SCIENCE ON THE PERIPHERY ENRICHES MAINSTREAM SCIENCE, BUT AT WHAT COST?

The Case of Ethnobotany

Subbiah Arunachalam
Central Electrochemical Research Institute,
Karaikudi (India)

Introduction

This study is about cross-cultural transfer of knowledge. It is about the Western world learning from and taking advantage of non-Western systems of knowledge, especially in the area of plants and their medicinal uses. I begin with the limitations to the concept of universality of science and the characteristics of the periphery and then examine how advanced countries of the North are learning from and adapting alternative systems of medicine. In particular, I examine how government agencies, academia and multinational pharmaceutical companies in the advanced countries are taking advantage of the enormous plant wealth of the South and the traditional knowledge about the medicinal uses of the plants of the folk healers. I end with the ethical and political implications of this unequal transaction.

Science is a truly global endeavour that knows no frontiers. Together with technology, science has long been recognized as an essential driving force in the development process. In principle, anyone, anywhere can contribute to the growth of knowledge in the sciences and take advantage and make use of the collective knowledge – provided one has the inclination and capacity to do so. Also, scientific findings, be they concerned with the Sun and the stars, the human body, the plant, animal and mineral wealth on our globe, or abstract phenomena such as mathematical equations, are universally valid, irrespective of whoever discovers them. The cognitive content of science, with rare exceptions, is context free. To that extent science is universal. But in reality there are limitations to the universality of science: largely a result of the vast differences in the social, intellectual and economic structures of the different civilizations (1) (2).

The Centre-Periphery Dichotomy

In the real world, production and efficient utilization of scientific knowledge are highly concentrated in a few countries. A large majority of countries – those on the periphery,

Table 1. Fifteen Leading Developing Countries, Ranked According to Number of Mainstream Publications Produced (a)

	1973 (b)		1981-1985 (c)		1991	
Rank	**Country**	**Number of publications**	**Country**	**Number of publications**	**Country**	**Number of publications** (annual average)
1	India	6,880	India	10,116	India	10,468
2	Argentina	764	People's Rep. China	1,669	People's Rep. China	6,630
3	Egypt	683	Brazil	1,397	Brazil	3,438
4	Brazil	573	Argentina	1,079	Taiwan	2,815
5	Mexico	368	Egypt	956	Argentina	1,864
6	Chile	356	Nigeria	752	South Korea	1,818
7	Nigeria	280	Mexico	667	Egypt	1,688
8	Venezuela	200	Chile	563	Mexico	1,458
9	Taiwan	186	Taiwan	485	Chile	1,088
10	Iran	174	Hong Kong	348	Hong Kong	965
11	Malaysia	138	Saudi Arabia	301	Saudi Arabia	752
12	Kenya	125	South Korea	296	Nigeria	742
13	Singapore	120	Venezuela	279	Singapore	658
14	Thailand	117	Kenya	241	Venezuela	466
15	Lebanon	114	Singapore	200	Kenya	372

a) All data based on *SCI of ISI*, Philadelphia.
b) Data from Gaillard J. in *The Uncertain Quest*, UNU Press, Tokyo. (8)
c) Based on A., Schubert, W. Glanzel and T. Braun, *Scientometrics* 16 (1989) 3-478.

contribute precious little to the growth of scientific knowledge (3). The nature of the relations between the centre and the periphery tends to constantly bring to the fore the conditions of underdevelopment, and to widen the gap between developed and underdeveloped countries. As in development economics, in science and technology also, the periphery is very much dependent on the centre. Peripheral countries perform little research and depend on imported books and journals. Education in these countries, at least in science and technology, is based on foreign knowledge and much of the technology is imported.

I have discussed the nature of peripherality in science in earlier papers (4-6). In essence, science on the periphery is characterized by (i) absence of a viable scientific community (ii) an insularity resulting from inadequate access to relevant information and inadequate communication within the local scientific community and with international invisible colleges; (iii) an unduly long time lag before participants in peripheral societies can take part in hot/emerging research fronts; (iv) weak institutional infrastructures (in, for example, academies, research journals, and, more importantly, peer review systems); (v) an excessive dependence on science done in the centre, the source from which influence radiates, for its growth and sustenance; and, (vi) negligible contribution to the world's pool of knowledge, as seen from publication and citation impact data.

