides. They are to replace natural seeds.

Enzyme: a protein catalyst that facilitates a specific biochemical reaction necessary for a function of an organism.

Escherichia coli: (E. coli) A usually harmless bacterium that inhabits the intestinal tract of most vertebrates. Much of the work using recombinant DNA techniques has been carried out with this organism because it has been genetically well characterized.

Fermentation: processing of food or other mixtures by micro-organisms or cultured cells or by enzymes derived from them.

Follicle stimulating hormone (FSH): mammalian hormone which stimulates the development of sperm and egg cells.

Gene: a segment of DNA carrying, due to its base sequence, a very specific information. Some genes carry the information for the synthesis of proteins (structural genes), others carry information for regulatory functions (regulatory genes).

Gene diagnostics: methods of diagnosing genetic aberrations and congenital diseases.

Gene mapping: in classical genetics this means only the determination of the relative locations of genes on a chromosome. In biochemical work it is used for localizing any isolated piece of DNA on the chromosome, even if the function of the DNA piece is not known.

Gene therapy: therapy for congenital diseases involving the replacement of a deficient gene.

Genetic engineering: a technology used to alter the genetic material of living cells through direct interference with the genome in order to make them capable of producing substances or performing functions alien to the unmanipulated cells.

Genetically altered: changes applied to the genome of an organism either through genetic engineering or a less direct method, such as induced mutation, etc.

Genome: the entirety of genetic material of a cell.

Genome mapping: mapping of the entire genome of an organism.

Germplasm: the total genetic variability available to a particular population of organisms.

Glanders: a contagious, febrile and ulcerative disease come from horses, mules and asses to humans.

Growth hormone (somatotropin): mammalian hormone which promotes growth and stimulates the metabolism.

Herbicide: more or less specific plant poison.

Herbicide tolerance (HT): ability of plants to tolerate herbicides.

High fructose corn syrup (HFCS): sweetener made of maize and rich in the sugar fructose.

Hybridoma cell: a hybrid cell produced by fusing a certain immune cell (B-lymphocyte) with a certain cancer cell (myeloma cell). It is used for the production of monoclonal antibodies.

Hydrolized milk: milk whose lactose (milk sugar) content has been predigested (hydrolized), so that it can be tolerated by people with lactose intolerance.

Iatrogenic disease: a secondary disease arising from the treatment of an original condition.

Immunodeficiency: deficiency in the normal defence reaction of higher organisms against a foreign substance, especially against disease-causing agents.

In vitro: literally 'in glass' (Latin), meaning in a laboratory container or apparatus under laboratory conditions as opposed to 'in vivo'. Both refer to biochemical experiments and methods.

In vitro fertilization (IVF): fertilization of an egg cell with a sperm cell outside the womb under laboratory conditions.

In vivo: in the living organism.

Lactose intolerance: incapability of digesting the milk sugar (lactose) due to a deficient or missing enzyme.

Metabolism: turnover of nutrients in an organism by biochemical reactions.

Microbe: micro-organism.

Micro-organism: any organism that can be seen only with the aid of a microscope. Also called microbe.

Monoclonal antibodies: highly specific antibodies derived from only one clone of a specific hybridoma cell, therefore of exactly the same type. They specifically recognize only one site of an antigen.

Mustard gas: a highly poisonous chemical existing in gas form. It is used as a chemical weapon.

Mutation: inheritable physical change in the genome of a cell. The change can occur spontaneously; in the course of germ cell maturation; due to the action of a chemical or radiation; or other influences on the organism.

Mutant: a variation of an organism as a result of a mutation.

Myeloma: a type of tumour of the immune system. Cells from such a tumour are used to form hybridoma cells for the production of monoclonal antibodies.

Nitrogen fixation: a biological process which involves the binding of nitrogen in the air to form ammonia, which is needed as a nutrient since it is essential for the building of all proteins and DNA. Some plants (e.g. leguminous plants) form a symbiosis with nitrogen fixing micro-organisms and thus receive their nitrogen requirement directly from them. (The plants themselves are not able to fix nitrogen.)

Nucleotide: a DNA unit consisting of one of the four organic bases—adenine, guanine, cytosin and thymine—a sugar and a phosphate.

Nucleus: a body in a cell of an organism higher than bacteria, which houses the chromosomes.

Phytoproduction: the commercial production of natural substances in plant cell culture.

Plasmid: a small bacterial DNA ring occurring in the bacteria cell separate from the bacterial chromosome. A plasmid carries certain additional genes not absolutely necessary for bacterial growth, such as genes for antibiotic resistance. Plasmids can be replicated independently from the bacterial chromosome and can be passed on to another bacteria cell when the two cells touch. They turned out to be ideal tools for genetic engineering.

Prophylactic: preventive.

Protein: a molecule composed of amino acids. Proteins are ubiquitous and most abundant in all organisms. They serve many crucial purposes in an organism, e.g. as enzymes to catalyse all the reactions, as structural proteins to support the organism, as transport proteins transporting nutrients to all parts of the organism, etc.

Pseudomonas syringae: a bacterium which belongs to the family of Pseudomonadaceae. They are aerobic bacteria (need air for growth) which receive energy by respiration not fermentation.

Pseudorabies vaccine: vaccine against a viral pig disease which is sexually transmitted by wild boars. It causes, among other symptoms, litter loss. The pseudorabies virus belongs to the group of herpes viruses.

Psittacosis: disease of parrots, pigeons and budgerigars which is occasionally responsible for a form of pneumonia in humans.

Q-fever: febrile disease transmitted to humans by sheep and cattle in which the causative organism does not produce symptoms. Pasteurization of the milk kills the infecting agent.

rDNA: recombinant DNA.

R&D: research and development, meaning the research towards a product and the development of the product.

Recombinant DNA (rDNA): the DNA formed by combining in vitro segments of DNA from different sources.

Restriction enzyme: an enzyme that catalyses the cleavage of DNA at a highly specific site. Each one recognizes a specific DNA sequence, where it catalyses cleavage.

Retrovirus: a virus belonging to a group of extremely small viruses whose carrier of genetic information is not DNA but the closely related RNA. In the usual course of information retrieval for protein synthesis DNA is first translated into RNA. With retroviruses RNA is first translated into DNA which is then inserted into the genome of the infected host cell, thus altering the genetic information. This can be one of the reasons for cancerous diseases.

Rhizobia: family of soil bacteria. They can form symbioses with leguminous plants—little nodules are developed at the roots of the plants. When in symbiosis they are capable of nitrogen fixation, which also benefits the plant.

Secondary metabolite: plant secondary metabolites are plant compounds which have no obvious metabolic function in the plant. Secondary metabolites are used for certain types of pharmaceuticals, colorants, fragrances, flavours, etc.

Sequencing: determination of the sequence of the bases of DNA.

Serratia marcescens: a soil bacterium which produces a dye. It is related to Escherichia coli (E. coli).

Szintillation counting: method to measure radioactivity.

Somatic cells: normal body cells as opposed to reproductive cells.

Somatic embryogenesis: induction—via hormones—of the development of an embryo out of a somatic cell cluster. So far this is only possible with plants.

Superovulation: the maturation and release of more than the usual number of ova (mature egg cells) in an animal induced by the additional application of hormones.

Tissue culture: cells isolated from tissue or tiny pieces of tissue grown in vitro in a culture medium.

Tissue plasminogen activator (t-PA): a protein which is involved in the process of dissolving blood clots. As the name says t-PA activates the enzyme plasminogen, which plays a crucial role in dissolving blood clots. t-PA can be used in the treatment of heart attack patients.

Transgenic organism: a genetically manipulated organism containing in its genome one or more inserted genes of another species.

Tularaemia: (also deer-fly, tick or rabbit fever): an endemic disease of rodents transmitted by biting insects. It can be acquired by humans either in handling infected animals or by the bite of an infected insect. A suppuration at the inoculation site is followed by inflammation of the draining lymph glands and by severe constitutional upset.

Vaccinia serum: vaccinia is a virus which has been used to confer immunity against smallpox. Genetically manipulated vaccinia viruses are now being used more and more for immunizations against other diseases. Vaccinia serum is the inoculation liquid containing vaccinia viruses.

Venezuelan equine encephalitis: specific horse encephalitis, i.e. inflammation of the brain.

Virologist: scientist studying, and working with, viruses.

Virulence: infectiousness; the disease producing power of a micro-organism. It is responsible for the micro-organism to overcome the infected organism's resistance.

Virus: an organism consisting only of a few proteins and DNA or a very similar molecule (RNA) carrying a minimum of genetic information. Contrary to bacteria they cannot by themselves carry out any functions of life. They need to usurp the system of a host organism to carry out these functions of life. In the process of reproduction they usually destroy or severely damage the host cell, thereby afflicting the host organism with disease.

Waldsterben (forest death): phenomenon first observed in European, especially central European, forests. It results in an alarming rate of dying trees due to environmental pollution.

Yeast: a type of single-celled fungi that can asexually reproduce by budding or splitting. Yeasts can ferment carbohydrates (starches and sugars). The specific fermentation process of some of them makes them useful for wine making, brewing, baking, etc.

List of Abbreviations

ABC	Association of Biotechnology Companies (US)
ATAS	Advanced Technology Alert System, UN
BAP	Biotechnology Action Programme
BRIDGE	Biotechnology Research for Industrial Development and Growth
BSCC US	Biotechnology Science Coordinating Council
CIMMYT	Centro Internacional de Mejoramiento de Maiz y Trigo (International Maize and Wheat Improvement Center)
ELCI	Environment Liaison Centre International
EMBO	European Molecular Biology Organization
EPA	Environmental Protection Agency (US)
EPC	European Patent Convention
FAO	Food and Agriculture Organization, UN
GATT	General Agreement on Tariffs & Trade
HAI	Health Action International
IARC's	International Agricultural Research Centers
IBA	International Biotechnology Association
IBFAN	International Baby Food Action Network
IBPGR	International Board for Plant Genetic Resources
ICDA	International Coalition for Development Action
ICGEB	International Centre for Genetic Engineering & Biotechnology
ILO	International Labour Organization, UN
IOCU	International Organization of Consumers Unions
IRRI	International Rice Research Institute
IUCN	International Union for the Conservation of Nature and Natural Resources
JACOB	Joint Action Committee on Biotechnology
NGLS	Non-Governmental Liaison Service
OECD	Organization for Economic Cooperation & Development
OTA	Office of Technology Assessment (US)
PAHO	Pan American Health Organization
PAN	Pesticide Action Network
PCT	Patent Cooperation Treaty
PTO	Plant Treaty Office
PVPA	Plant Variety Protection Act (US)
PVPO	Plant Variety Protection Office (US)
RAFI	Rural Advancement Fund International
SAN	Seeds Action Network
UNCSTD	UN Centre for Science & Technology for Development
UNCTC	UN Centre on Transnational Corporations
UNCTAD	UN Conference on Trade and Development
UNDP	UN Development Programme
UNEP	UN Environment Programme
UNESCO	UN Educational, Scientific, and Cultural Organization

UNICEF	UN Children's Fund
UNIDO	UN Industrial Development Organization
UPLB	University of the Philippines at Los Banos
UPOV	International Union for the Protection of New Varieties of Plants
USDA	United States Department of Agriculture
WHO	World Health Organization, UN
WIPO	World Intellectual Property Organization, UN

Sources of Information

I Periodicals

Agricell Report, published monthly by Agritech Consultants, Inc., P.O. Box 255, Shrub Oak, NY 10588, USA. Cost: US $219 per year, US $244 foreign airmail. This newsletter specializes in plant tissue culture. Each issue contains useful listings of recent articles and research papers pertaining to the subject. International coverage.

Agricultural Biotechnology News, published bimonthly, by Freiberg-Frederick Press, Box 7, Cedar Falls, Iowa 50613, USA. Cost: US $55 per year, US $65 per year outside US. Good, general coverage on plant and animal biotechnology, gives information on corporate and university research, coverage almost exclusively on US situation.

Agricultural Genetics Report, published 6 times annually by Mary Ann Liebert, Inc., 165 Third Avenue, New York, NY 10128, USA. Cost: US $125 per year, US $154 per year airmail outside US. Excellent coverage of agricultural biotechnology (commercial aspects, not technical). Newsletter form, usually 10-12 pages in length. Contains very good analysis of market and investment trends in biotech. Mostly US coverage, with some international.

