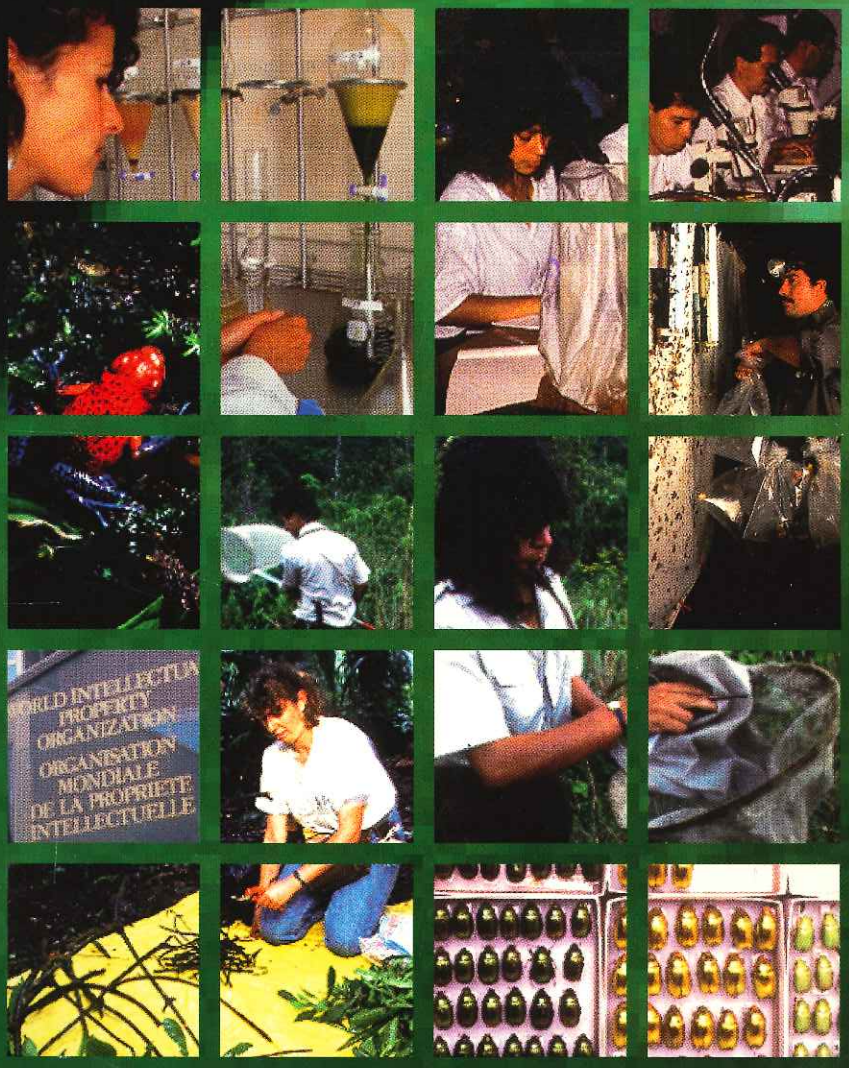


# BIODIVERSITY PROSPECTING

A World Resources Institute Book

# BIODIVERSITY PROSPECTING:

## Using Genetic Resources for Sustainable Development

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# FOREWORD

More than half the world's plant and animal species live in one tropical forest or another—and nowhere else on Earth. Coral reefs and other coastal ecosystems add hundreds of thousands, if not millions, more species to the thin and variegated film of life that covers the globe. As the search for wild species whose genes can yield new medicines and better crops gathers speed, these rich habitats also sport more and more specimens of a relatively new breed—the biodiversity prospector. Like the nineteenth-century California gold rush or its present-day counterpart in Brazil, this "gene rush" could wreak havoc on ecosystems and the people living in or near them. Done right, though, bioprospecting can bolster both economic and conservation goals while underpinning the medical and agricultural advances needed to combat disease and sustain growing human numbers.

What "doing right" means in this context is the central question of *Biodiversity Prospecting*, by WRI Vice President Walter V. Reid and seven of his colleagues, here at WRI and elsewhere. The need for answers is urgent since all the major pharmaceutical firms are already hard at work screening the genetic storehouses found in Brazil, Costa Rica, China, Micronesia, and other biologically diverse countries. Arguing that the very great potential benefits from such ventures may be overwhelmed by the actual harm they cause, the authors describe the kinds of organizations, contracts, and laws needed to ensure that both human communities and their natural surroundings benefit from the bioprospecting boom.

Although many institutions around the world are pioneering this new field, the report focuses on Costa Rica's National Biodiversity Institute (INBio) because its arrangement with Merck & Co., Ltd.—the world's largest pharmaceutical firm—represents

new ways to promote conservation, as well as manage information and inventory. Indeed, INBio's stated aim is conserving biodiversity, not exploring its commercial potential, which it views as merely one way to finance conservation. The authors do not view the INBio-Merck arrangement as a model that other would-be contractors should follow, but as a promising pilot project that offers lessons vital to the success of bioprospecting ventures elsewhere.

At the Earth Summit last year, the United States refused to sign the biodiversity convention joined by more than 150 nations, claiming that agreements like that between Merck and INBio would obviate the need for an international treaty. The authors of *Biodiversity Prospecting* take the opposite view, asserting that contracts entered into by one or another gene-rich country will be feasible and effective only in the context of international agreements that settle such questions as who owns biodiversity, how access to it can be controlled, and how intellectual property rights and profits can be equitably divided between local communities and prospecting corporations. As this book goes to press, President Clinton has just reversed the U.S. position and promised to sign the biodiversity convention, so there is reason to hope that the United States will play a constructive role in resolving all these issues.

Since wealth and technology are as concentrated in the North as biodiversity and poverty are in the South, the question of equity is particularly hard to answer in ways that satisfy everyone with a stake in the outcome. The interests of bioprospecting corporations are not the same as those of people who live in a biodiversity "hot spot," many of them barely eking out a living. The authors describe ways that hard-pressed rural communities can benefit from bioprospecting in their vicinity—for instance, through the training and jobs provided by INBio's parataxonomist program. They also stress that people have a right to regulate and charge for access to the biodiversity that surrounds them and to be compensated for their intellectual contributions to the discovery and development of new products. Unfortunately, as the authors note, experience has taught that these rights mean little in practice unless they are clearly defined and strongly defended by local and national governments. Since such clarity and support are often absent, the authors recommend that corporations and governments in the industrial world assume more responsibility for ensuring that bioprospecting

is done legally and with the informed consent of the communities involved.

The contract between Merck and INBio is a private contract and not open to public inspection. *Biodiversity Prospecting* includes a draft contract that can help pharmaceutical companies and collecting organizations negotiate agreements. The draft contract, as the authors note, is not a universally applicable model, however, and is not intended for wholesale adoption. Rather, it is an educational tool intended to enable collectors and institutions in developing countries to enter negotiations with large corporations and their representatives with some knowledge of the issues and potential solutions.

Altogether, the essays in *Biodiversity Prospecting* explore many different strands of thought and theory that come together in this relatively new industry, elaborating on issues only touched on in other publications. Its recommendations extend those laid out in the *Global Biodiversity Strategy* and in such WRI reports as *Conserving the World's Biological Diversity, Keeping Options Alive: The Scientific Basis for the Conservation of Biodiversity,* and *Trees of Life: Saving Tropical Forests and Their Biological Wealth.*

We would like to thank the Dutch Ministry of Foreign Affairs, the Norwegian Royal Ministry of Foreign Affairs, the Swedish International Development Authority, the United Nations Development Programme, the Canadian International Development Agency, The Surdna Foundation, the Sasakawa Peace Foundation, and the W. Alton Jones Foundation for their generous support of WRI's general research on biodiversity conservation issues. For their foresight and support, we are deeply grateful.

Jonathan Lash
*President*
World Resources Institute

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*W.R.*
*S.L.*
*C.M.*
*R.G.*
*A.S.*
*D.J.*
*M.G.*
*C.J.*

# I.

# A NEW LEASE ON LIFE

*Walter V. Reid, Sarah A. Laird, Rodrigo Gámez, Ana Sittenfeld, Daniel H. Janzen, Michael A. Gollin, and Calestous Juma*

In September 1991, Costa Rica's National Biodiversity Institute (INBio)—a private, non-profit organization—and the U.S.-based pharmaceutical firm Merck & Co., Ltd., announced an agreement under which INBio would provide Merck with chemical extracts from wild plants, insects, and micro-organisms from Costa Rica's conserved wildlands for Merck's drug-screening program in return for a two-year research and sampling budget of $1,135,000 and royalties on any resulting commercial products. INBio agreed to contribute 10 percent of the budget and 50 percent of any royalties to the government's National Park Fund for the conservation of national parks in Costa Rica, and Merck agreed to provide technical assistance and training to help establish drug research capacity in Costa Rica (Aldhous, 1991).

This agreement represents a watershed in the history of "biodiversity prospecting"—the exploration of biodiversity for commercially valuable genetic and biochemical resources. (*See* Eisner 1989, 1992.) For decades, ecologists and environmentalists have been arguing that pharmaceutical and other commercial applications of biodiversity should help justify its conservation. However, industry investment in natural products research since the mid-1960s has been small, and it actually declined in the pharmaceutical industry during the 1960s and 1970s. Clearly, the INBio-Merck agreement demonstrates a shift in industry focus and the true economic potential of these resources.

This ground-breaking agreement also shows how companies can return a portion of the benefits of pharmaceutical development to the developing country where the chemical compounds originated. Further, it ensures that some of these proceeds will directly finance conservation while the remainder will indirectly finance conservation through biodiversity research and development in association with the national parks. Coming as it did during the final negotiations of the International Convention on Biological Diversity, the Merck-INBio agreement validated what was becoming—after heated debate—an underlying tenet of the convention: the fair and equitable distribution of the benefits of the use of genetic resources among *all* those who invest in their continued existence.

Although its close link to conservation efforts has earned it exceptional attention, the Merck-INBio agreement is just one of a rapidly growing number of biodiversity prospecting ventures. For example, Japan has launched a major biodiversity research program in Micronesia, the U.S. National Institutes of Health is screening wild species for compounds active against HIV and cancer, and both Indonesia and Kenya are establishing inventory programs similar to INBio's, and are exploring possible biodiversity prospecting activities.

This flurry of interest and enthusiasm in biodiversity prospecting is taking place in a policy vacuum. Virtually no precedent exists for national policies and legislation to govern and regulate wildland biodiversity prospecting. Yet, the more than 150 countries that signed the International Convention on Biological Diversity in 1992 now must pass implementing legislation that establishes just such a policy framework.

The stakes are high as countries begin to fill this policy vacuum. Done well, biodiversity prospecting can contribute greatly to environmentally sound development and return benefits to the custodians of genetic resources—the national public at large, the staff of conservation units, the farmers, the forest dwellers, and the indigenous people who maintain or tolerate the resources involved. But carried out in the mold of previous resource-exploitation ventures, biodiversity prospecting can have a negligible or

potentially harmful effect on biodiversity conservation and environmentally sound development.

This report offers suggestions to governments, non-governmental organizations, scientists, and industry on designing effective and equitable biodiversity prospecting programs, with a particular focus on the use of biodiversity in the pharmaceutical industry. The premise of *Biodiversity Prospecting* is that appropriate policies and institutions are needed to ensure that the commercial value obtained from genetic and biochemical resources is a positive force for development and conservation.