Bioprocessing Technology, published monthly by Technical Insights, Inc., 32 North Dean St., Englewood, NJ 07631, USA. One-year subscription is US $280 in or US $316 outside the US. Excellent newsletter, with coverage of industrial biotechnology which is not limited to agriculture. Provides a monthly feature, 'On the Horizon', which looks at emerging biotech trends, potential products, and also company profiles. Contains a listing of patents issued as well as a listing of forthcoming biotech meetings. Also provides names and addresses of corporate and university contacts where further information can be obtained.

BiolTechnology, the self-described 'international monthly for industrial biology'. Published by Nature Publishing Co. Cost: US $59; outside US $112. Write: BioATechnology, Customer Relations, P.O. Box 1543, Neptune, NJ 07754-1543, USA. This monthly magazine gives very good coverage of all areas of biotechnology—medical, industrial waste, energy, pharmaceuticals and agriculture. In-depth treatment, offering both highly technical and popular articles dealing with current biotech developments. International coverage, particularly US and Japan.

European Biotechnology Newsletter, published 22 times a year by Biofutur S.A., 29, rue Buffon, 75005 Paris, France. One-year subscription in Europe, FF 2550, US $400, rest of the world US $430. This is the best newsletter for coverage of commercial biotechnology throughout Europe.

GeneWatch, published bimonthly by the Committee for Responsible Genetics, a progressive non-governmental organization in the US devoted to discussing, evaluating, and distributing information about the social impacts of genetic engineering. *GeneWatch* covers social issues in genetics and biotechnology and is a major source of information on biological warfare. Cost: US $12 per year for individuals and $20 for institutions. Add $5 for foreign subscription. Address: 186A South St., Boston, MA 02111, USA.

Genetic Engineering and Biotechnology Monitor, compiled by the Technology Programme of the United Nations Industrial Development Organization. Cost: Free upon request. Write: UNIDO, P.O. Box 300, A-1400 Vienna, Austria. The monitor contains a wide selection of excerpts from biotechnology publications worldwide. Covers all biotechnology sectors—including very good coverage of agriculture. Provides one section by country, also covers regulatory issues, research, applications, patents and intellectual property issues. Highly recommended.

Genetic Engineering News, published monthly in a newspaper-like format. In-depth coverage of biotech industry (medical, pharmaceutical, agricultural) with some coverage of European and overseas biotech. Mostly non-technical information. Published by Mary Ann Liebert, Inc., 1651 Third Avenue, New York, NY 10128, USA. Cost: US $135.00; $190.00 overseas.

Genetic Technology News, a newsletter published monthly by Technical Insights, Inc., 32 North Dean St., Englewood, NJ 07631, USA (same publisher as *Bioprocessing Technology,* see above). Price: US $296 per year; $332 outside US. Very good, capsule information on all sectors of commercial biotechnology. Also lists patents in back. Gives addresses and phone numbers of corporate and university contacts where further information about specific research programmes can be obtained.

McGraw-Hill's Biotechnology Newswatch, a newsletter published twice monthly. Brief, capsule information focusing on all aspects of commercial biotechnology. Cost: US $537 per year, worldwide. Address: McGraw-Hill, Inc., 1221 Avenue of the Americas, New York, NY 10020, USA.

Trends in Biotechnology, a newsletter published by Elsevier Publications (Cambridge) 68 Hills Road, Cambridge CB2 1LA, United Kingdom. Cost: UK £33, US $57.00. Published bimonthly. Quality varies. Usually contains in-depth articles on various sectors of biotechnology, including agriculture. Usually technical, with contributions from European researchers, academics—not especially good information on commercial biotechnology or specific company research.

II Books and reports

Algeny, by Jeremy Rifkin, Viking-Penguin, Inc., 1983. A provocative critique of the emerging era of genetic engineering. Rifkin examines the far-reaching implications of society's new-found ability to create and control life in the age of biotechnology. Order from: Viking-Penguin, 40 W. 23rd St., New York, NY 10010, USA.

Altered Harvest: Agriculture, Genetics and the Fate of the World's Food Supply, by Jack Doyle, Penguin Press, 1985. Order from: Viking-Penguin Inc., 40 W. 23rd St., New York, NY 10010, USA. Price: US $8.95. Overview and introduction to changes in modern US food production, with detailed background on US seed patent legislation and the rise of commercial biotechnology and its impact on agricultural production. Especially useful for US audience.

ATAS Bulletin I, 'Tissue Culture Technology and Development', published by the Centre for Science and Technology for Development, United Nations, November, 1984. Edited by Cary Fowler and Pat Mooney. A collection of articles describing new technologies, their potential application and use. The bulletin serves as an 'early warning system' to alert Third World nations and others to the possible Socioeconomic consequences of agricultural biotechnology. To order, contact: Advance Technology Alert System, Centre for Science and Technology for Development, United Nations, New York, NY 10017, USA.

Biotechnology Revolution and the Third World: Challenges and Policy Options. Published by Research and Information System for the Non-Aligned and Other Developing Countries, New Delhi, 1988, 451 pp.

Biotechnology: The University-Industrial Complex, by Martin Kenney, Yale University Press, 1986. Kenney examines the development and growth of the US biotechnology industry and the university industry relations which played a vital role in commercializing the new biosciences. The book also examines the structure of the biotechnology industry: the role of venture capital in the formation of new companies and the relationships between small, entrepreneurial biotech companies and multinational chemical and pharmaceutical firms. Order from: Yale University Press, 92A Yale Station, New Haven, CT 06520, USA. Price US $23.95.

Biotechnology in Western Europe, International Trade Administration, US Government, November, 1987. This 276-page report gives a technical and industrial assessment of biotechnology in the major nations of Western Europe. Includes country reports which describe the national environment for biotechnology in 11 European nations. Order from: Dept. 36-XG, Superintendent of Documents, Washington, D.C. 20402-9325, USA. Request stock No: 003-009-00509-4. Price US $13.00.

Biotecnología, Universidad y Política, by Daniel J. Goldstein, Siglo Veintiuno Editores, Mexico City (forthcoming, early 1989). In Spanish. This book deals with the biotechnology industry and the academic-industrial relations in both North America and Latin America. For more information, contact: Siglo Veintiuno Editores, Cerro del Agua, 248, Mexico, D.F. 04310.

Broken Code: The Exploitation of DNA, by Marc Lappe, Sierra Club Books, 1985. Lappe's 368-page book is a very good, non-technical introduction to recombinant DNA technology, its discovery, development and potential uses. Lappe believes That most developments in biotechnology have occurred because of market prospects instead of potential social impact, and that strict guidelines and priorities should be developed to steer research. Order from: Sierra Club, 2034 Fillmore St., San Francisco, CA 94115, USA. Price US $17.95.

Commercial Biotechnology: An Industrial Analysis, US Congress, Office of Technology Assessment, January, 1984. Published in 1984, this 612-page book is a valuable, early reference on the biotechnology industry. Provides a primer on the basics of biotechnology and examines worldwide competition within the industry.

Order from: N.C. Biotechnology Center, P.O. Box 13547, Research Triangle Park, NC 27709-3547, USA. Price: US $30; outside US $35.

Double Dividends? US Biotechnology and Third World Development, by John Elkington, World Resources Institute, November, 1986. This 50-page report examines what the US biotechnology industry might contribute to Third World. Elkington illustrates the potential of the US biotechnology industry in meeting Third World needs for food, fibre, fuel, pest control and health. Specific companies and potential products are cited. Useful company profiles are included in the appendix. Order from: WRI Publications, P.O. Box 620, Holmes, PA 19043-0620, USA. Price: US $7.50.

First the Seed: The Political Economy of Plant Biotechnology 1492-2000, by Jack Kloppenburg, Cambridge Univ. Press, 1988. ISBN 0-521-32691-5. Important new contribution to the debate of genetic resources and biotechnology. Order from: Cambridge University Press, 32 E. 57th St., New York, NY 10022, USA.

The Gene Hunters: Biotechnology and the Scramble for Seeds, by Calestous Juma, Zed Press, London, 1988. Paperback available for £8.45. Order from: Zed Books Ltd., 57 Caledonian Road, London N1 9BU, UK.

New Hope or False Promise? Biotechnology and Third World Agriculture, by Henk Hobbelink, International Coalition for Development Action, 1987. Order from: ICDA, 22 rue des Bollandistes, 1040 Brussels, Belgium. Price: US $7.50. This 72-page booklet describes some of the possibilities and pitfalls for the Third World arising from the introduction of agricultural biotechnologies. A good introductory critique. Concludes with a discussion on the possibilities and problems related to the appropriation of biotechnology by the Third World, and the role that non-governmental organizations can play in that process.

Recursos Genéticos, Nuestro Tesoro Olvidado, by Daniel L. Querol, Lima, 1988. In Spanish. An important new work on plant genetic resources, with especially good technical information covering collection, description, storage, use, documentation and evaluation of genetic resources. For more information, contact: Daniel Querol, Av. Javier Prado (Este) 461, San Isidro, Lima, Peru.

Shattering: The Diversity of Life in the Age of Biotechnology, by Cary Fowler and Pat Mooney, (forthcoming) 1989.

Major Plant Biotechnology Companies[1]

Company Profiles[2]

*Advanced Genetic Sciences, Inc. (AGS).** Founded in 1979, based in Oakland, California, USA. Merged with DNA Plant Technology (see below) as of 12/87. AGS has 60 per cent of its enterprises in plant genetic engineering, including work on ice nucleation and development of herbicide and disease-resistant crop varieties. The company is developing 'Snow-Max', a bacterium to aid ice-formation in making snow, and 'Frostban' a genetically-engineered bacterium to prevent frost damage on strawberries and other frost-sensitive crops. In March, 1986, AGS became first biotech company ever fined by the US Environmental Protection Agency for deliberately falsifying key scientific data. In April, 1987, AGS became the first company to conduct legal, outdoor testing of genetically-engineered micro-organisms (the so-called 'ice minus' bacterium designed to prevent frost damage on crops).

Corporate investors include: Rohm & Haas (Philadelphia, Pennsylvania, USA) which owns 15 per cent of AGS stock; Hilleshög (Landskrona, Sweden); and Du Pont (Wilmington, Delaware, USA). AGS and Eastman Kodak have a joint venture to market snow inducers to ski resorts. AGS owns 32 per cent of Plant Genetic Systems of Ghent, Belgium (see profile below).

DNA Plant Technology Corporation (DNAP). Merged with Advanced Genetic Sciences 12/87. Founded in 1981, based in Cinnaminson, New Jersey, USA. DNAP devoted $ 5.2 million to research and development in 1986. The company is using tissue culture to develop plant varieties and is marketing a line of monoclonal-antibody-based kits to detect agricultural diseases.

Corporate investors include: Campbell Soup Co. (Camden, New Jersey, USA, which holds about 15 per cent of DNAPs t o c k) ; Koppers (Pittsburgh, Pennsylvania, USA). DNAP has research agreements with the following companies: American Home Products on popcorn; Brown & Williamson on tobacco; Campbell Soup on tomatoes; Du Pont for the development of edible plant oils; and Hershey Foods on cacao.

Agracetus. Founded in 1984, based in Middleton, Wisconsin, USA. Agracetus is a joint venture of Cetus Corporation, (Emeryville, California), 49 per cent, and W.R. Grace & Co. (New York, NY, USA) 51 per cent. The company was formed to develop agricultural products based on genetic engineering in the areas of improved crops, microbial crop treatments, and animal health therapeutics and vaccines. Agracetus research is directed principally at corn, soybeans and cotton. In 1986, Agracetus became the first company in the world (legally) to field-test a genetically-engineered plant. R&D budget not known, but W.R. Grace has committed more than $60 million to fund the venture's activities.

* In December 1987, it was announced that Advanced Genetic Sciences of Oakland. California (USA) and DNA Plant Technology Corporation, Cinnaminson, New Jersey (USA) would merge. This represents the first merger of two leading biotech firms. As of this writing, the new company has not been named. What follows is a separate profile of each company.

Agricultural Genetics Co., Ltd. Founded in 1983, based in Cambridge, England. The company was founded by the British government for the purpose of commercializing ideas from government-funded research institutes such as the Agriculture and Food Research Council (AFRC). Original investors include Ultramar PLC, Advent Eurofund and British Technology Group. The company has rights to three major areas of research conducted at AFRC, including microbial innoculants, biological control agents, and non-conventional plant breeding.

The company has research agreements (past and present) with Ciba-Geigy, Danish Sugar Co., Eli Lilly and J. Bibby and Sons Plc.

Allelix, Inc. Founded in 1981, based in Mississauga, Ontario, Canada. Privately held. Allelix was established as a joint venture between the Canada Development Corporation, John Labatt Ltd., and the government of Ontario with shareholdings of 50, 30 and 20 per cent respectively. Allelix started with a budget of $100 million (1981-1991). The company has three broad areas of research and development: agricultural crops, industrial products and processes, and analytical systems. Allelix is developing new plant varieties with improved yield, vigour and properties such as cold tolerance and herbicide resistance. Particular emphasis on rapeseed, potatoes and corn.

Past and present research agreements include: McGill University, five-year, $2 million, for research on micro-organisms and plant interaction: University of Guelph, for reduction of fatty acid content in rapeseed oil: United Grain Growers, joint development and marketing agreement on herbicide resistant canola (rapeseed). Weibull AB (Volvo), a European research and marketing agreement for rapeseed yield improvement. As of late 1986, the company had 220 employees.

Biotechnica International, Inc. Founded in 1981, based in Cambridge, Massachusetts, USA. Biotechnica is a diversified biotech company with commercial operations in the fields of agriculture and dental diagnostics, and research programmes in production technologies for industrial applications. In 1986, the company's R&D expenses were $6.1 million. The company has several subsidiaries or joint ventures outlined below:

- Biotechnica Canada, formed in 1985, an affiliate of Biotechnica International, which has a 42 per cent shareholding.
- Biotechnica Diagnostics, subsidiary of BI, formed in 1985.
- Biotechnica Agriculture, Inc., based in Overland, Kansas, formed in March, 1987.
- Biotechnica Ltd., formed in United Kingdom in 1984, the company has a 25 per cent interest.

In the field of agriculture, Biotechnica is focusing on biological nitrogen fixation, creation of improved varieties of major crops, and new crop characteristics such as herbicide tolerance. In 1985-1986 the company had six corporate research agree-

cultures to produce vanilla, grape and strawberry flavours. The company's major emphasis is on vanilla, and they hope to release a commercial product in mid-1989. Because Escagen is privately held and newly formed, there is little additional information available as we go to press.

Molecular Genetics, Inc. Founded in 1979, publicly held since 1982. Based in Minnetonka, Minnesota, USA. Molecular Genetics has traditionally focused on the application of genetic engineering and monoclonal antibody-based technology to develop and produce animal health care and agricultural products. In November, 1987, the company announced that it would discontinue all animal health care manufacture and research. The company terminated approximately half of its employees in January, 1988, and has about 70 employees at present. In 1986 (most recent figures available) the company spent $6.1 million on R&D.

Schering Animal Health (division of Schering Plough Corp.) will take over manufacture and market rights to 'Genecol 99', a monoclonal antibody-based product developed by Molecular Genetics for prevention of calf scours. Molecular Genetics will now focus on development of new hybrids of corn, both nutritionally superior and herbicide tolerant types.

Some corporate agreements include: Contract with US Army to develop fast breeding hybrid for the Rift Valley fever virus; contract with Rhone Poulenc to study diseases affecting corn; joint venture with Terra International to produce and sell corn and other seeds in US.

Molecular Genetics has a minority interest (11 per cent) in a Dutch agricultural subsidiary, Mogen International, based in Leiden, the Netherlands.

NPI (original name Native Plants, Inc.). Based in Salt Lake City, Utah, USA. Company is privately held, approximately 400 employees. NPI specializes in plant genetics, especially plant cell and tissue culture, biological nitrogen fixation, stress tolerance, plant disease and insect resistance, new crop development. Company sells plant and seed products, including virus-free potato, hybrid asparagus, tissue culture roses ('Forever' brand), biopesticides and bioherbicides.

Company investors include: Martin Marietta Corp., Sandoz, Elf Aquitaine, British American Tobacco, Venrock Associates, Novatech Resource Corp., BAT Industries, Vista Ventures. NPI's corporate agreements include: joint venture with Synergen and W.R. Grace to develop seasonings; contract with Kyowa Hakko Kogyo, Sumitomo, Tata Enterprises to develop new strains of tea and coffee for Southeast Asia (this is a joint venture called 'Plantek'); joint venture with McCormick & Co. on rDNA development of sources of seasonings; $10 million joint venture called 'Phytotec' for research and marketing of plants in Europe and Africa with Societé Européene de Semances and Compagnie de Développement des Agro-Industrie et des Biologie (Belgium); $3.5 million joint venture called 'Bio

Plant Limitada' to build a bio-engineering lab with Souza Crus (BAT Industries Plc): collaboration with the University of Utah on gene mapping and expression in plants.

Phytogen, Inc. Founded in 1980, based in Pasadena, California, USA. Company is privately held, approximately 20 employees. Phytogen is an agricultural biotechnology company established to produce new plant varieties and treatments through the application of rDNA techniques and plant tissue culture. Ongoing research devoted to improving resistance to disease, insects and herbicides in cotton and soybeans. Principle stockholders are J.G. Boswell Co. and Ciba-Geigy Corp.

According to the company, Phytogen was the first company to regenerate commercially-grown varieties of cotton through tissue culture, and first to begin the genetic manipulation of commercial cotton and soybean varieties by direct gene transfer. Phytogen has signed an agreement with Ciba-Geigy Corp. for the development of certain cotton and soybean varieties which will be marketed worldwide through Funk Seeds International, a subsidiary of Ciba-Geigy.

Plant Genetics, Inc. Founded in 1981, privately held until 1987, based in Davis, California, USA. The company has approximately 65 employees, and devoted $7.6 million to R&D in 1987. The company focuses on developing agricultural crop varieties for medium-sized markets, including potatoes, alfalfa, tomatoes, mushrooms, celery and lettuce. R&D efforts concentrate on tissue culture, and 'artificial seeds' (somatic embryogenesis) for mushrooms, celery, lettuce and rice. Plant Genetics Inc. has a patented encapsulation system called 'Gel-Coat' (water-soluble capsules) used to deliver a variety of agricultural products including seed, chemicals, biologicals and somatic embryos.

In February 1987, acquired Lovelock Seed Company. Corporate research agreements include: agreement with Kirin Brewery Co., Ltd. (Tokyo, Japan) on synthetic seeds; contract with McCormick & Co. to regenerate garlic plants from tissue culture; agreement with Merrill Lynch Technology Ventures, L.P. to support genetic improvements in commercial potato varieties. Together with Twyford Seeds Ltd., Plant Genetics formed Twygen Ltd., a joint venture which will produce 'NU-SPUD' products in Scotland for the European potato market.

Plant Genetic Systems (PGS). Founded in 1982, based in Ghent, Belgium. Major investors in the company include GIMV NV (Flemish Industrial Development Agency), Hilleshög, Radar NV, Tienen Sugar Refinery NV, Advanced Genetic Sciences. PGS specializes in plant genetic engineering, plant growth, soil microorganisms, increased yield and disease resistance, and biological pesticides. As of November 1986 the company had 101 employees, including 36 PhD scientists.

Corporate agreements include: Joint venture with Brazilian government (50 per cent financing from World Bank) to transfer protein from a Brazilian nut into agricultural crops; a five-year, $12-million research agreement with Gist-Brocades

and Amylum on protein engineering; agreement with Hilleshög to develop virus-resistant sugarbeet varieties; commercialization agreement with Janssen Pharmaceutical on polybase coated membranes; agreement with Radar for improved forage inocula; agreement with Rohm & Haas to develop biopesticides. In early 1987 it was announced that PGS scientists had produced plants resistant to Hoechst's 'Basta' herbicides.

Sungene. Founded in 1981, based in San Jose, California, USA. Privately held; initiated biotechnology research in 1982. The company has approximately 65 employees. Major investors include: Lubrizol (30 per cent), Hambrecht & Quist, Mitsubishi (15 per cent), Morgenthaler Assoc., Allsop & Assoc., Princeton/Montrose Partners. The company's focus is on genetic engineering and tissue culture techniques to improve major agricultural crops (corn, sunflowers, soybeans, barley, sorghum, sesame and rapeseed). Special focus on modifying plant oils and seeds. In 1987, Sungene received 7 US patents, including 3 patents related to the development of sunflower varieties with high levels of oleic acid.

Twyford International, Inc. Based in Cambridge, UK, organized in 1982 by venture capital investors. The company's major products are clonally-propagated plants developed via tissue culture (mostly ornamentals, vegetables, flowers, woody plants).

Twyford International is the parent company of Twyford Plant Laboratories (Glastonbury, UK) and Twyford Plant Laboratories Inc. (Santa Paula, California, USA).

In 1987, Twyford International announced that it planned to open a $10 million laboratory to focus on a molecular biological approach to plant diseases. The laboratory will be known as the Centre for Advanced Technology. Research will focus on resistance to diseases in potato, cotton, sugar beet (among others), and on the genes that determine flower colour and the shelf-life of fresh fruit and vegetables. The new facility opens in Cambridge in 1988 with a staff of over 30 scientists.

1. The companies included in this list were suggested by George H. Kidd, Advanced Science Consultant, L. William Teweles & Co., Milwaukee, WI, USA. No attempt is made to rank companies or list in special order.
2. Information compiled from annual reports, telephone interviews with company personnel, industry journals and other published sources.

UN Agencies and Biotechnology

An Overview of the Involvement of the United Nations in the New Biotechnologies*

IAEA/FAO

International Atomic Energy Agency (IAEA) and Food and Agriculture Organization of the United Nations (FAO)

The work of the Joint FAO/IAEA Division of Isotope and Radiation Applications of Atomic Energy for Food and Agricultural Development which was created in 1964 is mainly directed towards biotechnology involving, to some extent, radioactivity. Biotechnological research and training work is carried out at the FAO/IAEA Agricultural Biotechnology Laboratory located at the Seibersdorf Research Centre near Vienna, Austria. In addition, research is carried out in some 400 research stations mainly in Third World member states. Furthermore, FAO, IAEA and the Ministry of Agriculture and Fisheries of the Netherlands established the International Facility for Food Irradiation Technology (IFFIT), Wageningen, the Netherlands, to support food preservation activities for two years as of January 1st, 1986.

The FAO/IAEA programme attempts to find ways to improve agriculture in the Third World by developing new methods, disseminating information, and by providing training, expertise and special equipment. By 1984, 130 technical field projects had been coordinated in 53 Third World countries. Among them have been several large-scale projects jointly organized with other agencies such as the United Nations Development Programme, UNDP, (Indonesia and Peru) and the Swedish International Development Authority, SIDA, (Bangladesh and India). Training courses are regularly held at the Seibersdorf Research Centre.

The main goal of the programme is to assist member states in the development of their own technology and to promote technical cooperation between them and between North and South. Among the objectives are: increasing and stabilizing agricultural production; reducing production costs; improving food quality and availability; protecting agricultural products from spoilage and losses; minimizing pollution of food and the agricultural environment. Currently the main areas of activity are:

1. Soil fertility, irrigation and crop production: The overriding idea is to optimize various farming systems using the nitrogen in the air rather than expensive nitrogen fertilizers. Radioactive isotope measures are used to maximize the symbiotic nitrogen fixation of Rhizobium bacteria in association with legume plants or of bluegreen algae in association with the fern Azolla. The latter could provide flooded rice fields with sufficient nitrogen. Isotope methods are also used to select crop varieties tolerant to salinity.

2. Plant breeding and genetics: Induced mutation combined with tissue culture techniques, and gene transfer techniques combined with plant regeneration from single cells are being developed for the purpose of improving crops. Traits such as higher yields, early maturity, better lodging resistance and resistance to pathogens and pests are envisaged. Under research are, among other crops, rice, legume crops, oil crops and some basic African food crops.

*This material was collected and arranged in the early part of 1987.

3. Animal production: Research is being carried out to develop diagnostic tests using monoclonal antibodies to identify animal disease agents, especially parasites, and to measure levels of reproductive hormones. A kit for the determination of blood and milk progesterone was developed. Isotope-aided research on nutrition and environmental physiology is also underway. Studies are being conducted for example on the nutrient value of low-quality roughages and agro-industrial by-products as potential feedstuff for ruminant animals and the productivity of domestic animals in Asia and Latin America.