The value of biodiversity as a raw material for pharmaceutical and biotechnology industries is only a portion of its value to society. It makes good economic sense—and often meets ethical norms—for countries and communities to conserve biodiversity whether or not they become biodiversity prospectors. Indeed, it is entirely possible—and sometimes highly appropriate—for nations to invest in biodiversity conservation without ever seeking to commercialize genetic and biochemical resources. The normative question of whether or not countries should commercialize genetic and biochemical resources is not addressed here, but the urgent need to ensure that the commercialization already under way supports conservation and development is. In particular, three problems must be overcome if biodiversity prospecting is to contribute to national sustainable development and the long-term survival of wildland biodiversity.

First, growing commercial interest in biodiversity will not necessarily fuel increased investment in resource conservation. Genetic and biochemical resources are often described by economists as "non-rival public goods." In other words, their use by one individual does not reduce their value to others who use them. Because any user benefits from investments in their conservation, market forces will lead to less conservation of the resource than its value to society warrants.[1] In fact, unregulated biodiversity prospecting and drug development could speed the destruction of the resource. In one particularly egregious example, the entire adult population of *Maytenus buchananni*—source of the anticancer

compound maytansine—was harvested when a mission sponsored by the U.S. National Cancer Institute collected 27,215 kg in Kenya for testing in its drug development program (Oldfield, 1984).

Second, there is no guarantee that the institutions created to capture the benefits of biodiversity will contribute to economic growth in developing countries. Quite the opposite has been the case historically. The chief commercial beneficiaries of genetic and biochemical resources found in developing countries have been the developed countries able to explore for valuable resources, develop new technologies based on the resources, and commercialize the products. The Convention on Biological Diversity provides a framework that may boost developing countries' negotiating strength and foster needed investments in conservation, but it will be up to individual nations to pass the laws and establish the regulations needed to achieve these benefits. From a conservation standpoint, unless developing countries *do* realize benefits from these resources, summoning the political will to conserve them will be difficult.

Finally, biodiversity prospecting is just one of many forms of biodiversity development that could take place in the countryside to help raise living standards there. In most countries, the people living side by side with wildland biodiversity—farmers and villagers, indigenous peoples, forest dwellers, medicinal healers, and fisherfolk—hold the key to its survival. If local and national citizens do not get something out of maintaining wildland habitats, the habitats will be converted to timber plantations, farms, or other productive uses harmful to biodiversity. Yet, in many cases sustainably managed wildlands won't yield enough direct economic benefits to support large local populations, so governments will have to ensure that a share of the national benefits from activities such as biodiversity prospecting are used to meet rural development needs. How well biodiversity prospecting institutions contribute to sustainable development thus ultimately depends on how effective local and national government policies for conservation and development are.

Many institutions involved in biodiversity prospecting are described in this report, but most attention is given to INBio because

of the world-wide interest it has generated and the demand for detailed information on its structure, objectives, and operations. INBio is a product of Costa Rica's biological, political, and social environment. And Costa Rica, with its high percentage of conserved wildland, highly educated population, relatively small indigenous population, small size, and considerable scientific capacity is a friendly climate in which to attempt innovative structures for biodiversity management. The processes that are being fostered at INBio as a pilot project are, however, relevant throughout the tropics. No doubt, the biodiversity management needs in other countries will require unique solutions, but useful guidance can be obtained from the experiences of INBio and other institutions discussed here.

This report is aimed at two overlapping audiences—one interested primarily in the general policy issues related to biodiversity prospecting and another in specific guidance on the design of organizations, legislation, and contracts for biodiversity prospecting. This chapter—oriented to the first audience—introduces the issues related to biodiversity prospecting and broadly sketches the types of policies needed in "source countries" to ensure biodiversity's sustainable and equitable use. It addresses fundamental questions of ownership and access to biodiversity, the economic opportunities provided by biodiversity, the costs and benefits of public versus private control of the resource, and the rights of indigenous people and other local "custodians" of biodiversity.

The subsequent chapters provide detailed guidance on specific biodiversity prospecting activities. In Chapters II and III, Rodrigo Gámez, Ana Sittenfeld, Alfio Piva, Eugenia Leon, Jorge Jimenez, and Gerardo Mirabelli describe INBio's institutional structure and current biodiversity-prospecting program. Since INBio was designed to meet both conservation and development objectives, these chapters may help others trying to launch similar institutions or activities.

Biodiversity prospecting typically involves several types of written or implied contracts: between the collector and the company interested in the resource, between the collector and the state,

between the collector and the communities providing ethnobotanical data, and sometimes between local collectors and larger collecting institutions. In Chapter IV (and Annex 2), Sarah Laird explores the nature of collector-company contracts and tells how they can be shaped to serve conservation, development, and equity. In Chapter V, Dan Janzen, Winnie Hallwachs, Rodrigo Gámez, Ana Sittenfeld, and Jorge Jimenez examine the "contract" or research agreement between the collector and the state from these same perspectives.

Chapter VI, by Michael Gollin, explores one of the more contentious issues of biodiversity prospecting—Intellectual Property Rights (IPR)—evaluating whether or not IPR regimes can be structured to support conservation. And, in Chapter VII, Calestous Juma tackles the question of how countries should structure their technology policies to ensure that the use of biodiversity leads to the development of a technical infrastructure that will yield long-lasting benefits.

In this rapidly evolving field, it is not surprising that this report leaves some questions unaddressed. But it should nonetheless help policy-makers at least become aware of the questions surrounding the potential for biodiversity prospecting. Historically, the exploitation of a "new" resource has led to its exhaustion and to the destruction of local communities and cultures. It will be no easy task to ensure that biodiversity prospecting harnesses these same forces in support of biodiversity conservation and rural development.

## Growing Demand for Genetic and Biochemical Resources

The driving forces behind the evolution of new biodiversity-prospecting institutions has been the growing demand for new genes and chemicals and a growing awareness that an abundant and virtually untapped supply of these resources exists in wildland biodiversity. While genetic and biochemical resources have long been important raw materials in agriculture and medicine, biotechnology is opening a new frontier. Furthermore, democratization and economic development in many developing countries has fanned interest in the local development of in-country resources.

In the pharmaceutical industry, after a hiatus in natural products research in the 1970s, interest has intensified over the past decade. As a source of novel chemical compounds, natural products research is an important complement to "rational drug design"—the chemical synthesis of new drugs. Natural products research has been revived by the development of efficient automated receptor-based screening techniques that have increased a hundred-fold the speed with which chemicals can be tested. Although only one in about 10,000 chemicals yields a potentially valuable "lead" (McChesney, 1992; Principe, unpublished ms.), these new techniques have made large natural products screening programs affordable. Researchers are thus returning to such natural sources of biologically active chemicals as plants, insects, marine invertebrates, fungi, and bacteria.

Another and quite different stimulus to natural products research has come from decades-old ethnopharmacology—the study of medicines used by traditional communities. Leads based on the use of plants or animals in traditional medicine can greatly increase the probability of finding a commercially valuable drug. For small pharmaceutical companies, drug exploration based on this indigenous knowledge may be more cost-effective than attempting to compete in expensive random screening ventures. For example, Shaman Pharmaceuticals—a small company in California—bases all of its drug exploration on plants used in traditional medicine (King, 1992). One of its most promising products is an anti-fungal agent derived from a species commonly used as a folk remedy for wound-healing in Peru and parts of Mexico. Other examples of natural products research programs now under way include the U.S. National Cancer Institute's five-year $8-million program to screen 10,000 substances against 100 cancer cell lines and HIV, and new screening programs at SmithKline Beecham, Merck & Co., Inc., Monsanto, and Glaxo. *(See Table I.1.)*

In the United States, some 25 percent of prescriptions are filled with drugs whose active ingredients are extracted or derived from plants. Sales of these plant-based drugs amounted to some $4.5 billion in 1980 and an estimated $15.5 billion in 1990 (Principe, unpublished ms.). In Europe, Japan, Australia, Canada, and the U.S.,

**Table I.1.** A Sample of Companies Active in Plant and Other Natural Product Collection and Screening

**Abbott Laboratories**
Active since: 1950
Collectors: University of Illinois; independent collectors
Capacity: 20–50 primary screens
Natural Product Focus: Microbes, plants
Therapeutic Groups: Anti-infective, cardiovascular, neuroscience, immunoscience

**Boehringer Ingelheim**
Active since: 1986–89
Collectors: University of Illinois, New York Botanical Garden (pilot program in 1986); independent collectors
Capacity: 8–12 screens; 5,000 compounds per year
Natural Product Focus: Plants, microbes
Therapeutic Groups: Cardiovascular, respiratory, gastroenterology

**Bristol-Myers Squibb**
Active since: company established
Collectors: Scripps Institute of Oceanography; Oncogen (pokeweed protein); independent collectors
Capacity: not available
Natural Product Focus: Fungi, microbes, marine, plants
Therapeutic groups: Anti-infective, cancer, antiviral

**CIBA-GEIGY**
Active since: 1989 (marine); 1992 (tropical plants)
Collectors: Chinese Academy of Sciences; Harbor Branch Oceanographic Institute; independent collectors
Capacity: 4,000 samples tested (1991)
Natural Product Focus: Microbes, marine, plants
Therapeutic groups: Cancer, cardiovascular, anti-inflammatory, CNS, respiratory, anti-allergy

**Eli Lilly**
Active since: active in 1950s and 1960s
Collectors: now collaborates with NCI, Shaman Pharmaceuticals and independent researchers
Capacity: not available
Natural Product Focus: Plants, algae
Therapeutic groups: Anti-infective, diabetes, cardiovascular, cancer, CNS, pulmonary, anti-viral, skeletal diseases

**Glaxo Group Research**
Active since: 1988
Collectors: Royal Botanic Gardens Kew; Chelsea Physic Garden; Institute of Medicinal Plant Development (Beijing); Biotics, Ltd.; University of Illinois/NCI
Capacity: not available to the public
Natural Product Focus: Fungi, microbes, marine, plants
Therapeutic groups: Gastrointestinal, respiratory, anti-infective, cardiovascular, dermatology, metabolic diseases, cancer, anti-inflammatory, infectious diseases

**Inverni della Beffa**
Active since: late 1950s
Collectors: in-house and independent collectors in Asia, Africa and South America
Capacity: in-house screening of hundreds of samples per year
Natural Product Focus: Plants
Therapeutic groups: Cardiovascular, gastro-enterologic and anti-inflammatory

**Merck & Co., Inc.**
Active since: 1991
Collectors: INBio; New York Botanical Garden; MYCOsearch
Capacity: not available to the public
Natural Product Focus: Fungi, microbes, marine, plants
Therapeutic groups: Respiratory, anti-allergy, anti-inflammatory, cancer, cardiovascular, anti-infective, antiviral, gastrointestinal, prostate, bone disease

**Table I.1.** (Continued)

**Miles, Inc.**
Active since: 1991
Collectors: contract companies; independent collectors
Capacity: not available to the public
Natural Product Focus: Microbes, plants, marine, fungi
Therapeutic groups: CNS, anti-infectives, cardiovascular, anti-diabetes, rheuma diseases

**Monsanto**
Active since: 1989
Collectors: Missouri Botanical Garden
Capacity: 9,000 samples per year, mainly from North America and Puerto Rico; number of screens is not available to the public
Natural Product Focus: Plants, microbes
Therapeutic groups: Anti-infectants, cardiovascular, anti-inflammatory

**National Cancer Institute**
Active since: 1960–1980; 1986–present
Collectors: U.S. Department of Agriculture (1960–80); Missouri Botanical Garden; New York Botanical Garden; University of Illinois; Kunming Institute of Botany, China; Central Drug Research Institute, India; Brigham Young University; Harbor Branch Oceanographic Institute; Australian Institute of Marine Sciences; Coral Reef Research Foundation; Smithsonian Oceanographic; University of Connecticut; University of Hawaii at Manoa; University of Miami; Michigan Biotechnology Institute; Tel Aviv University
Capacity: 1960–1980: received almost 35,000 species of plants, 16,000 marine extracts, and 180,000 microbe extracts; under current program, receives almost 10,000 plant, marine, invertebrate, fungi, and algae samples each year
Natural Product Focus: Plants, microbes, insects, marine, fungi
Therapeutic groups: Cancer, AIDS, antivirals