4. Insect and pest control: The objective is to control or eradicate major crop pests and disease vectors, such as the tsetse fly and the Mediterranean fruitfly. Emphasis is placed on the release of sterile insects in infested areas and integrated pest management. Research on sterile insects is a major focus. Big scale release projects are carried out, for example, in Egypt, Peru and Kenya.

5. Agrochemicals and residues: Pesticide residues in livestock products, stored grains, food plants and rice/fish ecosystems are studied with the help of isotopes. Similarly drug residues are determined. Investigation into biochemical and biological pest control agents from natural sources, and the natural resistance of plants to pests are envisaged. Another major objective is the improved utilization of agricultural waste through the use of micro-organisms.

6. Food preservation: Food irradiation is used to reduce post-harvest losses and to promote safe food supplies and is studied for its usability as a quarantine treatment of food and agricultural commodities. The International Consultative Group on Food Irradiation with 23 participating countries, focuses on trade promotion, training, feasibility studies and the public acceptance of food irradiation.

Other work of IAEA related to biotechnology: IAEA is involved in research on the application of radioactivity in medicine with special respect to the Third World. A lot of work is being done in the area of diagnostics (radio-immunoassays; monoclonal antibodies), the investigations of abnormalities such as tumours, quality control and training.

Radioactive isotopes are also used in vivo either as tracers or as a therapy in certain cases of cancer. Various surveys have been carried out on radiation-induced chromosomal aberrations.

Nuclear techniques are also used in health-related environmental research, for example in the determination of toxic elements in foodstuffs and environmental factors at the work place. Work on nuclear analytical techniques to study trace elements in human diets, hair, kidney and liver is being done.

Contact address: Joint FAO/IAEA Division of Isotope and Radiation Applications of Atomic Energy for Food and Agricultural Development IAEA, Vienna Interna-

tional Centre, Wagramerstrasse 5, P.O. Box 100, A-1400 Vienna, Austria, Tel.: (0222) 2360, Telex: 1-12645, Cables: INATOM **VIENNA.**

Contact person: Björn Sigurbjörnsson, PhD, Director, Joint FAO/IAEA Division.

Publications and documents:
- Since 1964, more than 100 publications on topics relevant to the FAO/IAEA programme have been issued. They include proceedings of meetings, reports of studies carried out by expert panels, laboratory training manuals, other technical manuals and other relevant literature on nuclear medicine, radiation biology, entomology (insect management), agronomy (soils, irrigation, crop production), food preservation, plant breeding and animal science. All these publications are listed in the IAEA Publications Catalogue 1985 and subsequent supplements available at the IAEA Division of Publications.
- The Joint Division maintains regular contact with scientists in member states by periodical newsletters.
- The *IAEA Bulletin ,* the Agency's quarterly magazine, includes news on IAEA and biotechnology.

Upcoming meetings: Normally one symposium and two seminars are organized annually as part of the joint FAO/IAEA programme in addition to several smaller scientific meetings. The participants in specific co-ordinated research programmes meet regularly to review results and to discuss and decide on the future approach.

UNIDO

United Nations Industrial Development Organization

UNIDO is interested in the transfer of technology and the development of the Third World countries' own capabilities in the field of biotechnology as this branch of technology will strongly affect Third World economies. UNIDO has examined the potentials and limitations of biotechnology including genetic engineering in industrial application. It has mainly focused on the impact of this technology on the pharmaceutical, petrochemical and food processing industries and the implications of these advances for Third World countries.

UNIDO provides technical assistance and expertise to countries, mainly in the Third World, which are attempting to build up their own biotechnological capacities. For example, UNIDO assists Saudi Arabia and Kuwait in working out blue prints for biotechnological research on oil, agriculture, health and marine biology. India, Egypt, Tunisia and maybe Senegal are in line for similar cooperation with UNIDO. Training and the building up of skilled personnel is most important for these countries. At least the ability to evaluate the technology offered by the North should be acquired, if not research and development capacities. Such assistance projects are sometimes carried out in cooperation with other UN agencies such as UNDP.

UNIDO has cooperated with IAEA on nitrogen fixation. Together with WHO and

UNEP it has formed an informal working group on biotechnology safety (see below). Apart from UN agencies, UNIDO also cooperates with many research institutions in the North. In the course of many joint research ventures, Third World institutions are linked with centres in the North. Plans to develop diagnostic kits for common diseases in Third World countries with Swedish and Swiss pharmaceutical companies are under negotiation.

UNIDO's International Centre for Genetic Engineering and Biotechnology (ICGEB)

UNIDO's consideration of national biotechnology policies and the building of infrastructure led in 1981 to a meeting of experts to discuss the question of how the Third World could build up its own biotechnological capacity. It resulted in the idea of ICGEB, which was officially established in 1983 by 26 countries at a meeting in Madrid, Spain, organized by UNIDO. ICGEB was to be devoted to the problems of the Third World countries but did not find too much support among the industrialized countries. It has 40 member countries, mainly Third World and poorer European countries. It was decided to divide ICGEB into two centres, one located in Trieste, Italy, and one in New Delhi, India.

The centre in New Delhi is going to concentrate on agriculture and health. Some of the agricultural projects envisaged are biological nitrogen fixation, soil microbiology, stress tolerance in plants and improvement of the nutritional content of crop plants. The animal health sub-programme covers growth, development and reproduction, as well as vaccines and immunology. Tropical diseases would be the main thrust of human health research.

The Italian half of ICGEB will focus on industrial microbiology including bioconversion of biomass, development of industrial-scale fermentation processes and protein engineering. Advances in transforming cellulose waste into fodder, sugars and alcohol fuels are hoped for. The study of micro-organisms could lead to new methods of refining crude oil cheaply, breaking up oil slicks and utilizing petroleum solids in dried oil wells. In March 1986, an ICGEB Workshop on Biotechnology and Industrial Commodities was held in Trieste in order to make recommendations for the Trieste components of ICGEB.

Training of scientific and technological personnel from Third World countries will represent a key element in ICGEB's activities. The aim is to catalyse the creation of innovative groups for research and industrial development by the trainees in their home countries.

ICGEB will play the role of a clearing house of information between the North and the South. In this connection a gene bank, containing genetic stocks and information, is planned for at least one of the sites. In addition ICGEB will be the focal point for a network of affiliate regional and national research and development institutes, where work of special interest will be carried out. Advisory services will be provided to members to develop technological capabilities.

The centres have not yet taken up normal work, but provisional facilities have been made available. The director of ICGEB, Dr. I. Gunsalus of the University of Illinois, and part of the scientific staff of the proposed 31 scientists, 20 post-doctoral fellows and 30 technicians have been appointed.

ICGEB is expected to cooperate with various UN agencies, especially with WHO, FAO, UNESCO, UNEP, UNU and of course UNIDO.

Contact address: UNIDO, P.O. Box 300, Vienna International Centre, A-1400 Vienna, Austria, Tel.: (0222) 26 31 0, Telex: 135612, Cables: UNIDO VIENNA.

Contact person: Mr Wafa Kamel, Officer-in-Charge, Development and Transfer of Technology Branch, UNIDO.

Publications and documents:
- UNIDO's quarterly newsletter *Genetic Engineering and Biotechnology Monitor* which carries news on UNIDO's and ICGEB's activities in the field of biotechnology and those of other UN agencies, news about regulations concerning biotechnology, country news and news about research and application in biotechnology.
- A number of documents on biotechnological applications, potential impact and implications of biotechnology and genetic engineering, commercialization of the new technologies, and national policies for biotechnology, as well as the documents of the ICGEB meetings and other proceedings. (These are listed in UNIDO's *Bibliography of Documents Relating to the Transfer of Technology* compiled by the UNIDO Technology Programme.)
- The Draft Work Programme for the First Five Years of Operation of the International Centre for Genetic Engineering and Biotechnology prepared by the UNIDO Secretariat, December, 1984.

Shortly after the 1987 Dag Hammarskjöld Seminar on 'The Socioeconomic Impact of New Biotechnologies on Basic Health and Agriculture in the Third World', UNIDO withdrew a good part of its commitment to ICGEB and biotechnology in general. The Technology Programme Unit, which had been in charge of the programme until then, was practically dissolved. The head of the unit, Mr Wafa Kamel, main actor of UNIDO's biotechnology programme, including ICGEB, was transferred to another post, where he is now in charge of establishing a joint UNIDO/FAO programme on food and agriculture. The other staff of the unit were transferred as well.

The new liaison person between UNIDO and ICGEB is Mr Krishnaswamy Venkataraman, Senior Technical Advisor at the Department for Industrial Promotion, Consultations and Technology, but his areas of expertise are restricted compared with those of Mr Kamel.

The slow withdrawal of UNIDO from ICGEB meets the interests of certain indus-

trialized countries with well developed biotechnology capacities, which had opposed ICGEB from the very beginning.

World Health Organization

WHO does not have a separate division for biotechnology. But various WHO divisions are dealing with specific aspects of biotechnology in connection with their respective areas of work. The Division of Biologicals, for example, is interested in the safety of biological medical products for the market and for international shipment. It is trying to work out guidelines for the evaluation of products in this respect.

The WHO Division of Communicable Diseases is interested in biotechnology with respect to its programmes on (a) vaccine development, (b) new rapid diagnostic techniques, and (c) transfer of vaccine production technology to Third World countries. The programmes include a commitment to ensure safety of the products and safety for the industry workers and the community in the vicinity of the industrial plant.

WHO has long been interested in laboratory safety and published a Laboratory Biosafety Manual in 1983, which included safety in gene technology laboratories. It was preceded by the Special Programme on Safety Measures in Microbiology and the development of international biosafety guidelines. WHO began to work on safety guidelines for medical biotechnological products and their industrial production. UNIDO and UNEP had similar interests and plans. Together they formed an informal working group on biotechnology safety (see below).

A Subcommittee of the Advisory Committee on Health Research (ACHR) working to enchance the transfer of health-related technology to Third World countries considered at a meeting in October 1986 the following items important for future health care activities:

- the study of the genetics of infection by disease-causing organisms in order to learn about immunological aspects;
- the preparation of monoclonal antibodies for diagnostic purposes;
- the exploration of the genetic engineering of vaccines;
- the development of easy and reliable procedures to diagnose communicable diseases using monoclonal antibodies;
- the development of antiviral or antimicrobial compounds;
- the production of therapeutically active proteins such as hormones and enzymes, of high purity;
- the identification of the culprit genes of hereditary diseases for the development of genetic approaches to health promotion;
- research into the possibilities of gene therapy or related treatments;
- genetic manipulation in order to control disease vectors;

- research on the genetics of cancer to develop methods for early detection and identification of specific cancers.

New approaches to vaccine development, improved techniques for diagnosis and the early detection of hereditary disorders were considered the most important areas by the Subcommittee. Four WHO programmes are concerned with the development of new or improved vaccines to a major extent: the Special Programme for Research and Training in Tropical Diseases (TDR); the Diarrhoeal Disease Control Programme (CDD); the Special Programme of Research, Development and Research Training in Human Reproduction (HRP); and the Vaccine Development Programme. These programmes will be dealing with the relevant aspects of biotechnology, including training of young Third World scientists and technical assistance in building up relevant capacities in Third World countries.

The ACHR Working Group on Diagnostic Tests for Use at the Primary Health Care Level is one of the groups within WHO concentrating on diagnostic techniques using monoclonal antibodies and other modern methods. The Subcommittee hoped that gene diagnostic methods could help eradicate such hereditary scourges as the blood disease thalassaemia, endemic in many Third World countries.

The Environmental Health Service of the WHO Regional Office for Europe organized a working group on the Health Impact of Biotechnology in Dublin, Ireland, in November 1982 to look at safety aspects and possible adverse impacts on human health of new developments in biotechnology. The recommendations of the group referred to both occupational and environmental concerns of modern biotechnology. Although the occupational and public health risks were considered small the Regional Office was to continue to review and evaluate the rapid developments in biotechnological research and application.

The Regional Office for Europe is especially concerned about safety aspects of genetic engineering and the industrial and environmental applications of biotechnology, including those posed by biological waste. The Environmental Health Service of WHO-Europe has a strong interest in research covering health impact assessments of the developments in biotechnology. The assessment of biotechnology systems or products is part of the Regional Programme on Appropriate Technology for Health under its activities on biosafety.

In addition, WHO is concerned with ethical implications and legal aspects of the new technology. The WHO Health Law Unit is collecting information on national laws relating to biotechnology.

Apart from other UN agencies, WHO cooperates in the field of biotechnology with various NGOs, the pharmaceutical industry and scientific centres. WHO has established four biosafety collaborating centres at institutions with expertise in biosafety training, research and consultation in the US, Canada and Australia. Their services

are made available to member states. WHO also collaborates with institutes in India, Japan and Sweden.

Contact address: World Health Organization, CH-1211 Geneva 27, Switzerland, Tel.: (022) 91 21 11, Telex: 27821, Cables: UNISANTE GENEVA.

Contact persons: Mr. Vinson R. Oviatt, Coordinator, Safety Measures in Microbiology, Division of Communicable Diseases, WHO, Geneva. Mr. Jorma Järvisalo, Regional Officer for Occupational Health, WHO, Regional Office for Europe, 8, Scherfigsvej, DK-2100 Copenhagen, Denmark.

Publications and documents:
- News about biotechnological achievements in the field of health, pharmaceuticals and vaccines are reported in the scientific literature published by WHO, such as *World Health Forum*.
- *Laboratory Biosafety Manual,* WHO, Geneva, 1983.
- 'Biotechnology—An International Viewpoint', by Vinson R. Oviatt, in *Genetic Engineering to Biotechnology: The Critical Transition*,Whelan, W.J. and Black, Sandra (eds.), John Wiley & Sons Ltd., 1982.
- 'Quality Control of Biologicals Produced by Recombinant DNA Techniques', WHO consultation, *Bulletin of the World Health Organization,* 61(6):897-911,1983.
- 'Health Impact of Biotechnology', Report of a WHO Working Group, Dublin, 9-12 November, 1982.
- 'Enhancement of Transfer of Technology to Developing Countries with Special
- 'Reference to Health', Report of a Subcommittee of the Advisory Committee on Health Research, 28th Session, Geneva, 7-10 October, 1986, agenda item 5.1, WHO, CHR28/86.5.

United Nations Environment Programme

UNEP is concerned with the environmental implications of the modern techniques of biotechnology. UNEP's subprogramme in this area aims at gearing genetic resources conservation with rational utilization for sustainable development.

Together with UNESCO and the Economic Commission of Europe (ECE), UNEP has undertaken work on the use of microbial technologies to solve environmental problems. UNEP has studied the application of such technologies with the aim of controlling desertification of land and increasing the productivity of arid land. Efforts have been made in cooperation with FAO to study the potential of the application of biological nitrogen fixation in Third World countries as an alternative to the use of synthetic nitrogen fertilizers. In addition, UNEP has been supporting policy-making and infrastructure development and activities of national and regional professional associations in the field of modern biotechnology. UNEP's present activities in the field concentrate on:

1. The promotion of the field application of environmentally sound biotechnologies in Third World countries using local resources and skills for increasing soil fertility and food production; pest and (disease) vector control; bioconversion of agro-industrial organic wastes and surpluses into fuel, food, fodder and organic fertilizers; biodegradation of persistent pollutants and bioleaching of metals.

Projects relating to pest and vector control, the degradation of persistent chemical pesticides in the environment and the increasing legume protein production through biological nitrogen fixation have been carried out in Egypt and Kenya. Biological nitrogen fixation projects with legumes have also been carried out regionally for Africa and Latin America and one is in progress in Senegal. Regional projects on the upgrading of cassava wastes and coffee processing by-products by appropriate biotechnologies are being carried out in Asia and Latin America. A global project, on bio-geotechnology of metals as an environmentally sound and rational use of mineral resources, is also in progress.

2. The setting up of a global referral system of information on the availability of various microbial strains and cell lines and their possible uses as the cornerstone of biotechnology.

This international Microbial Strain Data Network (MSDN) is to make the rapidly increasing data on micro-organisms and cell lines available to interested users. The data include property descriptions, sources and availability of organisms usable in basic science and applications in pharmaceutical and food technology and many other manufacturing processes. The MSDN secretariat was established in September, 1986, with support from UNEP, CEC, USAID and CODATA and will be located at the Biotechnology Centre, Cambridge University. A system of committees is planned to advise the secretariat on the needs of the users, on classification and nomenclature, on network development and interaction, financing and related issues. User liaison functions for training in network usage are also planned.

A global project to compile data on microbial genetic resources in the world's collections of micro-organisms has been carried out. Another one to support the establishment and operation of the coordinated international MSDN is in progress.

3. The establishment of the means to guide research and development in contained as well as uncontained applications of biotechnology and its risk assessment, in particular for the Third World.

So far some attention has been paid to the development of safety guidelines for genetic engineering work in laboratories and in the industrial application. Comparatively less attention has been paid to the safety of environmental and agricultural applications of genetically manipulated organisms. UNEP saw a need for adequate safety measures, guidelines and regulatory actions for the production, field testing and release of such organisms. The potential risks associated with the interaction of released organisms with the ecosystem have to be evaluated.

Such an assessment would be problematic, though, because of the lack of reliable data and data on long term effects; different risks from one case to the other; difficulties in predicting the fate and effects of released organisms; secrecy associated with gene technology, and the absence of monitoring procedures. Ecological analyses would be needed on a case-by-case basis.

UNEP's interest in the above problem led to its membership in the Informal UNIDO/WHO/UNEP Working Group on Biotechnology Safety (see below). As a contribution to this Working Group, UNEP conducted a study on successful and unsuccessful introductions of alien organisms in the environment. Based on such case studies conjectural prediction methods could be developed. A data base for follow-up activities, particularly with regard to the development of risk assessment methodology and safety guidelines, will be provided.

Many of UNEP's projects, including the MSDN, are being implemented or supported by the network of regional Microbiological Resources Centres (MIRCENs) conceived by UNEP, and established with its support, in Bangkok, Cairo, Dakar, Guatemala, Nairobi and Porto Alegre. They are active in environmental management, increased bioproductivity, the conservation of microbial resources and the development and application of microbial technologies of high regional relevance. In addition they provide formal as well as on-the-job training in environmental microbiology.

UNEP's International Register of Potentially Toxic Chemicals (IRPTC) based in Geneva collects information on biotechnologically-produced chemicals with the exception of pharmaceuticals, but has no separate section on biotechnological products.

Contact address: United Nations Environment Programme, UNEP headquarters, P.O. Box 30552, Nairobi, Kenya, Tel.: 33 39 30, Telex: 22068, Cables: UNITERRA NAIROBI.

Contact person: Mr. Hamdallah Zedan, Senior Programme Officer, Environment Management Service.

Documents and features:

- *Needs and Specifications for an International Microbial Strain Data Network,* Proceedings of a Workshop held in Brussels, Belgium, 15-17 November, 1983, and Executive Summary of the Working Group Meeting, Bangkok, Thailand, 23-25 November, 1984, Hill L.R. and Krichevsky M.I. (eds.), UNEP, Nairobi, 1985.
- *Biological Nitrogen Fixation in Africa,* Proceedings of the First Conference of the African Association for Biological Nitrogen Fixation (AABNF) held in Nairobi, Kenya, 23-27 July, 1984, The Nairobi Rhizobium Microbiological Resources Centre (MIRCEN), 1985.
- *A Network of Microbiological Resources Centres (MIRCENs) for Environmental*

Management and Increased Bioproductivity in Developing Countries, by Zedan, H. and Olembo, **R.,** UNEP.
- 'Solving the Fertilizer Issue: UNEP Promotes Natural Nitrogen Fixation', UNEP Feature 84/16, August, 1984.
- 'Microbes and Men: Introducing UNEP's Work with Microbes', UNEP Feature 84/27.
- 'UNEP Shows Concern as Crisis Faces Crop Plants', UNEP Feature 84/31, December, 1984.
- 'Microbial Technologies for the Developing World', UNEP News, November/ December, 1986.

UNIDO/WHO/UNEP

Informal UNIDO/WHO/UNEP Working Group on Biotechnology Safety

The first meeting of the Informal UNIDO/WHO/UNEP Working Group on Biotechnology Safety took place in Vienna, Austria, in January, 1986. Observers from the Joint FAO/IAEA Division (see above) and OECD attended the meeting. The objectives were: (i) to review existing safety practices as they apply to biotechnology R&D and industry; (ii) to review existing safety rules and regulations for biotechnology R&D institutions and bioscience-based industry; (iii) to review existing practices that attempt to ensure the safety of releasing genetically-engineered organisms into the environment; (iv) to consider what elements are required for minimal guidelines useful to the managers of ICGEB and to R&D institutions, especially in Third World countries; (v) to consider what elements are required for minimal guidelines useful to Third World countries that may wish to regulate bioscience-based and biotechnology-utilizing industry; (vi) to determine if safety guidelines should be formulated for the release of genetically-engineered organisms into the environment; (vii) to indicate further activities for each member of the working group.

The following projects were to be implemented by the time of the second meeting in Geneva, November, 1986.

1. The development of Minimal Guidelines for Laboratory and Industrial Scale Biotechnology Facilities with UNIDO as the lead agency and with equal input from UNEP and WHO.

The UNIDO/WHO consultant entrusted with the work presented a preliminary report at the second meeting. It reviews the current guidelines of the US and the UK and provides general recommendations for laboratory-scale genetic manipulation. The consultant will discuss the appropriateness of the proposed guidelines with selected Third World governments on the way to final approval at an expert meeting.

The Minimal Guidelines are supposed to be simple, easily readable and globally valid. They should include: (a) safety guidelines for laboratory scale practice, including biological containment; (b) safety guidelines for large scale ('scale-up')

practice; (c) safety and risk assessment guidelines for release of genetically engineered organisms into the environment.

2. An assessment of whether biowastes from large-scale industrial practices where genetically engineered organisms are used may pose hazards to human beings or the environment, with UNIDO as the lead agency in close cooperation with UNEP. It was at the development stage at the second meeting.

3. A study on the successful and unsuccessful introductions of genetically manipulated organisms (micro-organisms, plants, animals) into the environment. Special emphasis was to be placed on cases relevant to Third World countries.

UNEP circulated a draft report on 'Evaluating the Effects of Introducing Novel Organisms into the Environment' at the second meeting. The report reviews successful and unsuccessful cases of such releases, discusses ecological effects and provides a methodology for environmental risk assessment. The report would be an important contribution to the development of the Minimal Guidelines.

4. A round table discussion on the subject sponsored by UNEP in association with the International Conference on Microbial Ecology. It was held in August, 1986, in Yugoslavia.

5. A UNEP survey of already existing national environmental protection acts and the status of their implementation in collaboration with its Law Unit.

By the second meeting none of the responding Third World countries had reported any applicable acts or laws. Industrialized countries had replied to the effect that OECD Recommendations for Recombinant DNA Safety Considerations were being followed.

6. An assessment of the awareness of biosafety or laboratory safety, particularly in Third World countries, by WHO surveying the impact of its own Laboratory Biosafety Manual and its biosafety 'Train the Trainer' courses.

This process led to the conclusion that there was considerable interest in biosafety globally. Less interest was evident in Africa, more in Central and Latin America.

7. A review of existing biotechnology legal requirements on a global basis by WHO.

8. WHO would make the institutions it is collaborating with in the field of biotechnology accessible to the Informal Working Group and ICGEB.

The Working Group further recommended that ICGEB develop an orientation course in risk assessment in collaboration with members of the Working Group; that all UN agencies active in environmental programmes relating to biotechnology be invited to attend the next meeting of the Group (the second meeting was attended

by observers from OECD, ILO and the International Programme on Chemical Safety—WHO, ILO, UNEP—who distributed the report on 'Modern Biotechnology and the Possible Role of IPCS'); and that FAO should be encouraged to make a formal request to join the Working Group as a member.

Contact addresses: see addresses of the member agencies.