**Pfizer**
Active since: not available
Collectors: Natural Product Sciences (now lapsed); New York Botanical Garden
Capacity: not available to the public
Natural Product Focus: Plants, spider venom
Therapeutic groups: Cardiovascular, anti-inflammatory, anti-infective, psychotherapeutic, anti-diabetes, atherosclerosis, cancer, gastrointestinal, immunoscience

**Pharmagenesis**
Active since: 1990
Collectors: In-house experts in herbal medicine and over 15 collaborating entities throughout China and Asia
Capacity: 2,000–3,000 samples per year; 50 screens
Natural Product Focus: natural products used in Traditional Asian Medicine
Therapeutic groups: Immune, endocrine, CNS, cardiovascular

**Phytopharmaceuticals**
Active since: 1992
Collectors: University of São Paulo, Brazil; Chinese Academy of Sciences; independent collectors
Capacity: not available
Natural Product Focus: Plants
Therapeutic groups: Cancer

**Rhone-Poulenc Rorer**
Active since: 1991
Collectors: University of Hawaii; Beijing Medical University; Shanghai Medical University; Tianjin Plant Institute, China; independent collectors
Capacity: hundreds of samples per year; 9–20 screens
Natural Product Focus: Plants, marine, microbes
Therapeutic groups: Cardiovascular, anti-infective, AIDS, CNS, respiratory, bone disease, cancer

**Table I.1.** (Continued)

**Shaman Pharmaceuticals, Inc.**
Active since: 1989
Collectors: In-house botanists and a network of collaborators in Africa, Asia, and South America
Capacity: 200 samples per year
Natural Product Focus: Plants
Therapeutic groups: Anti-viral, anti-fungal, analgesics, diabetes

**SmithKline Beecham**
Active since: 1987
Collectors: Biotics, Ltd.; Royal Botanic Gardens, Kew; University of Virginia; Scripps Institution of Oceanography; Morris Arboretum, University of Pennsylvania; MYCOsearch; in-house collectors
Capacity: 2–3,000 samples per year; in-house library of 17,800 natural product extracts; 10–15 screens
Natural Product Focus: Microbes, plants, marine
Therapeutic groups: Anti-infective, cardiopulmonary, CNS, gastrointestinal, anti-inflammatory

**Sphinx Pharmaceuticals**
Active since: 1990
Collectors: Biotics, Ltd.; independent collectors
Capacity: 15,000 samples per year; 3 screens

the market value for both prescription and over-the-counter drugs based on plants in 1985 was estimated to be $43 billion (Principe, 1989).

Biotechnology has also opened the door to greater use of biodiversity in agriculture. Genetic diversity has always been a key raw material in agricultural research, accounting for roughly one half of the gains in U.S. agricultural yields from 1930 to 1980 (OTA,

Natural Product Focus: Plants, marine, fungi, algae
Therapeutic groups: Psoriasis, anti-fungal, cancer

**Sterling Winthrop**
Active since: 1988
Collectors: Mississippi State University: Brigham Young University; New York Botanical Garden (one shipment); independent collectors
Capacity: few hundred samples per year
Natural Product Focus: Microbes, plants, marine
Therapeutic groups: Cancer, anti-inflammatory

**Syntex Laboratories**
Active since: 1986
Collectors: Chinese Academy of Sciences
Capacity: receive 10,000 plant extracts per year; 10 screens
Natural Product Focus: Plants, microbes
Therapeutic groups: Anti-inflammatory, bone diseases, immunology, cancer, gastroenterology, cardiovascular, antiviral, dermatology, oral contraceptives

**Upjohn Co.**
Active since: 1986–87
Collectors: Shanghai Institute of Materia Medica
Natural Product Focus: Microbes, plants
Therapeutic groups: CNS, cardiovascular, anti-infectives, AIDS

1987). But whereas previously only close relatives of crops could be used in breeding programs, now the genes from the entire world's biota are within reach.

Traditional crop and livestock breeding methods will still comprise most crop-breeding activity for years to come. But genetic engineering is an important new addition to breeders' toolboxes. For example, a gene responsible for a sulfur-rich protein found in the

Brazil nut has been isolated, cloned, and transferred into tomatoes, tobacco, and yeast (Molnar and Kinnucan, 1989). And pest-resistant genes from the bacterium *Bacillus thuringiensis* (Bt) have been transferred to tobacco, tomatoes, potatoes, and cotton (Gasser and Fraley, 1992). All told, more than 40 species of food and fiber crops have been "transformed" through genetic engineering and, as evidence of likely rapid growth in the commercial importance of genetic engineering, almost 600 field tests of genetically engineered crops have now been undertaken in more than 20 countries.

Most of the initial commercial applications of genetic engineering will involve genes from bacteria and viruses since these groups are easy to work with. But plants, animals, fungi, and invertebrates are increasingly important sources of genes as well. A trout growth hormone gene, for example, has been transferred into carp (Crawford, 1990). Genes that produce a natural antifreeze in the winter flounder have been transferred into tobacco, where they protect the plant from freezing temperatures (Gladwell, 1990). And efforts are now afoot to transfer an insect-resistance gene from the cowpea to the potato (Ward and Coghlan, 1991).

The products of agricultural biotechnology are just now entering the marketplace, but by the year 2000 farm-level sales are expected to reach at least $10 billion and possibly as much as $100 billion annually, nearly equal to the total world market for agrochemicals and seeds in 1987 (World Bank, 1991). Research expenditures are equally striking. In 1987, total R&D expenditure on agricultural biotechnology was estimated at $900 million (Giddings and Persley, 1990).

The demand for genetic resources in agriculture is thus likely to grow substantially as techniques for genetic manipulation are improved and investments in research begin to pay off. While much of this demand will be for genes from domesticated species, wild species too will increasingly be the focus of searches for novel genes. For example, the number of requests for samples of wild species of rice received by the International Rice Research Institute doubled between 1988 and 1990 (D. Sendahira, IRRI, pers. comm., Dec. 1990).

Apart from new chemical leads for pharmaceuticals and new genes for agriculture, other new uses of biodiversity abound. A Brazilian fungus discovered in 1986 has been patented by a University of Florida researcher as a natural fire ant control (IFAS, 1990). Chemicals extracted from the neem tree have been patented as natural insecticide (Stone, 1992). Scientists have now genetically engineered plants to produce biodegradable plastic (*WSJ*, 1992). Naturally occurring micro-organisms can be used in various environmental applications, including oil spill clean-up (OTA, 1991). And genetically modified organisms are proving valuable in such applications as mining, wastewater treatment, carbon-dioxide scrubbing, chemical detoxification, and bioremediation.

Growth in this "biotechnology industry" foretells increasing demands for novel genetic and biochemical resources. Between 1985 and 1990, the number of biotechnology patent applications filed in the United States grew by 15 percent annually—by 9,385 in 1990 alone (Raines, 1991). Total product sales for the U.S. biotechnology industry in 1991 totaled approximately $4 billion—a 38-percent increase over 1990—and by the year 2000 sales are expected to have grown more than 10-fold to some $50 billion (IBA, 1992).

## What is at Stake?

All else being equal, the growing demand for genetic and biochemical resources should increase the potential market value of the raw material. But, given the high revenues generated from the final products developed in the agricultural and pharmaceutical industries, it is easy to misjudge how much money might actually be involved.

Many of the industries using genetic and biochemical resources produce high-value commodities and thus enjoy substantial gross earnings from the commercial product. Two drugs derived from the rosy periwinkle—vincristine and vinblastine—alone earned $100 million annually for Eli Lilly (Farnsworth, 1988)—a figure that is sometimes erroneously cited as the "value" of the rosy periwinkle. But sales of a product provide little indication of the potential market value of the unimproved genetic material in the source country.

Most of the industries using these resources are capital-intensive ventures that invest substantial time and money in the production of a commercial product, and most are far removed from the original source of the genetic or biochemical material.

In the U.S. pharmaceutical industry, a commercially marketable drug requires an estimated $231 million and 12 years on average to develop (DiMasi et al., 1991). These costs cover the process of screening candidate compounds, isolating active compounds, testing for possible toxicity, and undertaking clinical trials, as well as failed attempts to discover and produce a new drug. Developing agricultural products through genetic engineering also entails substantial costs. For example, the successful introduction of Bt genes into plants took several years and cost some $1.5 million to $3 million (Collinson and Wright, 1991).

In any given trial, the likelihood of discovering a valuable compound for the pharmaceutical industry is quite low. By most estimates, only about one in 10,000 chemicals yields a promising lead, and less than one fourth of the chemicals reaching clinical trials will ever be approved as a new drug (McChesney, 1992; DiMasi et al., 1991; Principe, unpublished ms.). For example, of 50,000 extracts put through an HIV screen in the natural products research program of the National Cancer Institute, only 3 are likely to wind up in clinical trials, and of 33,000 extracts screened for cancer only 5 are receiving further study (Sears, 1992).[2]

Given the high value added in both the pharmaceutical industry and agriculture, the abundance of unimproved genetic and biochemical resources, and the low probability that any specific sample will have commercial value, the holders of unimproved material are likely to receive a relatively low payment for access to the resource, current heightened demand notwithstanding. In agriculture, Barton (1991) estimates, the total revenue that might be gained if developing countries sought royalties for unimproved genetic material could amount to less than $100 million annually.[3]

Even in the pharmaceutical industry, possible earnings from the sale of raw materials are smaller than might be thought given the

industry's worldwide sales of roughly $200 billion—more than 30 times that of the seed industry (Lisansky and Coombs, 1989). In this industry, typical royalties paid for samples of unknown clinical activity (e.g., new synthetic chemicals) amount to only 1 to 5 percent of net sales—a range of royalties likely to apply to natural products as well. Consider an institution that supplies 1,000 chemicals to a pharmaceutical company in return for a 3-percent royalty on the net sales of any commercial product. Given the need to screen roughly 10,000 chemicals to find a single lead, a 1 in 4 chance of a lead being developed into a commercial product, a 5-percent discount rate, a 10-year wait before a product is ready to be marketed, and 15 years of patent protection while it is being marketed, and assuming that a drug, if discovered, generates $10 million net annual revenues, the present value of the agreement to the supplier is only $52,500.[4] More sobering, there is a 97.5 percent chance that the 1,000 chemicals will not turn up any commercial product at all, and if they do, royalty payments won't begin until more than a decade after chemical screening commences.

However, the prospects for success are raised with natural products, since any extract from a species will contain hundreds or thousands of different chemicals that might result in a pharmaceutical "lead." Moreover, the probability of success can be increased through the use of multiple—and higher quality—screens. Thus, for natural products research using current technologies, the probability of success could easily be ten times that of the example above, and thus produce promising leads at a rate of about 1 per 1,000 samples.[5] The probability of developing at least one commercial product in the above example would then grow from 2.5 percent to 22 percent, and the present value of the agreement would grow accordingly, to $461,000. And, if a "blockbuster" drug—earning $1 billion in sales annually—happens to be discovered under this scenario, that value would swell to $46 million.

Biodiversity prospecting does involve financial risks. With the odds against striking it rich, it often makes economic sense for biodiversity prospectors to hedge their bets by seeking advance payments and relatively small royalties rather than forgoing collecting fees and holding out for higher royalties that may never materialize.