Contact persons: for UNIDO, WHO and UNEP see above. Observers: Dr. Björn Sigurbjörnsson, Director, Joint FAO/IAEA Division (see above); Ms. Bruna Teso, Biotechnology Unit, Science and Technology Policies Division, Organization for Economic Cooperation and Development (OECD) (see below); Dr. A. Aguilar Salinas, Medical Section, Occupational Safety and Health Branch, International Labour Office (see below); UNIDO/WHO Consultant: Dr. D.C. Ellwood, University of Durham, Industrial Research Laboratories, South Road, Durham DH1 3LE, United Kingdom.

Documents:
- Report of the first meeting of the Informal UNIDO/WHO/UNEP Working Group on Biotechnology Safety, UNIDO, ID/WG.463/3, 23 April 1986.
- Report of the second meeting of the Informal UNIDO/WHO/UNEP Working Group on Biotechnology Safety, WHO, Special Programme on Safety Measures in Microbiology, CDS/SMM/86.26.
- Safety Guidelines and Procedures for Bioscience-based Industry and other Applied Microbiology, ID/WG.463/1.
- Biosafety Guidelines for Manufacture of Vaccines and Biologicals, ID/WG. 63/2.
- Modern Biotechnology and the Possible Role of IPCS, report by the International Programme on Chemical Safety (WHO, ILO, UNEP).

Documents to be considered in developing the Minimal Guidelines:
- *Recombinant DNA Safety Considerations,* OECD, Paris, 1986.
- *Laboratory Biosafety Manual,* WHO, Geneva, 1983.
- Evaluating the Effects of Introducing Novel Organisms into the Environment, Sharples, Frances R., UNEP consultant (draft report, 1986).
- An International Approach to Biotechnology Safety, UNIDO/IS.627.

UNCTAD

United Nations Conference on Trade and Development

UNCTAD has taken an interest in biotechnology under its programme on transfer of technology. In 1984, it published a report on some economic, commercial and developmental aspects of new and emerging technologies. They include modern biotechnology with a main focus on recombinant DNA technology or genetic engineering. In the report, the characteristics of biotechnology, existing and potential applications and their impact are discussed as well as issues for consideration with respect to UNCTAD's work.

As UNCTAD is interested in the trade aspects of biotechnology, the report pointed out the commercial potentials of the technology, among other things, especially with respect to the Third World. Many industrialized countries already had national programmes on biotechnology, whereas only very few (Brazil, India) had a formal government policy.

The example of interferon was mentioned to demonstrate how promising biotechnology might be commercially. Recombinant DNA techniques could reduce the cost of producing a daily dose of interferon for the treatment of certain forms of cancer from US $150 (in 1984) to US $1.30. Biotechnology could have a great effect on any current industrial biological or chemical process, especially since the new processes are potentially safer, less energy-intensive and less polluting.

Potential applications in health care and medicine; agriculture; food-processing; energy resources; natural resources recovery; pollution control, and bio-electronics were discussed in the report.

The issues raised in the report are seen in the context of the overall impact of new technologies on Third World development. UNCTAD is concerned because (he rapid technical change brought about by a number of new technologies, mainly in the industrialized countries, is widening the technology gap between them and the Third World. This has far-reaching implications for production and trade in the Third World.

As part of its effort to improve the knowledge of the application of new technologies and to promote national and international discussions of sound policies in this field, UNCTAD concentrates on:

1. The impact of the technologies (and their transfer) on the export prospects of Third World countries.

2. The structure and characteristics of international markets for these technologies and their effect on the transfer of technology to Third World countries.

3. The factors affecting the ability of Third World countries to utilize and assimilate these technologies.

These areas of work were singled out because of their importance for the Third World and because they would complement other work pursued elsewhere in the United Nations system. UNCTAD's work was to range from research and policy analyses to the convening of expert meetings and seminars and the provision of advisory services to Third World efforts to develop strategies for technological transformation.

In its research on the impact of new and emerging technologies on trade and development, UNCTAD gave special emphasis to the impact on export perform-

ance and the possibilities available to Third World countries. One of the major concerns discussed in a 1986 review of the research findings is the so-called 'de-materialization'. In short, this means a diminution of the demand for raw materials in industrialized countries. However, UNCTAD has noted that several Third World countries have reacted to the adverse effects of technological substitutions of raw materials on their export receipts. They have set up their own programmes for the development of new end uses for their raw materials.

The work programme of UNCTAD's Committee on Transfer of Technology for the near future includes the continuation of research and monitoring work on the impact of new technologies on trade and development of Third World countries. In particular it will focus on how the new technologies have spread into the Third World, which economic sectors have been affected more than others and how exports and imports are affected. Case studies will be carried out. Previous impact analyses are to be deepened.

Contact address: UNCTAD, Palais des Nations, CH-1211 Geneva 10, Switzerland, Tel.: (022) 34 60 11, Telex: 289696, Cables: UNATIONS GENEVA.

Contact person: ***Mr.*** Y. Soubra, Technology Division.

Documents:
- Report of the fifth session of the UNCTAD Trade and Development Board, Committee on Transfer of Technology, Geneva, 22 October, 1984; item 6(c) of the provisional agenda: Economic, Commercial and Developmental Aspects of New and Emerging Technologies; TD/B/C.6/120, 2 August, 1984.
- Report of the sixth session of the UNCTAD Trade and Development Board, Committee on Transfer of Technology, Geneva, 27 October, 1986; item 4 of the provisional agenda: Impact of New and Emerging Technologies on Trade and Development, a review of the UNCTAD secretariat's research findings; TD/B/C.6/136, 14 August, 1986.

International Labour Office

ILO has an interest in workers' safety and occupational health and a general interest in the impact of new technologies on the health of the workers. It has done work on workers' exposure to biological agents in laboratories, hospitals and research units. In this field ILO works closely together with WHO and recommends the WHO Laboratory Biosafety Manual. It participates in studies on working conditions in laboratories. A study report on Employment and Conditions of Work in Health and Medical Services adopted by a meeting on the same topic in October 1985, covers quite generally the issue of safety and health of the workers concerned.

Within the Foundation on Occupational Safety and Health (FUNDACENTRO) in Sao Paulo, Brazil, the Latin American Centre on Occupational Safety, Health and Medicine (CLASED) has been established. It is concerned with safety programmes

relating to biotechnology. Information on this topic is collected and analysed to enable decisions on lLO's involvement.

ILO is involved in an International Occupational Safety and Health Hazard Alert System. It convened expert meetings in 1985 and 1986, one on Implications of New Technologies for Work Organization and Occupational Safety and Health in Industrialized Countries, and the other on Occupational Safety and Health and Working Conditions Specifications in Transfer of Technology to Developing Countries.

ILO has attended the second meeting of the Informal UNIDO/WHO/UNEP Working Group on Biotechnology Safety as an observer and has been invited to join the Group.

Contact address: International Labour Office (ILO), 4, chemin des Morillons, CH-1211 Geneva 22, Switzerland, Tel.: (022) 99 61 11, Telex: 22271, Cables: INTERLAB GENEVA.

Contact person: Dr. Aguilar Salinas, Medical Section, Occupational Safety and Health Branch.

United Nations Development Programme

UNDP is a technical assistance agency. It supports development projects through financial contributions, pre-investment and feasibility studies and the provision of expertise. The projects are carried out in cooperation with the respective governments, who make counterpart allocations. Often other UN organizations, such as UNIDO, WHO or UNESCO, are involved as executing agencies.

Among the UNDP assistance programmes are various projects involving biotechnology. For example UNDP has long been extending assistance to India in the field of scientific research including the development of bioscience and bioengineering.

The Indian bioscience and bioengineering project (started in 1981, estimated completion in 1987) was approved to assist the Government of India in carrying forward research in manufacturing processes of biotechnological products.

The immediate project objectives include the development of processes for cheap production of fuels and source material for nutritional and agricultural needs; the production of controlled-release pesticides and of penicillin for the control of pests and diseases; the strengthening of the facilities and the research work of the National Chemical Laboratory at Bangalore and the training of national scientists in research techniques in relevant areas.

In this particular project UNDP provides technical expertise, training in biosciences and high-technology equipment items. The National Chemical Laboratory provides qualified and professional staff, the building, equipment and administrational facilities. The executing agency for this project is UNIDO. The project costs are shared between UNDP and the Government of India.

UNDP currently assists in bioengineering projects in Brazil, Bulgaria, Cuba, India (see above), Pakistan, Paraguay and Turkey and in biomedical engineering projects in Cuba, Egypt, India, Morocco and Turkey. In addition, two regional bioengineering projects are in progress. Projects in Cameroon, Czechoslovakia, Guatemala, Peru and Turkey have already been completed. In these projects UNDP is or has been cooperating with UNIDO, UNESCO, WHO, FAO and IAEA, apart from the respective governments.

Contact addresses: UNDP Headquarters, 1 United Nations Plaza, New York, N Y 10017, USA, Tel.: (212) 754 + ext., Telex: 236286, Cables: UNDEVPRO NEW YORK; UNDP European Office, Palais des Nations, CH-1211 Geneva 10, Switzerland, Tel.: (022) 98 58 50, Telex: 289620, Cables: UNDEVPRO GENEVA.

Contact person: Ms. Ch. Vanastraceele, UNDP European Office.

WIPO

World Intellectual Property Organization

WIPO's involvement in biotechnology-related issues started with the instruction in late 1983 by the Assembly of the International Union for the Protection of Industrial Property (Paris Union) 'to study the existing situation concerning the protection, by patents or by other means, of inventions in the field of biotechnology (including "genetic engineering") and possible means of providing for industrial property protection for such inventions, both at the national and international level'. The Committee of Experts on Biotechnological Inventions and Industrial Property was formed and had its first session in Geneva, November, 1984.

Of particular interest for the WIPO study was a study by the International Union for the Protection of New Varieties of Plants (UPOV) on Biotechnology and Plant Variety Protection. The study deals with the question of the patentability of plant varieties—whether obtained by breeding or by genetic engineering methods—a question relevant to the WIPO study. A 1984 report by the OECD Committee for Scientific and Technological Policy on patent protection in biotechnology was also considered.

The following are the main areas of current legal protection of biotechnological inventions considered in the study, which was adopted by the Committee of Experts at its second session in February, 1986:

1. Protection at the national level:
- the distinction between inventions concerning products, processes and applications;
- the borderline between inventions and discoveries;
- whether biological methods can be covered by the existing concept of invention;
- possible exclusions from patentability of certain sectors of biotechnology (in some countries there are laws which exclude categories such as plant varieties,

animal breeds and essentially biological processes for the production of plants or animals);
- the applications of the conditions of patentability to biotechnological inventions (an invention has to be new, represent an inventive step, be industrially applicable, repeatable, and has to be fully disclosed in order to be patentable);
- the definition of the scope of protection.

2. Protection at the international level.
Various existing international treaties relating to the protection of biotechnological inventions were examined:
- the Paris Convention for the Protection of Industrial Property, which establishes basic principles for the international protection of inventions;
- the International Convention for the Protection of New Varieties of Plants, which contains detailed regulations for protection of new plant varieties;
- the Patent Cooperation Treaty, which deals with patent procedures and offers the possibility of filing international applications with effect, at the option of the applicant, in all or some of its contracting states;
- the Budapest Treaty for the International Recognition of the Deposit of Micro-organisms for the Purpose of Patent Procedure, which establishes a system of International Depositary Authorities which accept deposits of micro-organisms for the purpose of patent procedure. (The deposit of micro-organisms serves as a supplement or substitution for the full description of an invention.)