Moreover, a risk exists that the market for natural products could quickly become saturated. While a number of pharmaceutical firms have natural products research efforts under way *(see Table I.1)*, most are small in scale, and the demand for chemical extracts from plants, animals, and microbes might be saturated by a handful of large-scale suppliers. As, say, Costa Rica, Indonesia, India, Brazil, and Mexico establish biodiversity prospecting institutes, the growing supply may well lead to steadily declining prices for raw materials.

Finally, there is no sure way of projecting future demand for biological samples on the part of the pharmaceutical industry. Within a decade or two, advances in synthetic chemistry, biotechnology, and medical sciences may curtail interest in natural products. On the other hand, wild species will continue to be a source of novel genes and proteins, as well as a source of insights into chemical and physiological processes. Nobody knows whether natural products will fall from favor in several decades or become even *more* valuable in medicine and in industrial applications.

In sum, while biodiversity prospecting can return profits to source countries, institutions, and communities, the amounts involved are likely to be small relative to the market value of the final products, a decade or more may pass before significant revenues materialize, a good chance exists that no commercial drugs will be produced, and late-comers may find a market already saturated with suppliers. On the other hand, given the scale of revenues generated in the pharmaceutical industry, even a relatively small share of net profits may amount to extremely large revenues for a developing country. And, if nations add value to genetic resources domestically and build technical capacity for improving the resource themselves, biodiversity prospecting could become an important component of a nation's economic development strategy.

## The Evolution of Biodiversity Prospecting Institutions

The increasing value of wildland genetic resources to private industry—combined with many countries' growing sense of national

identity and desire for greater control over their destiny—has created incentives for new kinds of institutional arrangements for capturing the return on investment in the use of biodiversity. In particular, genetic resource property rights, international agreements, and the use of intermediary organizations are three critical institutional arrangements whose evolution must be guided to ensure the sustainable and equitable use of biodiversity. (For wildland biodiversity, a "sustainable use" is one that does not diminish the diversity of wild species through time.)

### *Property Rights*

For decades, the major trend in the evolution of intellectual property rights for improved genetic and biochemical resources has been a gradual expansion in the scope and strength of ownership. As a result, two different systems now govern ownership and access to genetic and biochemical resources. On the one hand, "unimproved genetic material"—wild species and traditional varieties of crops and livestock grown by farmers—is treated as an ownerless, open-access resource.[6] On the other, intellectual property rights (IPR) regimes—including patents, plant breeders rights, and trade secrets—establish ownership for new varieties of plants and animals developed by commercial breeders and chemicals isolated and developed by pharmaceutical firms.

The biodiversity prospecting "industry" falls squarely between these two systems inasmuch as it seeks to locate wild resources with commercial potential. Not surprisingly, considerable controversy surrounds the applicability of property rights to wild biodiversity and to information about its potential use.

"Intellectual" property rights are used to grant private ownership to genetic and biochemical products because of the ingenuity involved in finding, identifying, and developing them. Unlike personal property regimes, intellectual property law secures ownership in the particular form or expression embodied in things, not over the tangible properties of the thing itself. Like knowledge or information, the costs entailed in discovering and developing new genetic or biochemical products can be quite high, but once

developed the product can be replicated easily at low cost, thereby undermining the ability of a seed company or pharmaceutical firm to recoup its development costs. Without protection for intellectual property or, alternatively, public funding to support development costs, less investment in research and development would take place than is socially desirable.[7] For example, agricultural research investments yield extraordinarily high returns—often more than 50 percent—but capturing the economic returns from the research is so difficult that little private investment occurs (Evenson, 1990).

Historically, unimproved genetic and biochemical resources were regarded as the common heritage of humankind, freely accessible by anyone. Scattered efforts to control ownership amounted to what would today be considered "trade secret" protection. Brazil, for example, tried unsuccessfully to prevent the export of rubber tree seeds, and for good reason. Just 20 years after the first rubber trees were established in Malaysia, the Brazilian rubber industry that had once commanded 98 percent of the world supply was exporting virtually nothing, while Singapore became the rubber capital of the world (Brockway, 1988). Similarly, Andean nations' attempts to prevent the export of Cinchona—the source of an anti-malarial compound—were eventually overcome, again by British plant explorers (Juma, 1989).

As early as 1873, however, a new type of ownership was extended to certain genetic resources: the patent. In that year, Louis Pasteur was awarded a patent in the United States for a yeast culture, giving him a limited monopoly over the culture, enforced by the state, in recognition of his intellectual contribution to the creation of the product (Juma, 1989).

Beginning in 1930, IPR for genetic and biochemical resources began to expand rapidly in breadth and scope. In 1930, the United States passed the Plant Patent Act, which allowed patenting of asexually reproduced plants such as roses, other ornamentals, and fruit trees. In the 1940s, European countries established Plant Breeders Rights (PBR) protecting sexually reproduced plants and the United States followed suit in 1970 with its Plant Variety

Protection Act.[8] To address issues arising from international trade in species protected by Plant Breeders Rights, the International Convention for the Protection of New Varieties of Plants—commonly referred to as the UPOV Convention—was adopted in 1961.[9]

With the exception of early patents like that granted to Pasteur, intellectual property rights granted for plants and animals were not formal "utility" patents. Neither Plant Breeders Rights nor Plant Patent legislation requires the same standards of novelty, utility, and non-obviousness (that is, innovation that would not be obvious to the average person skilled in the art) required for a utility patent and, in turn, neither system provides as much protection for the innovation as utility patents.

The most significant step in the expansion of IPR coverage for genetic resources took place in 1980, when the U.S. Supreme Court ruled in the case of Diamond vs. Chakrabarty that a genetically altered bacterium could be granted a utility patent under standard patent law (U.S. Supreme Court, 1980, 447 U.S. 303). Then, in 1985, the U.S. Patent and Trademark office ruled that a corn plant containing an increased level of a particular amino acid could also receive a utility patent. In 1988, the first animal was patented—a mouse carrying a human cancer gene used in medical research. The extension of patents to human life took place over the same period. Human cells—cancerous cells taken from a leukemia patient—were first patented in 1984. In 1991, the U.S. National Institutes of Health filed patent applications for the structure of 337 human gene fragments identified with an automated sequencing machine and in 1992 applied for patents on a further 2,375 gene fragments (Roberts, 1992). (The first of these applications was rejected by the U.S. Patent and Trademark Office in 1992, but reportedly will be amended and re-submitted.)

Countries differ widely in the patent protection they offer for living material. At one end of the spectrum, the United States grants patents on novel DNA sequences, genes, plant parts, plant or animal varieties, and biotechnological processes. In contrast, while they do grant patents for plant and animal genes, European countries have only recently extended patent protection to plant

varieties. Recently, a patent was also granted for the Harvard mouse in the United Kingdom, though the court decision allowing the patent indicated that a criterion of clear human benefit must be used in determining the patentability of an animal. Many developing countries exempt biological processes and products entirely from their patent regimes.

Chemical compounds and processes have long been subject to patent protection in most industrialized countries, though drugs and other types of chemical products are sometimes excluded from patentability. For example, patent protection for pharmaceutical products was extended only in 1958 in France, 1968 in the Federal Republic of Germany, 1976 in Japan (when it ranked second in world drug production), and 1978 in Italy (Chudnovsky, 1983). As recently as 1990, Finland, Norway, and Spain did not patent pharmaceutical processes and products (Lesser, 1990).

The gradual expansion of IPR protection raises an important and fundamental question: How can anyone "own" genes or biochemicals that occur in nature? In most fields, patents are granted only for innovations, not for discoveries. Is it right for someone to possess an exclusive right to a naturally occurring gene or chemical?

No uniform standards exist for the treatment of discoveries by intellectual property regimes in different countries, particularly for discoveries relating to natural products like genes and chemicals. In many industrialized countries, patents are allowed if the discovery requires notable input of human effort and ingenuity (Lesser, 1990). For instance, in the case of agriculture, a gene will usually be patentable only if it is used in a species in which it did not evolve or which it could not have been transferred to through conventional breeding (Barton, 1991). Similarly, a longstanding U.S. legal doctrine holds that the purified form of a chemical can be patented if the chemical is found in nature only in an unpurified form (Barton, 1991). Thus, in the United States, Europe, and Japan, pharmaceutical companies can patent chemicals derived from natural sources and genes that have been transferred to unrelated organisms.[10] In contrast, a number of developing countries exclude drugs and/or biological materials from patent protection.

### *International Agreements*

Even as the scope of property rights for improved genetic resources expanded over the past century, unimproved genetic resources retained their "common heritage" status until well into the 1980s. Beginning in the mid-1970s, however, questions surfaced in international forums over the nature of the institutions governing access to these resources.

In agriculture, a significant fraction of so-called "unimproved" genetic resources was actually the product of the hard work and ingenuity of farmers as they selected and bred crop varieties to fit local conditions and tastes (Mooney, 1983; Fowler and Mooney, 1990). Similarly, many pharmaceutical products developed from natural products were first "discovered" by traditional healers. Why, more people began to wonder, didn't these intellectual contributions receive the same IPR protection as the contributions of plant breeders and pharmaceutical companies? Or, alternatively, if these contributions were freely available to all, shouldn't the same apply to the products developed by pharmaceutical firms and seed companies?

A second concern revolves around ownership of the genes, seeds, and chemicals themselves. Developing countries began to question why individuals and companies based in the gene-poor developed countries were obtaining resources free-of-charge from the gene-rich developing countries, then patenting the genes and chemicals and selling the patented products back to the country where they originated. Since these were the raw materials used in agricultural breeding and pharmaceutical development, why shouldn't companies pay for them just as they would pay for, say, coal or oil?

In the agricultural arena, these debates quickly escalated in the early 1980s into a bitter "Seed War" between the North and the South. Since then, the resolution of this dispute through international mechanisms has moved at a glacial pace. In 1983, a Commission on Plant Genetic Resources was established through the Food and Agriculture Organization (FAO) of the United Nations and the "International Undertaking on Plant Genetic Resources" was signed by most developing countries and some industrialized

countries. This Undertaking initially held that *all* genetic resources (including the elite lines of private plant breeders) should be considered common heritage and thus freely accessible. Needless to say, few developed countries with established seed industries supported the Undertaking.

In 1987, the Commission on Plant Genetic Resources accepted the legitimacy of IPR protection for breeders in exchange for recognition of the concept of "farmers' rights." These were defined to be communal rights, vested in the international community through the International Undertaking on Plant Genetic Resources, recognizing the contributions of local communities and farmers in creating and maintaining genetic resources. In this same year, the Commission established a "Fund for Plant Genetic Resources" to fulfill the obligations inherent in the concept of farmers' rights by compensating developing countries for the use of their genetic resources, though donor countries never have provided more than token sums for this Fund.

The debate over ownership and access to genetic resources shifted venue in the late 1980s to the negotiations for a Convention on Biological Diversity. *(See Annexes 3 and 4.)* Here, countries quickly agreed to recognize that biodiversity was a sovereign national resource and a "common concern" of humankind—not a common heritage. But up until the very end of the negotiations, developed and developing countries couldn't agree on mechanisms for protecting intellectual property and for allocating the benefits of the use of biodiversity. The final convention, signed by more than 150 nations at the Earth Summit in June 1992, recognizes nations' obligations to ensure that both the countries supplying biodiversity and those using it receive economic benefits and even notes that countries should encourage the "equitable sharing of the benefits arising from the utilization of [the knowledge, innovations and practices of indigenous and local communities]."

### *Biodiversity Prospecting Intermediaries*

The final element of the evolution of biodiversity prospecting institutions has been the recent emergence of new intermediary

arrangements to facilitate access to genetic and biochemical resources and their transfer to the pharmaceutical, agriculture, or biotechnology industry. A wide range of such institutions already exists, and many more are being planned.

One outstanding example is Costa Rica's INBio. This private, non-profit organization was established to facilitate the conservation and sustainable use of biodiversity. It uses its income and donations to support a wide array of conservation actions—from carrying out the national biodiversity inventory in collaboration with the Ministry of Natural Resources, Energy, and Mines (MIRENEM) to conducting and facilitating biodiversity-prospecting activities to support its conservation mission. Many other private non-profit intermediaries are based in developed countries. For example, the New York Botanical Garden, the Missouri Botanical Garden, and the University of Chicago have all contracted with private pharmaceutical companies and with public research organizations to provide samples of biodiversity for pharmaceutical development. Increasingly, these intermediaries also enter into contractual relationships with the countries—or appropriate institutions within the country—where they pursue their collecting activities.

Private for-profit intermediaries also exist in both developed and developing countries. Biotics, Ltd., a private firm based in the United Kingdom, works as a broker, providing pharmaceutical companies with plant genetic resources. Biotics buys samples and, through a contract, agrees to share any royalties with the source country institution. Similar contracts are drawn up between Biotics and the pharmaceutical firms, which would ultimately hold the patent on any discovery. Numerous collectors in developing countries also make a business of supplying plant and animal samples to industry. While most large pharmaceutical companies rely on other organizations to collect natural products, smaller firms—such as Shaman Pharmaceuticals—may both collect biodiversity samples and develop drugs.

Public organizations have also begun to serve as intermediaries. Mexico's National Biodiversity Commission—established in February 1992—may seek to play much the same role for Mexico

that INBio does for Costa Rica. Similarly, Indonesia—and the Asian Development Bank—have considered establishing a Biodiversity Marketing and Commercialization Board. Elsewhere, the U.S.-Japan Environmental Partnership will be providing $20 million annually from 1994 to 1997 to establish several Natural Resource Conservation and Management Centers in Asia, some of which may undertake biodiversity prospecting. And three U.S. government agencies established a program in 1992 to fund "International Cooperative Biodiversity Groups" designed to "promote conservation of biological diversity through the discovery of bioactive agents from natural products, and to ensure that equitable economic benefits from these discoveries accrue to the country of origin" (NIH et al., 1992: 3).

Finally, some collaborative efforts between the public and private sectors have been established. For example, 24 Japanese corporations—including Suntory, Nippon Steel, and the Kyowa Hakko Pharmaceutical Company—and the Ministry of International Trade and Industry have established the Marine Biotechnology Institute in Micronesia. Researchers at this institute, with some 80 employees, two research laboratories, and a research vessel, are looking for new anti-bio-fouling agents, oil-eating bacteria, phytoplankton that fix atmospheric carbon dioxide, and new pharmaceutical compounds. (No arrangements have been made to share royalties with Micronesia or to pay an exploration fee.) (Sochaczewski, 1992)

Biodiversity prospecting intermediaries have been established for various purposes. Some are strictly money-making ventures. Others carry out basic research or spur conservation or economic development. But nearly all of the commercial collection programs of these institutions are young and thus by nature experimental.

## Biodiversity Prospecting Guidelines

Although the mission of some organizations engaged in biodiversity prospecting is primarily one of conservation, most have evolved primarily in response to growing commercial demand for the resource, rent-seeking by commercial ventures, and public policies designed to foster innovation in the extension of IPR. None of these

factors provides a sufficient incentive for resource conservation, the survey and description of biodiversity, local economic development, or the distribution of the benefits from biodiversity to those who pay the direct or opportunity costs for developing and maintaining it.

Biodiversity prospecting has attracted the interest of environmentalists and developing countries because it may provide significant incentives and funds for conservation and could contribute to economic development in regions rich in genetic and biochemical resources. But this dual potential will not be realized unless new policies are established to steer the evolution of the institutions toward these ends.

The remainder of this chapter summarizes general principles that can guide the development of such policies. These guidelines, derived from more detailed chapters that follow and based largely on the experiences of INBio in Costa Rica, should help governments, NGOs, and industry develop appropriate property rights regimes, intermediary institutions, collecting agreements, contracts, collecting regulations, and technology policies. In the absence of detailed empirical and theoretical studies, these conclusions are tentative and must be modified to fit specific circumstances. But taken as a whole, they approximate the "state-of-the-art" of biodiversity prospecting policies today.

### *Role of Intermediaries*

**Whether through one or more organizations, countries should establish the capability to identify and locate biodiversity, to save representative samples of wild biodiversity in protected wildlands, and to use it non-destructively for the public good.**

Few generalizations about the diverse intermediary organizations involved in biodiversity prospecting hold. Intermediaries can support—or undermine—the conservation and sustainable use of biodiversity, whether they are public or private and whether they are located in the source country or in a foreign land.

Nevertheless, more than any other component of biodiversity prospecting programs, well-designed intermediaries have the potential to promote conservation, development, and equity. As a pioneering institution, INBio's activity as a biodiversity prospecting intermediary has received particular attention as a "model." However, in Chapter II, Gámez et al. reject the assertion that INBio is a model, but accept that it is an instructive "pilot project."

Perhaps the most important insight from INBio's experience is that biodiversity prospecting activities are only a means to an end. INBio was established to help identify and inventory Costa Rica's biodiversity and to integrate its non-destructive use into the intellectual and economic fabric of the society. Biodiversity prospecting helps fund conservation, but, more important, it demonstrates the economic value of biodiversity and thus helps convince policymakers that biodiversity conservation should figure centrally into all development planning.

Whatever intermediary organizations are established, the array of institutions involved in biodiversity activities should fill three basic needs: *saving* representative samples of wild biodiversity in protected wildlands, *knowing* what this biodiversity is and where it is to be found in those wildlands, and *using* biodiversity non-destructively for societal aims. If biodiversity is to survive, the society in whose custody it resides must perceive it as an asset. That will happen only through understanding what biodiversity is and seeking ways to use it to satisfy local and national social and economic needs.

Any effort to save, know, and use biodiversity requires the joint efforts of widely different sectors of society—including universities, museums, conservation ministries, commercial firms, and rural communities. But INBio's experience demonstrates that one organization can catalyze the integration of these sectors. INBio's inventory of Costa Rica's species provides employment for rural people as technicians—"parataxonomists"—in this venture. The institute is generating abundant information that is needed to wisely manage the country's biodiversity for a wide variety of users, developing the capacity to undertake chemical

screening and pharmaceutical development, and working with Merck & Co., Inc., and other corporations to develop—and share the benefits from—new products based on that biodiversity. In essence, INBio closes the loop between studying, saving, and using biodiversity.

In other countries, biodiversity management institutions may or may not be involved in biodiversity prospecting. They may build on existing public-sector institutions like universities, environment ministries, and national museums or they may take the form of new public or private institutions. Multi-national management and prospecting organizations may make sense in some regions, while provincial or state-level organizations may be needed in others.

Clearly, institutions designed to gather information on biodiversity management and to develop new products of value to the biotechnology or pharmaceutical industry address only one portion of biodiversity conservation needs. For example, such institutions can create some employment in rural communities and may develop new products that local entrepreneurs can market, but it is unlikely that they could make rural development their mission. Yet, actions to reduce poverty in rural areas and to provide alternatives to habitat conversion that meet the needs of rural communities rank at the top of biodiversity-conservation priorities (WRI et al., 1992). By contributing to economic and technological development, and by contributing user fees or taxes directly to the public sector, biodiversity-prospecting initiatives can provide a share of the resources needed to meet this broader array of conservation and development needs, but the responsibility rests with national and local governments to ensure that these resources are used appropriately. When governments are unable to meet these responsibilities, the potential for success of biodiversity prospecting will be diminished.

One serious concern is that the revenues governments earn from biodiversity prospecting and the economic gains stimulated by commercialization of new products based on biodiversity may sometimes enrich the few rather than contribute to rural development. Certainly, biodiversity prospecting institutions often return

some benefits directly to the individuals, landowners, and communities involved in biodiversity collecting activities. But, more typically, as when biodiversity is collected from public lands or without the benefit of local information, there is no alternative to effective public sector mechanisms for returning benefits to local communities. For those countries that have shown a commitment to biodiversity conservation and the development needs of rural communities, biodiversity-prospecting intermediaries can be a valuable element of biodiversity-conservation policies. Without such a national commitment, biodiversity prospecting may be nothing more than the newest unsustainable resource-commercialization venture.

### *Company-Collector Contracts*

**Contracts between companies and collectors can help ensure that the exchange of biological materials generates both immediate and long-term benefits for the source countries and communities.**

Contracts are an important means of distributing the costs, benefits, and risks between the collecting organization and the companies interested in developing products from genetic and biochemical resources. Through them, the portion of benefits that will return to the country that possesses the biodiversity can be determined. Contracts can be established even if countries lack intellectual property regimes or legislation governing the activities of collectors. They are an extremely flexible form of agreement that could, in theory, be used to ensure that the source country receives financial returns from biodiversity prospecting and that these funds are used to promote resource conservation.

However, as Laird explains in Chapter IV, contracts alone will not make a country's conservation and development objectives materialize. Such agreements can be expensive and difficult to draft, negotiate, and enforce, and any company negotiating such a contract is motivated by the desire to acquire useful samples for screening,[11] not to conserve resources. As a result, any provisions

for conservation, the return of benefits to local communities, technology transfer, and so forth are likely to be limited (even if they are the collecting organization's primary goals).

Company-collector contracts typically involve a fee for samples and, occasionally, advance payments to the collector. In such cases, the collector must determine how to disperse these in the country of collection. As countries begin regulating access to genetic resources, the collectors' obligations to in-country collaborators and to collecting regions are likely to become more stringently defined. Laird notes that while most collectors take responsibility for determining equitable relationships with their in-country collaborators, collecting regulations must be developed that will hold up regardless of whether personal relationships do.

One of the most striking aspects of the Merck-INBio contract was the size of the advance payment to INBio for services. Customarily, pharmaceutical plant collectors receive payments of $50 to $200 per sample. In sharp contrast, the $1.1 million paid by Merck in exchange for samples is nearly ten times the traditional service payment. Merck & Co. was asked to pay virtually all of the real costs of a sample, rather than be subsidized by the social and institutional backup that a pharmaceutical collector normally receives but does not charge to the company. From Merck and Co.'s standpoint, this sum is warranted by the greatly increased quality of the samples that it receives from INBio during the initial two-year agreement and in future years if the agreement is renewed. How often payments of this magnitude will be made depends on how often sourcing institutions can offer samples of such quality, whether all collectors choose to charge all of the real costs to the purchaser, and whether competition among collectors drives prices to below-cost levels. As in many other markets, product quality is likely to be strongly proportional to the price paid for the sample and its associated services.

In Chapter IV and Annex 2, Laird et al. describe a number of provisions that could be included in company-collector contracts to further conservation, development, and equity. For example, contracts could specify that future supplies of raw material would

be obtained from the country of origin, that royalties would be distributed to individuals (such as traditional healers) that provided information on the resource, or that a specified fraction of royalties would be dedicated to conservation. While such stipulations may currently be uncommon, the rules of biodiversity prospecting are changing rapidly. For example, all INBio-commercial contracts state explicitly what portion of the research and royalty budget goes directly to the National Park Fund at the Ministry of Natural Resources, Energy, and Mines and what portion is used for other kinds of wildland conservation activities. Similarly, all INBio samples must come from inside the conserved wildlands so that there is no contest over where the funds should be spent.

### *Property Rights*

There is no more fundamental and divisive issue related to biodiversity prospecting than the question of who owns biodiversity. Developing countries have long been frustrated with a system that labels their resources as "open access" but then establishes private property rights for improved products based on those resources. Is it possible to modify IPR regimes to internalize the cost of biodiversity loss and management and ensure that the source countries and the custodians of biodiversity within them receive more of the economic returns from its development?