3. Possibilities for improvement.
According to WIPO, certain shortcomings in the existing system of industrial property emerged, many related to the diversity of national laws. Thus, the study report made suggestions for improvement, including the following:
- recognition of biotechnological inventions is not uniform in the countries investigated. It is, therefore, essential to reach agreement on the concept of invention, and its application in the area of biotechnology;
- a distinction is to be made between inventions concerning products, processes and applications;
- it should be recognized that plants, animals and micro-organisms could be inventions. However, the invention must explain how to achieve a certain result, for example by a specific method of isolation;
- the exclusion from patentability of plant varieties, animal breeds and essentially biological processes for the production of plants or animals is no longer justified. All biotechnological inventions should be eligible for patent protection and patents should be granted provided the normal requirements of patentability are fulfilled. Only the inability to sufficiently describe an invention should be reason for not granting a patent;
- in principle, the availability of patent protection and the availability of special plant variety protection should not be mutually exclusive. Nevertheless, it might be worth studying whether or not there are reasons to limit the choice of the inventors so that they could not obtain double protection;

- when the description of a biotechnological invention is not possible, the deposit system, especially with respect to micro-organisms, should be applied as far as possible. If the deposit system is not applicable, the granting of a patent depends on a description by words and symbols, possibly supplemented by drawings, which will automatically limit patent protection in the field of biotechnology. It is compensated for by the special system of protection of plant varieties;
- countries which have not recognized the possibility of deposit should do so and should become party to the Budapest Treaty (see above);
- biological material such as plasmids, cell lines, enzymes, seeds, etc. should also become accepted for deposit and the Budapest Treaty should be amended accordingly;
- as certain divergencies regarding the conditions for the release of samples exist, the matter should be reserved for further study;
- the special system of protection for plant varieties could possibly be further developed. In particular, the possibility of an exclusive right which would not only cover the propagating material but also the plant as such could be examined. This should be pursued within the framework of UPOV;
- although it does not yet seem necessary, the question of whether a special system of protection for animal breeds is needed should be reserved for further study, taking into account future developments in animal breeding and economic developments.

Contact address: World Intellectual Property Organization (WIPO), 34, chemin des Colombettes, CH-1211 Geneva 20, Switzerland, Tel.: (022) 99 9111, Telex: 22376, Cables: OMPI GENEVA.

Contact persons: Mr. F. Balleys, Head, Industrial Property Law Section, Industrial Property Division, Mr. Ilardi, Senior Legal Officer, Industrial Property Law Section, Industrial Property Division.

Documents:

- Industrial Property Protection of Biotechnological Inventions, WIPO/Paris Union Committee of Experts on Biotechnological Inventions and Industrial Property, First Session, Geneva, 5-9 Nov., 1984; BIOT/CE/I/2, 31 August, 1984.
- Biotechnological Inventions and Industrial Property. Report adopted by the WIPO/Pans Union Committee of Experts (First Session), Geneva, 5-9 November, 1984; BIOT/CE/I/3. 9 November, 1984.
- Industrial Property Protection of Biotechnological Inventions, Analysis of Certain Basic Issues, prepared by Dr. Joseph Straus, Max-Planck-Institute, FRG; WIPO, BIG/281, July, 1985.
- Industrial Property Protection of Biotechnological Inventions, report prepared by the International Bureau, WIPO/Paris Union Committee of Experts on Biotechnological Inventions and Industrial Property, (Second Session), Geneva, 3-7 February, 1986; BIOT/CE/II/2, 5 November, 1985.
- Decision of the Board of Patent Appeals and Interferences of the USA, document submitted by the International Bureau, WIPO/Paris Union Committee of

Experts on Biotechnological Inventions and Industrial Property, (Second Session), Geneva, 3-7 February, 1986; BIOT/CE/II/INF/2, 3 February, 1986,
- Biotechnological Inventions and Industrial Property, report adopted by the WIPO/Paris Union Committee of Experts, (Second Session), Geneva, 3-7 February, 1986 BIOT/CE/II/3, 7 February, 1986.

UN Educational, Scientific and Cultural Organization
Like other UN agencies, UNESCO has focused on aspects of biotechnology relevant to Third World countries especially in economic terms. Dissemination of information on present and potential applications has been one of the first steps.

UNESCO is interested in the formulation of policies and the development and strengthening of infrastructure in the field of biotechnology and genetic engineering. It has emphasized the need for elaborating national policies for research in biotechnology and its application. It has embarked on activities for strengthening the existing microbiological research centres in a number of Third World countries through research grants and the formulation of joint research programmes in areas like biological nitrogen fixation, fermentation technology and rural development.

Together with UNEP and the Economic Commission for Europe (ECE), UNESCO has been involved in work on the use of microbial technologies to overcome environmental problems. In cooperation with UNEP, UNESCO has been extending support to the activities of national and regional professional associations in this field. Training for research workers and technicians in some areas of applied microbiology and biotechnology is another major activity. UNESCO also promotes cooperation among Third World countries in this field.

Contact address: UNESCO, 7, place de Fontenoy, F-75700 Paris, France, Tel.: (1) 577 16 10, Telex: 204461, Cables: UNESCO PARIS.

UN Centre for Science and Technology for Development
UNCSTD cooperated with other UN agencies to set up the Advanced Technology Alert System (ATAS) in 1984. Its objectives are technology assessment and forecasting with particular consideration for Third World countries. While other UN bodies concentrate on information dissemination and technology transfer, ATAS addresses the implications for society. Biotechnology was one of the first fields considered by ATAS. The first issue of the semi-annual ATAS Bulletin dealt with tissue culture technology and development.

Phase I of the ATAS project was a pilot project to gain experience and insight into 'an international mechanism designed to benefit developing countries by assessing the implications of new and emerging technologies on development'.

Phase II, from March 1987 to February 1989, is dedicated to the development of the ATAS Network. Institutions and individual experts involved in development planning, technology assessment and forecasting as well as in the application of specific new technologies in a development context will participate. The Network will focus on interdisciplinary cooperation, exchange of information and experiences, the production of relevant data, expansion of resources and expertise and identification of common information requirements.

Work teams will concentrate on specific themes, such as the Impact of Biotechnology (Tissue Culture). They are designed to produce policy analyses and options, trend forecasts, case studies, criteria for technology choice, data on assessment methodologies, a referral system on organizations and individual experts, etc.

An evaluation will be carried out by the ATAS Advisory Board during the last six months of the project. It will be the basis for an ongoing consultative mechanism of ATAS (Phase III).

The Economic Commission for Africa (ECA) is currently in the process of initiating a regional ATAS-Africa mechanism, particularly in the area of tissue culture.

Contact address: UNCSTD, 1 United Nations Plaza, New York, N Y 10017, USA, Tel.: (212) 754 + ext.. Telex: 232422, Cables: UNATIONS NEW YORK.

Contact persons: Mr. Dieter Koenig (in charge of ATAS Network), Mr. Peter Mwanza, Economic Commission for Africa (ECA), ATAS-Africa, Addis Ababa, Ethiopia.

Publications:
- Tissue Culture Technology and Development, *ATAS Bulletin I,* UNCSTD, New York, November, 1984.
- The ATAS Network: Transforming objectives into services, Project Description, prepared by ATAS, UNCSTD, New York, August, 1986.

UNCTC *UN Centre on Transnational Corporations*

UNCTC has been engaged for some time in a study of transnational corporations (TNCs) active in biotechnology. A publication entitled *Transnational Activities in Biotechnology* is being prepared. In the meantime, a summary of the relevant work has been included in a document on Ongoing and Future Research prepared for the next session of the Commission on Transnational Corporations.

Contact address: UNCTC, United Nations, New York, N Y 10017, USA, Telex: UNCTNC 661062, Cables: UNATIONS NEWYORK.

United Nations University

UNU has undertaken work in biotechnology with the ultimate aim 'to help developing nations apply new science to their traditional knowledge, thereby creating a self-reliant capability in this field'. Various programmes are meant to serve this aim:

1. Building of networks of cooperating institutions worldwide as a catalyst for international scientific cooperation and information exchange. Third World scientists are to gain access to new techniques applicable to practical local problems. UNU supports the networks through research grants, training fellowships for Third World scientists and assistance towards international meetings and the dissemination of research results.

2. Studies of nitrogen fixation in the root system of rice to enhance the natural ability of the micro-organisms involved. A network of cooperating research stations in 16 countries is involved. A relevant workshop was held jointly with the International Rice Research Institute in the Philippines in May, 1984.

3. Research on vaccines for the tropical livestock disease brucellosis. The research capacity gained in the programme is later to be applied to the production of other vaccines. Institutes in Argentina, Canada, Chile, Columbia, Ecuador, Peru, UK, USA and Venezuela are participating in the project.

4. Research in the promising field of upgrading traditional fermented foods with modern biotechnology. Applied in small-scale and home industries this could contribute to raising employment and income levels and to improving the quality of food. Researchers and staff are being trained. In October, 1985, a workshop on traditional and fermented foods in Africa was held in Cameroon.

5. Improving edible fungi for food and fodder. Various fungi can be grown on plant lignocellulose (mostly wood) and agricultural waste, which are abundant renewable natural resources. Their protein content is comparable to that of meat.

6. Biotechnology programme in Latin America. This is to concentrate on productive, sustainable and affordable agriculture, prevention, detection and treatment of diseases and the conversion of biomass resources into food, energy and chemicals. The government of Venezuela has invited UNU to establish a Research and Training Programme for Biotechnology for the Andean and Caribbean region.

7. Communication for research networks. UNU encourages computer conferencing in the area of biotechnology to enhance information exchange. UNU has issued recommendations and guidelines on the potential of computer conferencing and is cooperating with IDRC in this area.

8. Implications for policy makers. UNU is also concerned with educational, social, legal and ethical implications of modern biotechnology. Therefore UNU projects include a component 'to help policy-makers implement biotechnology in countries

that possess widely disparate levels of industrialization, education and availability of biomass'. UNU assists policy-makers to ensure that the new technologies are socially and ethically acceptable.

Contact address: United Nations University (UNU), Toho Seimei Building 15-1, Shibuya, 2-chome Shibuya-ku, Tokyo 150, Japan, Tel.: (03) 499 28 11, Telex: 25442, Cables: UNATUNIV TOKYO.

Contact person: Mr. Robert Kokke, Senior Programme Officer, Development Studies Division.

Publications:
- 'Biotechnology for Development: UNU Activities in Biotechnology', *UNU Focus 1,* October, 1985.
- 'Bioconversion of Organic Residues for Rural Communities', *Food and Nutrition Bulletin,* Supplement 2.
- *Handbook of Indigenous Fermented Foods,* Steinkraus Keith H. (ed.).
- 'The Use of Organic Residues in Rural Communities', Shacklady Cyril A. (ed.), *Food and Nutrition Bulletin,* Supplement 7.

ECE

Economic Commission for Europe

ECE has also taken an interest in the economic relevance of biotechnology for the Third World and in the development of policies and infrastructure. ECE has examined national research and development policies and approaches to biotechnology as well as mechanisms for implementing these policies in its member states. As already mentioned, it has cooperated with UNESCO and UNEP in the area of microbial technologies to overcome environmental problems.

Contact address: United Nations Economic Commission for Europe, Palais des Nations, CH-1211 Geneva 10, Switzerland, Tel.: (022) 34 60 11, Telex: 289696, Cables: UNATIONS GENEVA.

OECD

Organization for Economic Cooperation and Development

The OECD has carried out a study on biotechnology safety issues, 'Recombinant DNA Safety Considerations', Paris, 1986. The study considers the risks and benefits of industrial and environmental applications of recombinant DNA technology. It sets forth scientific considerations for evaluating the risks of genetically manipulated organisms. These are not regulatory standards, but rather guiding principles. The study was approved by the OECD Committee for Scientific and Technology Policy in February, 1986.

With respect to environmental applications, the OECD working group on the study decided that it was too early to develop guidelines. With industrial applications it came to the conclusion that most organisms would require only minimum contain-

ment. The OECD working group recommended that OECD continue to watch recombinant DNA technology and that industry use low risk organisms as much as possible.

The study report constitutes only a first step in the direction of international safety guidelines (see Informal UNIDO/WHO/UNEP Working Group). OECD plans to continue to work in this field.

Contact address: OECD, 2, Rue André Pascal, F-75775 Paris Cedex 16, France.

Contact person: Ms. Bruna Teso, Biotechnology Unit, Science and Technology Policies Division.

Publication: 'Recombinant DNA Safety Considerations', OECD, Paris, 1986.

Networks Represented at the Bogève Workshop

The participants in the Bogève Workshop had quite different backgrounds. While actively engaged in one or more major third system networks, they did not represent them at Bogève. But since the knowledge and experience gathered by these networks formed such an important part of the proceedings, short descriptions of some of the leading ones seem proper.