**It is uncertain whether Intellectual Property Rights can be extended to wild genetic and biochemical resources and whether such rights would hurt or help the objectives of conservation and development.**

On the surface, the idea of extending IPR protection to wild species would seem to resolve the apparent imbalance between the rights of ownership for improved and unimproved genetic resources, thereby providing an incentive for resource conservation. Just as the individual who purifies a naturally occurring chemical is able to patent it, the individual (or nation) first spending the time and money needed to identify a new species and bearing the cost of maintaining that species could be granted exclusive rights to its use or sale (Sedjo, 1988; Sedjo, 1992). By assigning such rights,

some would argue, the opportunity cost of the loss of the resource could be internalized and market forces and legislation might then lead to an "optimal" investment in conservation, at least with respect to biodiversity's genetic and biochemical value.

Michael Gollin explores this possibility in Chapter VI and concludes that the extension of IPR to wild species is unworkable at present. From a pragmatic standpoint, patent offices would be deluged with speculative claims on species whose utility was unknown. But, more important, such a step would place more of the "public domain" in private hands than would be justified to maximize social benefits, Gollin concludes.

More generally, Gollin reviews the various types of IPR that exist today and concludes that all are of limited use in promoting the conservation of wild species (but also do not necessarily hasten the loss of biodiversity). On the other hand, IPR can help stimulate domestic innovation and technology acquisition, thus providing an incentive for the sustainable development of the resource within the source country and generating economic benefits that may then be used to support conservation or to compensate the custodians of biodiversity.

**The most promising immediate opportunities for capturing greater benefits from biodiversity involve access restrictions, contracts, and value-added industries.**

If extending intellectual property rights to unimproved genetic resources fails to capture benefits from the use of the resource, what other mechanisms are possible? Three mechanisms are described in this report: contracts, access restrictions *(see below)*, and the promotion of value-added industries. Efforts to add value to biochemical and genetic resources—such as those described in Chapter II by Gámez et al. and in Chapter III by Sittenfeld and Gámez—may be particularly rewarding since they contribute directly to the development of the source country's technological capacity. Strengthened capacity, in turn, allows source-country institutions to enter into more profitable partnerships with technology-intensive industries.

The economic returns generated from biodiversity can be enhanced either by providing a service related to the unimproved resource or by improving the resource itself. For example, in its agreement with Merck, INBio is basically selling biodiversity prospecting services, not any intellectual property right that it holds. Among the services it offers are sample identification, ready access to further samples from the same species and of the same quality; and known and user-sensitive sample-processing methods. The Merck-INBio agreement is not exclusive. Merck is free to buy samples from others in Costa Rica, INBio can provide samples to other organizations, and other organizations can collect the same samples and sell them to Merck or any other user. Although INBio's agreements include stipulations that for six months to two years it will not send the same sample to a competing company, in no sense does INBio control access to—or "own"—the resource.

Institutions can also increase economic returns by developing information about the resource. A biodiversity-prospecting institution could undertake preliminary chemical screening of samples to identify those with promising biological activity, thereby raising their potential market value. Such work could be undertaken with no intent to seek a patent; indeed it could be undertaken in a country with no patent protection for biological materials. The increased commercial value would stem from the new information on the materials' potential use. In the pharmaceutical industry, for example, it is common to receive royalties of 1 to 6 percent of net sales for unscreened chemical samples, 5 to 10 percent for material backed by pre-clinical information on its medical activity, and 10 to 15 percent for fractionated and identified material with efficacy data.

INBio is already establishing chemical screening and bioassay facilities to explore Costa Rican species for potentially valuable compounds. Once active substances are discovered, INBio will be in a stronger position to negotiate royalty arrangements with foreign companies and can even isolate new products by itself.

**Indigenous People, farmers, and traditional healers can and sometimes should seek IPR protection. As a supple-**

**ment to these property rights, formal and informal contracts will often be a more promising avenue for ensuring just compensation for their knowledge. National collecting regulations can help ensure that equitable contracts are negotiated.**

Today, traditional knowledge is rarely involved in the development of new pharmaceutical products from biodiversity. Natural products chemistry today is based primarily on research by scientists, physicians, and pharmacologists. The screening programs used by large pharmaceutical companies are more likely to make use of phylogenetic information—screening organisms related to those that have proven their pharmaceutical worth—than indigenous knowledge, and new genes for agricultural breeding are increasingly found among wild species where farmers have played little role. But, in some cases, the discovery of new medicines or promising genes is due in part to the knowledge of traditional healers or the work of generations of farmers. In such cases, how can these people be equitably compensated?

Knowledge of the therapeutic properties of wild species is often held in confidence by traditional societies, both because considerable training is needed before the materials can be used safely and effectively and because widespread knowledge of the cures would undermine the healers' vocation. Historically, ethnopharmacologists have not seen the need to protect these secrets (though often researchers have attempted to negotiate compensation for the information provided.) For example, the author of *Medicinal Plants of East Africa* (which gives complete descriptions of the taxonomy, distribution, and uses of the medicinal plants) writes in the foreword:

"Many of the herbal medicine men will not like this book since it may deprive them of their profession once their secrets are revealed. The majority of them were reluctant to show me the drug plants as a whole for this reason. In most cases, I was given the leaves or root of the plant already crushed or picked. But after some persuasion, I was shown the plant on the condition that I would not reveal it to anyone else" (Kokwaro, 1976).

Though such practices were once commonplace, today this would be considered a misappropriation of trade secrets that could and should be prevented by legal means, including lawsuits.[12]

Issues of equity in the distribution of benefits from the use of traditional medicines and traditional crop varieties have underlain international debates over biodiversity for more than a decade (Mooney, 1983; Elisabetsky, 1991). And today, the issue of what represents "just compensation" for the holders of traditional knowledge is far from resolved. Some of the questions that arise include: How can the efforts of generations of farmers be equitably compensated through their descendants for developments in agriculture? Should a traditional healer be compensated for indigenous knowledge, or should the debt be paid to the community or to the state? Is a one-time payment to the deserving party or group enough, or do the bearers of traditional knowledge have a basic right to the fruits of their inspiration that goes beyond the labor effort involved?

The subjectivity of any definition of equitable compensation ensures that no mechanism for allocating benefits will appear "just" to all. And North-South questions of equity will be particularly troublesome. In a cohesive and well-integrated society where it can be shown that privatizing specific types of knowledge leads to greater public good, this "implicit" compensation ensures reasonable equity in the distribution of benefits (Brush, 1991). For example, when the United States grants a patent to a U.S. drug company that develops an anti-cancer compound made from a local plant, "implicit" social benefits accrue nationally in the form of a lessened incidence of cancer. But it is hardly surprising that equity issues come up when the actors are traditional healers living outside of market economies in Brazil on the one hand and genetic engineers in the United States on the other. What benefits return to a remote region of the Amazon from a new drug designed to fight diseases common only in the developed world, and too expensive for purchase by local people in any event?

One mechanism for meeting global obligations to the generations of farmers and healers who have developed and protected the genetic and biochemical resources now used in industry is

through an international financial mechanism such as the Fund for Plant Genetic Resources or the Convention on Biological Diversity (Fowler and Mooney, 1990). But can other mechanisms complement such international agreements? Specifically, can IPR be used to protect the knowledge of indigenous people, traditional healers, and farmers?

The answer is "sometimes." As Gollin explains in Chapter VI, most current IPR regimes would, in principle, allow the extension of IPR to cover the innovations and knowledge of traditional healers and farmers. Traditional healers could be granted patents for novel uses of a compound under most systems of patent protection. As a corollary, if a traditional medicinal use of a compound is public knowledge, then patent laws should be applied to prevent others from patenting that compound for the same purpose. Similarly, there is no compelling reason why a farmer who breeds a new variety of plant could not receive protection under most systems of Plant Breeders Rights.

Any number of practical problems crop up, however, when intellectual property rights are extended to these "informal" innovations and promoting their use in this context is somewhat disingenuous. The scope of protection of IPR is generally as much a function of the political and economic power of those seeking protection as it is of wise or just economic policy. Moreover, the utility of IPR regimes is always a function of the enforceability of the rights. Society can establish the legal framework governing such disputes, but, ultimately, the rights-holder must be able to identify infringements and challenge the infringing party. Clearly, a traditional healer in Brazil or a farmer in Ethiopia can rarely do either. Farmers and traditional healers cannot effectively claim ownership to a resource if they can't control access to it, and they are in no financial position to challenge IPR claims made by others.

Finally, the costs of enforcing the right may often outweigh any benefits. A farmer might well be able to file for Plant Variety Protection on a new plant variety, but why bother if the new variety is locally adapted to just one small region of the country? The market for the variety simply won't be big enough to repay the effort.

Thus, while farmers and traditional healers are in a position to seek formal intellectual property protection (in countries that provide it), seeking compensation for their knowledge and inventions more directly through contracts and informal agreements usually makes more sense. For example, by refusing access to knowledge or traditional seed varieties, individuals can at least establish a framework for negotiating an equitable settlement (WRI et al., 1992). These two avenues for compensation are not mutually exclusive and indeed recognition of the legal right may encourage formal negotiations for compensation.

Increasingly, biodiversity collectors, anthropologists, and scientists are recognizing their responsibilities to local communities and negotiating formally or informally for access to information held by the communities. Both Laird (Chapter IV) and Janzen et al. (Chapter V) cite codes of conduct that professional organizations and U.N. agencies are now developing to promote greater equity in the relationship of researchers with local communities and source countries.

National legislation regulating biodiversity collecting activities provides another, more formal, mechanism for ensuring that the rights of local communities and source countries are respected. Collecting permits could, for example, require collectors to obtain prior informed consent from local communities before collecting begins and, in some cases, to negotiate the terms by which they would be given access to land or to local knowledge.

### *Legal Guarantees*

Each of the policy tools discussed above—organizational design, company-collector contracts, and intellectual property rights—can help achieve the objectives of conservation, development, and equity. However, without effective national regulation, the attainment of these objectives may be the exception rather than the rule. Private intermediaries are more likely to be established with profit, rather than conservation, in mind. The parties to contracts will rarely agree on both the need for conservation and technology transfer. And it will be easy for commer-

cial collectors and companies to slight the contributions of farmers and traditional healers to new medicines and crop varieties.

The best means available to ensure that biodiversity prospecting does meet these broader social objectives is national policy, specifically biodiversity collecting regulations. Such regulations should be part of legislation established by countries to implement the Convention on Biological Diversity. (Costa Rica, for example, adopted a Wild Life Protection law on October 12, 1992, which declares all wild plants and animals to be "national patrimony" and requires collectors to: submit an application for a license that details their collection plans; deposit voucher samples with the national collection; and, send copies of publications resulting from the work to the national library. Collection for non-scientific purposes requires a special license and must involve the use of public bids, concessions, or contracts.) Sittenfeld and Gámez (Chapter III), Laird (Chapter IV), and Janzen et al. (Chapter V) examine a number of issues that could be addressed through the national legal framework.

The agreement reached between a biodiversity collector and society is, in essence, a research *contract*. Where past collecting activity has been regulated informally, if at all, the state should now ensure that in return for access to genetic and biochemical resources the collector assumes certain obligations with regard to conduct, liability, and payments. The most critical elements of such regulation are: i) user fees for access to genetic or biochemical resources on public or private land, and ii) requirements that collectors negotiate equitable arrangements with the local communities, the wildland administrators, the private landowners, the farmers, and healers who were the custodians of the biodiversity collected or who contributed to the discovery or development of valuable genetic or biochemical resources.

**To increase the benefits they receive from biodiversity, countries and local communities should regulate access to the resource and charge "user fees" where appropriate.**

Critics have charged that private biodiversity prospecting intermediaries inappropriately exploit the public domain for private

benefit (Kloppenburg and Rodriguez, 1992). This criticism is often valid: private commercial collectors often do obtain genetic resources freely from the public domain and sell them for private gain. Public policies should thus seek to ensure that private collectors pay local or national governments for access to biodiversity.

Nobody would expect a nation to allow a private timber company to use public timber resources free of charge or to mine on public land without reimbursing the state. A similar system of user fees—or biodiversity prospecting concessions—should be established for access to public lands for biodiversity prospecting ventures (Sedjo, 1990; Simpson, 1992). Ideally, such fees would be used to maintain the biodiversity, thereby internalizing part of the costs of conservation. INBio, by investing 10 percent of Merck's initial payment of $1 million in traditional conservation activities, agreeing to spend half of all royalties on conservation through MIRENEM, half on conservation through its own activities, and conducting all of its activities as development of the conservation areas, basically paid such a user fee, even though no national legislation required it at the time.

In Chapter V, Janzen et al. describe in detail a system of regulated access to biodiversity. They argue that the time has come for *all* research on biodiversity—whether commercial or scientific—to be strictly regulated by public institutions (or their designated representatives). This does not mean that all researchers must pay user fees. For example, scientists carrying out basic research on biodiversity—such as inventory and taxonomic work—return "in-kind" benefits to a nation instead of direct payments. Similarly, governments might set lower fees for local (as opposed to foreign) collectors, thus giving them an incentive to develop local industries based on these resources.[13]

Janzen et al. also discuss the types of compensation that might be received for access to biodiversity. They argue that the nature of the compensation must be based on what the researcher has to provide, which isn't necessarily money. Nonetheless, some user fees may be appropriate even for those engaged in "basic" rather than

commercial research. Scientists readily accept the notion that they must contribute to the overhead of their home institutions; they should not object to the idea that they should also contribute to the "overhead" of their research sites. (Nor should their granting agencies discourage such expenses.)

An alternative to systems of user fees would be for the state to control all aspects of the commercialization of the resource. Genetic and biochemical resources do have unique attributes that set them apart from other elements of a nation's patrimony—among them, its timber, minerals, and fisheries. For example, the sale of rights to a gene or chemical to a foreign company exhausts the local rights and control over the resource. Whereas local communities or future generations may have an opportunity to challenge forest or mineral leases, for genetic resources the deal is final. And the real value of the resource lies in the information contained in the genes or chemicals, not in its physical properties. Though an intermediary may be selling only a service related to the resource, its actions may make it easier for individuals with technological expertise not available in the source country to establish private property rights for that information.

But whether stronger control by national governments would better serve national interests is far from clear. Such a system could run into tremendous practical problems. For example, INBio is paid for the service and information it provides, not for licenses to intellectual property rights. A system that retains national control over all such information and services—as well as the right to the resource itself—would be unwieldy at best and fraught with inefficiency and corruption at worst. In many countries, the balance between local and national control over resources has shifted too far toward the latter, undermining prospects for sustainable use and equitable distribution of the benefits from resource use. With too much national control, for example, indigenous groups would lose their right to contract with a pharmaceutical company for the use of their knowledge. In an ideal world, the national government might assume that right and make sure that the local community is compensated equitably, but in most countries the retention of local control is more likely to achieve the social objectives.

In any event, where private biodiversity prospecting is allowed, governments should protect the public interest by regulating access to the resource, charging appropriate fees for that access, and using the revenue so generated to support conservation and rural communities near protected wildlands.

**Biodiversity prospecting on private lands should be subject to regulation and "user fees."**

The need for user fees is relatively clear on public lands, but somewhat problematic when applied to biodiversity collected on private lands. Almost all countries, for example, consider plants growing on private land to belong to the land owner, though wild animals are the property of the state. Individuals can cut a tree on land they own without the state's permission but—because wild animals move across property lines—must follow state regulations governing the harvest of wildlife.

The issue of ownership and access to genetic and biochemical resources is closer to that of the right to harvest wild animals on private lands than to that of plant ownership. When an individual cuts and sells a tree, nothing prevents another individual from cutting another tree of the same species on adjacent land and selling it. But only the first individual who sells a chemical extract that is later developed into a drug will receive the economic benefit associated with the discovery and associated property right.

Thus, following the same policy that governs the harvest of wild animals, nations should not allow all rights to these resources to be "bundled" with private property rights in land. While local land owners may regulate access to the resource and charge collecting fees, local and national governments should also regulate the exploitation of these resources and charge user fees where appropriate.

### *Technology Policy*

**Developing countries should establish technology policies that better enable them to benefit directly from their genetic and biochemical resources.**

The long-term contribution to economic development, conservation, and the equitable sharing of benefits from genetic resources may be greatest if biodiversity-prospecting policies foster the development of national capacity in biotechnology. Efforts that don't will fall victim to the historical mistakes of other export industries based on raw materials in developing countries.

In Chapter VII, Juma argues that a narrow focus on the sharing of returns on the sale of products derived from biological material is misguided. This approach can give developing countries financial incentives to conserve biological diversity, but even longer-term benefits will stem from technological cooperation and capacity building in science and technology. For this reason, biodiversity prospecting should be considered part of the larger issue of national biotechnology policy and should be treated as a capacity-building activity.

Juma downplays the obstacles intellectual property rights pose to access to new technologies. Most of the technologies needed by developing countries to build capacity in these fields are already in the public domain. The obstacle is *not* proprietary rights, despite the attention they receive in international debates.

Both Gollin (Chapter VI) and Juma (Chapter VII) argue that intellectual property rights should be viewed as a tool for enlarging technological capacity in developing countries. IPR regimes established without due consideration to the need for effective legal, political, and economic systems conducive to private business activity and the protection of private property rarely serve their stated ends (Evenson, 1990). IPR protection—tailored to a nation's development needs—can foster advances in technological innovation, but that protection must be coupled with other institutional changes to increase knowledge of public domain technologies, upgrade technical training, and provide access to the credit needed to develop new technologies and markets.

Juma notes that even small countries with limited industrial capacity can move to the frontiers of biotechnology in specific fields by enhancing their human resource capacity. By investing in training,

establishing systems that provide ready access to information about both biodiversity and new technologies, and seeking ways to add value to genetic resources through screening and characterization, developing countries can turn short-term economic benefits into a long-term development strategy.

### *International Agreements*

**The Convention on Biological Diversity and other multilateral agreements are important foundations for sustainable and equitable biodiversity prospecting programs.**

A central theme of this report is that a variety of national and sub-national actions and policies can help biodiversity prospecting contribute to sustainable development. Rather than relying strictly on multilateral agreements, therefore, countries, institutions, and individuals can use contracts, institutional design, national legislation, and common sense to steer the evolution of biodiversity prospecting institutions. Some have even argued that national policies and bilateral agreements like that between Merck and INBio are sufficient and that no multilateral action is necessary. In 1992, the United States used this argument as one justification for its refusal to sign the Convention on Biological Diversity.

In fact, multilateral agreements are necessary for several reasons. First, by themselves, bilateral biodiversity-prospecting agreements are likely to result in conservation and development benefits for only a limited number of countries. Countries that are quick to enter the market as suppliers of biodiversity and that have the necessary technical capacity to compete may reap substantial gains. But for most developing countries—and the bulk of the world's biodiversity—multilateral mechanisms are needed to provide financial and technical support for biodiversity conservation and technological development.

Second, the value of many of the economic benefits provided by biodiversity—clean water, healthy ecosystems, aesthetic pleasure—is not fully reflected in the market, so market-based strategies like

biodiversity prospecting can only complement public sector financial support for conservation. While some of these benefits are strictly local or national, others—like the maintenance of healthy forest and marine ecosystems—are global and justify multilateral action.

Third, multilateral agreements will help increase the benefits that source countries can derive from their genetic resources. As suppliers of biodiversity saturate the market, the price for genetic and biochemical resources will fall. The interests of source countries could be better served if uniform conditions were developed through multilateral agreements to govern access to biodiversity.

On the other hand, the ability of source countries to form effective genetic and biochemical resource cartels is probably limited. The demand for biochemical resources for the pharmaceutical industry, for example, is likely to be very elastic in response to price changes. Today's resurgence in natural products research is due in part to the decline in costs resulting from new screening technologies. If the price for access to natural products rises, pharmaceutical firms could respond with increased investment in synthetic chemistry and reduced investment in natural products research. In principle, the establishment of cartels is more likely in the case of genetic resources used in agriculture, but the relatively low value of the seed industry (compared to the pharmaceutical industry) could mean that the costs of creating a cartel, restricting the flow of crop genetic resources, and pursuing royalties and payments for these resources might easily exceed the economic benefits. Short of a cartel, though, countries could agree to establish minimum obligations for companies engaging in biodiversity prospecting.

Fourth, multilateral agreements can help level the playing field so that bilateral agreements can be negotiated fairly. Clearly, institutions in developing countries may have less negotiating experience than multinational corporations. Under a multilateral agreement, mechanisms could be established to provide information, legal advice, or the services of an ombudsman to help ensure equitable negotiations.

Many developing countries also lack the ability to effectively regulate access to genetic resources within the country. Without such capacity, laws requiring collecting permits or user fees could easily be circumvented by international collectors. By requiring prior informed consent of the source country for access to biodiversity, the Convention on Biological Diversity will help shift some responsibility for enforcement to the developed countries. Parties to the Convention, for example, could pass laws requiring that gene or biochemical patent applications within their country include evidence that the material in question was collected with the prior informed consent of the source country and of local landowners or land claimants.

Finally, as Gollin argues, an international agreement such as the Convention on Biological Diversity sets the stage for a "Grand Bargain" whereby developing countries would seek strengthened IPR so as to profit from their biological resources while the developed world would concede the possibility that each nation may tailor its intellectual property laws to meet its own conservation, development, and equity needs. Rather than weakening intellectual property laws—a fear that the United States cited when it refused to sign the convention—this new bargain is likely to strengthen them.

## Notes

1. That is, the private returns of conserving the resource are less than social returns.
2. These five include Taxol, the most promising drug of the decade for treating breast, ovarian, and lung cancer. Since the success rate for cancer screening is based on technologies used in the 1960s, current technologies are likely to yield higher rates of "hits."
3. This estimate is based on his 1979 calculation (Barton and Christensen, 1988) of the U.S. markup of seed sales derived from proprietary protection, extrapolated to the 1990s and to the global market (totalling $1.5 to $2 billion). With a 5-percent royalty returning to the suppliers of the genetic material, this would amount to $75 million to $100 million.
4. If p is the probability of a single chemical yielding a useful lead, q is the probability that a lead will result in a commercial product,

and n is the number of chemicals screened, then the probability of producing one commercial product (C) is $C = 1 - (1 - (p \times q))^n$. In this example, p = .0001, q = .25, n = 1000, and C = .0247. If R = the present value of the royalties from a single commercial product, then the present value of the agreement is calculated as C x R.