- *Health Action International (HAI).* HAI is an informal international network of non-governmental organizations (NGOs) and individuals committed to strive for 'Health for All'. It was founded in Geneva, Switzerland, in 1981, in order to form an effective 'Antibody' against the notorious malpractices of the pharmaceutical industry, especially in the Third World. HAI took up issues like drug dumping, industry's double standards for drug marketing in the North and in the South, and aggressive sales and promotion practices by the drug industry. HAI has since successfully led several campaigns to get dangerous drugs off the market. When in 1982 Bangladesh revolutionized its drug policy by rationalizing its drug market and focusing on essential drugs, HAI led a worldwide campaign in support of this exemplary measure. Consequently HAI broadened the scope of its work to further the rational, economic and safe use of pharmaceuticals throughout the world, but especially in poor countries. HAI advocates the recommendations of WHO's 1978 Alma-Ata Conference on Primary Health Care and the full implementation of WHO's Action Programme on Essential Drugs and Vaccines. HAI also promotes non-drug solutions to problems created by impure water and poor sanitation and nutrition. At the same time HAI keeps a close watch on the machinations of the pharmaceutical industry.

  HAI operates a clearing-house for information and data related to the above issues, which is based at the Regional Office for Asia and the Pacific of the International Organization of Consumers Unions (IOCU) in Penang, Malaysia. The HAI clearing-house publishes a bi-monthly newsletter—*HAI News*—which is HAI's organ presenting the happenings in the international campaign for more rational and fairer health policies as well as material supportive of the participants' work.

  Contact address: HAI Clearing-House, IOCU Regional Office, P.O. Box 1045, 10830 Penang, Malaysia, Tel.: (04) 20391, Telex: MA 40164 APIOCU.

- *International Baby Food Action Network (IBFAN).* The International Baby Food Action Network (IBFAN) is a coalition of voluntary organizations in both Third World and industrialized nations, working for better child health and nutrition through the promotion of breast-feeding and the elimination of irresponsible marketing of artificial infant foods.

  IBFAN was launched in October 1979 and now counts over 100 groups in 64 countries around the world. The network helped to develop the WHO International Code of Marketing of Breast-milk Substitutes and is committed to see marketing practices everywhere change accordingly. IBFAN has successfully used boycotts and adverse publicity to press companies into more ethical behaviour. Recently, IBFAN has found it necessary to reopen its boycott of Nestlés

due to the company's transgression related to the WHO code. It also helps to promote and support breast-feeding in other ways.

- *Code Documentation Centre (CDC).* The International Baby Food Action Network is committed to the implementation of the International Code of Marketing of Breast-milk Substitutes. It has assigned the IBFAN Service Centre in Penang to keep track of code implementation measures worldwide. To this end, the Code Documentation Centre (CDC) was set up.

  CDC collects and compiles national legislation, both in draft and final form. It also gathers codes (voluntary or binding, regional, national, or industry-wide). CDC, furthermore, analyses, compares, and evaluates the different measures, using the international code as a yardstick. CDC also offers skills training in code analysis and in effective monitoring of marketing practices.

- *Pesticide Action Network (PAN).* PAN is an international coalition of citizens groups and individuals opposed to the overuse and misuse of pesticides. Launched in 1982 in Penang, Malaysia, PAN unites over 300 organizations in some 50 countries. It aims to raise public awareness about pesticide abuse by campaigning against particularly toxic pesticides as well as unethical corporate marketing practices and seeks to promote alternatives to pesticides and sustainable agriculture. PAN lobbies national governments and international agencies to develop and implement effective policies on the manufacture, distribution and use of pesticides. It was actively involved in developing the International Code of Conduct on the Distribution and Use of Pesticides, which was adopted unanimously at the 1985 Conference of FAO (The FAO Code), and is playing a major role in monitoring its implementation.

  Since the adoption of the Code, PAN participants have collected information on industry's adherence to the Code and compiled it in a report for the participants of the 1987 Conference of FAO. It draws attention to the disturbing fact that, although the pesticide industry almost universally claimed their adoption of the FAO Code, their practices do not in any way resemble this policy.

  Contact addresses of the regional coordinating centres: Africa (English-speaking), Environment Liaison Centre International (ELCI), P.O. Box 72461, Nairobi, Kenya; Africa (French-speaking), ENDA/PRONAT, B.P. 3370, Dakar, Senegal; Asia, Organization of Consumers Unions (IOCU), P.O. Box 1045, Penang, Malaysia; PAN-Europe, 22, rue des Bollandistes, 1040 Brussels, Belgium; Latin America, Fundación Natura, Casilla 243, Quito, Ecuador; North America, Pesticide Education and Action Project (PEAP), P.O. Box 610, San Francisco, CA 94101, USA.

- *Seeds Action Network (SAN).* SAN, launched in 1985, arose from the work of both RAFI (Rural Advancement Fund International) and ICDA (International Coalition for Development Action) and is active on the 'seeds' issue all over the world. Through a decentralized, regionally-divided structure, SAN works to

facilitate communication and information exchange, as well as direct action, at multiple levels. Particular areas of emphasis include the patenting of plant varieties and other life forms, corporate concentration in the genetics supply industry, the conservation of genetic diversity and the movement of these issues at FAO in Rome and at WIPO and UPOV in Geneva. Most recently, SAN has devoted considerable time and attention to the issues related to agricultural biotechnology.

For more information, contact: ATU, Zamzam St., P.O. Box 495, Dokki Gizi, Egypt; SAN-Asia, SAM, 37 Birch Lane, 10250 Penang, Malaysia; RFSTNRP, 105 Rajpur Rd., Dehra Dun 248 001, India; SEARICE, c/o SIBAT, P.O. Box 375, Manila, The Philippines; SAN-Europe, Australia, New Zealand: ICDA Seeds Campaign, Apartado 23398, E-08080 Barcelona, Spain; SAN-Latin America: (not yet finalized) c/o RAFI-Brazil, Rua Tenente Manoel Alves dos Anjos 580, Sala 16, Centro Mogi das Cruzes, São Paulo, Brazil CEP 08730, Telex: 1154401 XIXA BR; SAN-North America: RAFI, P.O. Box 1029, Pittsboro, NC 27312, USA.

Rural Advancement Fund International—RAFI

As a small, non-profit NGO, RAFI focuses on the Socioeconomic impact of new technologies on rural societies. Although it undertakes extensive research into the science and corporations powering new technologies, RAFI emphasizes practical action at both the international political level (largely through the United Nations) and through grassroots organizing with those who will be most affected by technological change.

For several years, RAFI staff have led international NGO efforts to conserve and utilize plant genetic resources through FAO and at the community level. RAFI played a major role in stimulating the creation of the FAO Commission on Plant Genetic Resources, the FAO Undertaking on Plant Genetic Resources and the International Fund for Plant Genetic Resources. At the same time, however, RAFI has organized—with Third World partners—regional workshops for Africa, Asia and Latin America and numerous national and sub-regional workshops addressing both the global political concerns and the need for local farmers to secure their own crop genetic diversity.

An increasing and important part of RAFI's work has been to cooperate with Third World partners to find both the information and financial support they need to conserve their own genetic diversity.

Since 1984, RAFI has increasingly directed its attention to the new biotechnologies and their potential impact on rural societies. RAFI's communiques, analysing the consequences for specific crops and their producers, have attracted global attention. Currently, and in conjunction with other participants at Bogève who form JACOB (Joint Action Committee on Biotechnology), RAFI is developing a study/action programme dealing with the impact of biotechnology on agricultural inputs and the hopes for sustainable agriculture; food processing with special attention to tropical exports; basic community health and the new role of medicinal plants; and, finally, the threat of biological warfare. In each case, the programme calls for interregional South-South and South-North analysis leading to proposals for practical action by those most likely to be positively or negatively affected. Additional research has begun on the impact of the greenhouse effect on the Third World and the related role of new biotechnologies.

RAFI staff also organize and participate in short seminar programmes for Third World governments and NGOs on biotechnology and biological diversity.

Board of Directors: *Sven Hamrell,* Chairperson, Director, Dag Hammarskjöld Foundation, Uppsala, Sweden; *Tim Brodhead,* Treasurer, Executive-Director, Canadian Council for International Cooperation, Ottawa, Canada; *Daniel Pollitt,* Secretary of Law, University of North Carolina/Chapel Hill, USA; *Erna Bennett,* Plant Geneticist, Rome, Italy; *Anwar Fazal,* Past President, International Organization of Consumers Unions, Penang, Malaysia; *Sue Thrasher,* The Highlander Center, New Market, USA; *A.H. VandenBosche,* National Council of Churches,

Atlanta, USA; *Melaku Worede,* Director, Plant Genetic Resources Centre, Addis Ababa, Ethiopia; and *Camila Montecinos,* CET, Santiago, Chile.

RAFI Offices: For Africa and Europe—*Eva Lachkovics* and *Harald Wosihnoj,* RAFI/IIZ (Austria), Wipplingerstrasse 32, A-1010 Vienna, Austria, Tel: 43 222 53 347 86, Telex: A-116629 IIZ.

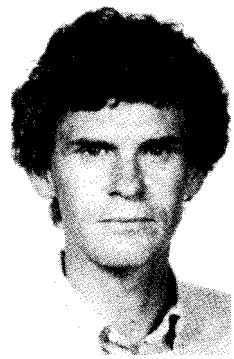
For North America— *Cary Fowler* and *Hope Shand,* RAFI (USA), P.O. Box 1029, Pittsboro, North Carolina 27312, USA, Tel: (919) 542-5292.

For Latin America—*Silvio Martens* and *Jose Roberto Manus de Deus,* RAFI/Grupo Mel, rue Prof. Flaviano de Mello 941, Mogi das Cruzes, Sao Paulo, Brazil CEP 08730, Tel: 55-11-469-6691 (or) 469-9402, Telex: 1154401 XIXA BR.

For Asia and general—*Pat Mooney,* RAFI, RR 1 (Beresford), Brandon, Manitoba R7A 5Y1, Canada, Tel: (204) 483-3955, Telex: (via New York, USA) 961 000-SRP3829.

Notes on the Authors

Cary Fowler has been a staff member of the Rural Advancement Fund/National Sharecroppers Fund in Pittsboro, North Carolina, since 1978. He studied at Simon Fraser University in Vancouver, Canada, and at Uppsala University in Sweden and is the author and editor of numerous publications on the world food crisis and on the erosion of the world's genetic resources. He has lectured on these subjects at many universities and given TV, newspaper, radio and film interviews around the world. In 1985 he received, together with Pat Mooney, the Right Livelihood Award, popularly known as the Alternative Nobel Prize. Together with Pat Mooney he has also written a new book, *Shattering: The Diversity of Life in the Age of Biotechnology,* to be published by the University of Arizona Press in 1989.



Eva Lachkovics has been with the Rural Advancement Fund International (RAFI) since 1986, working out of Vienna in her native Austria. She studied chemistry at the Technical University in Vienna and biochemistry at the University of Vienna. From 1982 to 1986, she served as Research Officer in the Pharmaceutical Programme of the International Organization of Consumers Unions (IOCU), Regional Office for Asia and the Pacific, Penang, Malaysia, seconded and sponsored by the Austrian Institute for International Cooperation (IIZ) in Vienna. In 1986 and 1987, she undertook, with the support of IIZ, two surveys of Asian and African non-governmental organizations working on the seeds issue in preparation for two regional workshops on genetic resources organized by RAFI in Indonesia and Ethiopia.

Pat Mooney, a member of the staff of the Rural Advancement Fund International (RAFI), has spent most of his life on the Canadian prairies and in agricultural development work in Asia, Africa and Latin America. In the mid-seventies he became increasingly concerned about the loss of agricultural genetic resources and in 1979 he published a report on the subject, *Seeds of the Earth.* This was followed in 1983 by his study *The Law of the Seed: Another Development and Plant Genetic Resources,* which attracted world-wide attention when it appeared as a special issue of *Development Dialogue* (1983:1—2). In 1985, Pat Mooney received, together with Cary Fowler, the Right Livelihood Award, popularly known as the Alternative Nobel Prize. Together with Cary Fowler, he has also written a new book, *Shattering: The Diversity of Life in the Age of Biotechnology,* to be published by the University of Arizona Press in 1989.

Hope Shand has worked with the Rural Advancement Fund/National Sharecroppers Fund since 1980. She grew up in Texas and is a graduate of Duke University, North Carolina, with a degree in comparative area studies, focusing on Latin America. Prior to joining RAF, Hope Shand's research concentrated on US agricultural policy, and problems of small farmers. She is editor of *RAFI Communique* and author of various articles on the Socioeconomic impact of agricultural biotechnology. She lives on a small fruit and vegetable farm in Chatham County, near RAFI's Pittsboro office.