5. Even this figure may be conservative. At a January 1986 workshop involving representatives of American and Swiss pharmaceutical companies involved in plant-based drug development, a consensus was reached that the probability of any plant yielding a *marketable* pharmaceutical (not simply a "lead") ranged from 1 in 1000 to 1 in 10,000 (Principe, pers. comm., 1993).
6. Clearly, a local crop variety bred by farmers is an "improved" variety even though it has not been commercialized. Similarly, the investment that a nation makes in conserving wild species or in inventorying and identifying its species arguably results in an "improvement" in that species analogous to that made by commercial breeders.
7. The costs and benefits of intellectual property regimes have been debated at length. By using the creation of a monopoly right to correct for a market failure, governments create new economic inefficiencies in the hopes of removing more serious ones. In one notable case of abuse of this right, a British subsidiary of Hoffman-La Roche was found to be claiming costs of $925 and $2,305 per kilo for materials available in Italy (where no patent protection was available for pharmaceuticals) at $22.50 and $50 per kilo, respectively, to justify artificially high drug prices (Boone and Mathieson, 1990). Since the costs and benefits of IPR protection differ among countries and among industries within countries, most analysts agree that intellectual property rights regimes must be tailored to countries' specific development needs. (Siebeck, 1990; WRI et al., 1992; Khalil et al., 1992) One generalization can be made about the forces influencing the evolution of IPR systems: industry will always seek to strengthen IPR protection, even if the strength of the protection exceeds socially optimal levels. From industry's standpoint, stronger IPR protection allocates ever more of the economic rent produced by a new innovation to the industry and less to the consumer. No market mechanism determines the optimal balance of this rent

capture—by establishing IPR regimes, governments assume the responsibility of making this determination.

8. Plant Breeders Rights grant an individual exclusive right to sell a specific variety but traditionally do not prevent farmers from saving and replanting the seed of the variety (farmer plantback), or breeders from using that variety in a breeding program (breeders' exemption). Many in the plant breeding industry have argued that this level of protection provides an insufficient incentive for research investment and have advocated closing "loopholes" related to both farmer plantback and the breeder exemption. (In response, the March 1991 revision of UPOV allowed countries to restrict farmer plantback and alters the breeders' exemption so that "essentially derived" varieties—that is, new varieties based largely on the genetic makeup of a protected variety—must obtain a license from the owner of the protected variety.)
9. All UPOV members were West European until 1978. Since that time, other countries including Australia, Czechoslovakia, Canada, Hungary, Israel, Poland, South Africa, and the U.S. have joined and some developing countries are considering joining.
10. Typically, drugs developed from natural products are altered from their natural forms during the drug development process and these derivatives are also patentable. The trail of patents filed during drug development can help in determining whether wholly or partially synthesized drugs originated from natural precursors.
11. A number of companies now recognize the need for conservation in their policies, but generally support for conservation is contributed through philanthropic foundations associated with the company. However, these foundations cannot legally donate money to institutions involved in a commercial arrangement with the parent company. *(See Chapter IV.)*
12. Several professional societies are developing ethical guidelines seeking to ensure that the rights of holders of traditional knowledge are respected and that just compensation is provided to local communities for access to such information.
13. This difference in treatment might raise red flags under international trade agreements. On the other hand, many countries already have two-tiered user fees for access to national parks, with foreign nationals paying higher fees than local residents.

## Bibliography

Aldous, Peter. 1991. 'Hunting licence' for drugs. *Nature* 353:290.

Barton, John H. 1991. Relating Scientific and the Commercial Worlds in Genetic Resource Negotiation. Paper presented at the Symposium on Property Rights, Biotechnology, and Genetic Resource, African Centre for Technology Studies and World Resources Institute, Nairobi, Kenya. June 10–14.

Barton, John H., and Eric Christensen. 1988. Diversity compensation systems: Ways to compensate developing nations for providing genetic materials. Pp. 339–355 *in*: J.R. Kloppenburg, Jr. (ed.) *Seeds and Sovereignty*, Duke Univ. Press, Durham, N.C.

Boone, Peter S., and John A. Mathieson. 1990. Intellectual property rights: Assessment of current policies and practices, and options for A.I.D. initiatives. *The Economics of Technology*. Working Paper No. 1, Bureau for Program and Policy Coordination, U.S. Agency for International Development, Washington, D.C.

Brockway, Lucile H. 1988. Plant science and colonial expansion: The botanical chess game. Pp. 49–66 *in:* J.R. Kloppenburg, Jr. (ed) *Seeds and Sovereignty*. Duke University Press, Durham N.C.

Brush, Stephen B. 1991. Intellectual property and traditional agriculture in the third world. Paper presented at the Roundtable on Intellectual Property Rights and Indigenous Peoples. Society for Applied Anthropology. Charleston, South Carolina.

Chudnovsky, Daniel. 1983. Patents and Trademarks in Pharmaceuticals. *World Development*. 2:3 pp 187–193.

Collinson, M.P. and K.L. Wright. 1991. *Biotechnology and the International Agriculture Research Centers of the CGIAR*. 21st Conference of the International Association of Agricultural Economists. Tokyo, Japan, August 22–29, 1991.

Crawford, Mark H. (ed). 1990. Transgenic Carp: Pond Ready? *Science*. 247:1298.

DiMasi, Joseph A., Ronald W. Hansen, Henry G. Grabowski, and Louis Lasagna. 1991. Cost of innovation in the pharmaceutical industry. *Journal of Health Economics* 10:107–142.

Eisner, Thomas. 1989. Prospecting for nature's chemical riches. *Issues in Science and Technology* 6(2):31–34.

Eisner, Thomas. 1992. Chemical prospecting: A proposal for action. Pp. 196–202 *in:* F.H. Bormann and S.R. Kellert (eds.) *Ecology,*

*Economics, and Ethics: The Broken Circle.* Yale University Press, New Haven, CT.

Elisabetsky, E. 1991. Sociopolitical, economic and ethical issues in medicinal plant research. *Journal of Ethnopharmacology* 32:235–239.

Evenson, R.E. 1990. Survey of empirical results. Pp. 33–46 *in*: W.E. Siebeck (ed.) *Strengthening Protection of Intellectual Property in Developing Countries.* World Bank Discussion Paper 112. World Bank, Washington, D.C.

Farnsworth, Norman R. 1988. Screening plants for new medicines. Pp. 83–97 *in*: E.O. Wilson and Francis M. Peters (eds.) *Biodiversity.* National Academy Press, Washington, D.C.

Findeisen, Christina and Sarah Laird. 1991. Natural Products Research and the Potential Role of the Pharmaceutical Industry in Tropical Forest Conservation. A report prepared by The Periwinkle Project of the Rainforest Alliance.

Fowler C., and P. Mooney. 1990. *Shattering: Food, Politics, and the Loss of Genetic Diversity.* University of Arizona Press, Tucson, AZ.

Gasser, Charles S., and Robert T. Fraley. 1992. Transgenic Crops. *Scientific American.* June, pp 62–69.

Giddings, Luthar Val, and Gabrielle Persley. 1990. Biotechnology and biodiversity. Unpublished manuscript prepared for the UNEP Negotiations on the Convention on Biological Diversity. U.S. Department of Agriculture, Hyattsville, MD, and International Service for National Agricultural Research, The Hague, Netherlands.

Gladwell, Malcolm. 1990. Genetics: Taking Natural Antifreeze from Flounder. *Washington Post.* 23 July p. A2.

IBA [Industrial Biotechnology Association]. 1992. U.S. biotechnology industry fact sheet. IBA, Washington, D.C.

IFAS [Institute for Food and Agricultural Sciences]. 1990. Press release. Gainesville, FL.

Juma, Calestous. 1989. *The Gene Hunters: Biotechnology and the Scramble for Seeds.* Princeton, NJ: Princeton University Press.

Khalil, Mohamed H., Walter V. Reid, Calestous Juma. 1992. Property rights, biotechnology and genetic resources. *Biopolicy International Series* No. 7, African Centre for Technology Studies, Nairobi, Kenya.

King, Stephen R. 1992. Conservation and Tropical Medicinal Plant Research, mimeo, Shaman Pharmaceuticals, Inc.

Kloppenburg, Jack, and Silva Rodriguez. 1992. Conservationists or corsairs? *Seedling* 9(2-3):12–17.

Kokwaro, J.O. 1976. *Medicinal Plants of East Africa*. East African Literature Bureau, Kampala, Nairobi, Dar es Salaam.

Lesser, William. 1990. An overview of intellectual property systems. Pp. 5–15 *in*: W.E. Siebeck (ed.) *Strengthening Protection of Intellectual Property in Developing Countries*. World Bank Discussion Paper 112. World Bank, Washington, D.C.

Lisansky, S.G., and J. Coombs. 1989. *Funding Mechanisms for the Fund for Biological Diversity*. CPL Scientific Limited, Newbury, U.K.

McChesney, James. 1992. Biological Diversity, Chemical Diversity and the Search for New Pharmaceuticals. Paper presented at the Symposium on Tropical Forest Medical Resources and the Conservation of Biodiversity, Rainforest Alliance, New York, January 1992.

Molnar, Joseph J., and Henry Kinnucan. 1989. Introduction: The Biotechnology Revolution. *In* J. J. Molnar and H. Kinnucan (eds.) *Biotechnology and the New Agricultural Revolution*. pp 1–18. Westview Press, Boulder, CO.

Mooney, Pat Roy. 1983. The law of the seed. *Development Dialogue* 1983(1-2):1–172.

NIH [National Institutes of Health], National Institute of Mental Health, National Science Foundation, and U.S. Agency for International Development. 1992. International Cooperative Biodiversity Groups: Request for Applications. June 12, Washington, D.C.

Office of Technology Assessment (OTA). 1987. *Technologies to Maintain Biological Diversity*. Washington D.C.: U.S. Congress, U.S. Government Printing Office.

Office of Technology Assessment (OTA). 1991. *Biotechnology in a Global Economy*. Washington D.C.: U.S. Congress, U.S. Government Printing Office.

Oldfield, Margery L. 1984. *The Value of Conserving Genetic Resources*. U.S. Department of Interior, National Park Service, Washington, D.C.

Principe, Peter P. 1989. The economic significance of plants and their constituents as drugs. Pp. 1–17 *in*: H. Wagner, H. Hikino, and N.R. Farnsworth (eds.) *Economic and Medicinal Plant Research, Volume 3*. Academic Press, London, U.K.

Principe, Peter P. Unpublished manuscript. Monetizing the pharmacological benefits of plants.

Raines, Lisa J. 1991. Protecting Biotechnology's Pioneers. *Issues in Science and Technology*. Winter 1991–92, pp. 33–39.

Roberts, Leslie. 1992. NIH gene patents, round two. *Science* 255: 912–913.

Sears, Cathy. 1992. Jungle potions. *American Health*. October 1992.

Sedjo, Roger A. 1988. Property rights and the protection of plant genetic resources. Pp. 293–314 *in:* J.R. Kloppenburg, Jr. (ed) *Seeds and Sovereignty*. Duke University Press, Durham N.C.

Sedjo, Roger A. 1990. Property rights, genetic resources, and the protection of biotechnological development. Unpublished manuscript, Resources for the Future, Washington, D.C. January 3.

Sedjo, Roger A. 1992. Property rights, genetic resources, and biotechnological change. *Journal of Law and Economics* 35:199–213.

Siebeck, W.E. (ed.). 1990. *Strengthening Protection of Intellectual Property in Developing Countries*. World Bank Discussion Paper 112. World Bank, Washington, D.C.

Simpson, R. David. 1992. Transactional arrangements and the commercialization of tropical biodiversity. Resources for the Future Discussion Paper, Washington, D.C.

Sochaczewski, Paul Spencer. 1992. Marine biodiversity: who benefits, who pays? Unpublished manuscript. World Wide Fund for Nature, Gland, Switzerland.

Stone, Richard. 1992. A biopesticidal tree begins to blossom. *Science* 255:1070.

U.S. Supreme Court. 1980. United States Supreme Court Cases 447:303. U.S. Government Printing Office, Washington, D.C.

*Wall Street Journal*. 1992. April 24, 1992.

Ward, Mike, and Andy Coghlan. 1991. Free genes for sweet potatoes. *New Scientist*. 16 February:28.

World Bank. 1991. *Agricultural Biotechnology: The Next Green Revolution?* World Bank Technical Paper No. 133. Washington, D.C.

World Resources Institute et. al. 1992. *Global Biodiversity Strategy*. WRI, IUCN, UNEP, Washington, D.C.