Science, at best, is a marginal activity in Third World countries. More importantly, it is rarely, if ever, that scientists on the periphery take part in the collective endeavour of setting the research agenda in any discipline or research front. No wonder that the centre views the periphery as a source merely of data gathering and survey-related research and not as a partner in the tasks of theoretical synthesis and proposing new theoretical configurations (7).

While in earlier work my interest was to look for ways by which science done on the periphery could be assimilated into mainstream science, in the present study I will look at how, in centre-periphery relations, the centre always takes advantage of the periphery – even in areas where the periphery has traditional strength.

Some Indicators of Peripheral Science

On the basis of papers indexed in *Science Citation Index,* developing countries (more than 120 of them) are credited with approximately 5-6 per cent of the world's scientific papers. This figure may be on the low side, as coverage of developing country publications in SCI is not comprehensive. It covers less than a dozen Indian journals. However, China and India together account for more than 7.0 per cent of entries in *Chemical Abstracts,* which is among the best of the secondary services in terms of the comprehensiveness of coverage of the literature. As Davidson Frame *et al.* (3). have pointed out, the distribution of mainstream science production – with the top ten countries producing about 80 percent of the world's scientific literature, is even more skewed than the distribution of wealth among nations.

Even within the developing countries (and regions) there is tremendous disparity in the distribution of science (8, 9). Table 1 shows how the position of the top 15 developing countries have varied over time. The scientific output of some of the leading developing countries, barring India and China, is less than that of a single university in scientifically advanced countries such as the USA and the UK. Moreover, if one considers the number of papers published in only the top journals (such as *Journal of the American Chemical Society, Nature, Cell* and *Science),* many university departments in the West publish larger numbers of papers than all the laboratories in India put together (Private communication from Prof. C.N.R. Rao, FRS, one of India's senior science policy-makers).

Apart from their low share in the enterprise of knowledge production, developing countries contribute even less to the growth of knowledge. Their work is rarely used and is cited much less often than their share of the world literature would warrant (9).

Often, scientists from developing countries are reduced to the status of "also rans". Very few of them are in referees panels or on the editorial boards of mainstream journals. Very few of them attend international conferences or are noticed by their peers. Even fewer are members of international invisible colleges or on the worldwide electronic mail network. Their access to information is poor (10). Their libraries are poorly equipped and only a very small percentage of them has access to online searching facilities and electronic databases. Indeed, the introduction of new information technologies such as online searching, electronic journals, etc., has helped to further marginalize scientists in developing countries. While the entire Western world is connected by Internet, most developing country scientists are in no position to use even basic telephone and fax facilities. How can they play the role of an equal partner? The periphery is not merely geographical, viz., far away (physically) from where the action is, but also intellectual. A vast majority of scientists in the developing world are scientists in name only (11).

Comparing science in the developing countries with that in advanced countries, one is reminded of Ilie Nastase's brief but telling comment on his contemporary Bjon Borg's absolute mastery in tennis in the 1970s: "They should send Borg to another planet. We play tennis, he plays something else"! Only the difference between mainstream science and science on the periphery is even more pronounced, so much so the late Michael Moravcsik has compared the scientists in developing countries to a bird whose wings have been clipped but nevertheless tries to fly (12).

Often developing country scientists work on problems that are of no great current relevance. Thus, it is no wonder that they tend to quote relatively old references. A cursory glance at the voluminous citing and cited journal package data provided in *Journal Citation Reports (JCR)* would reveal that most journals published from the developing countries quote a much higher percentage of older references and a much lower percentage of recent references than mainstream journals in the same subject areas (6). More importantly, one would also see a tremendously skewed citation balance. Most developing country journals quote a very large percentage of papers published in advanced country journals. But the articles published in developing country journals are rarely quoted.

We also find that not only does most of peripheral science appear in low-impact journals (as well as in non-*SCI* journals), it also has a low relative citation rate. That is to say, papers from the periphery are cited less often than papers from elsewhere that have been published in the same journals. Another striking feature of peripheral science is that it rarely shows signs of interdisciplinarity or internationality. A large portion of citations to peripheral country journals are from scientists from the same country and researchers from the same field. Thus, science on the periphery is somewhat like an island that depends on imports from the dominant countries for its survival but has very little to export (13). Peripherality, however, is not uniform across the board. Using citation analytic methods based on *JCR* data, we have shown in earlier work that, although overall science conducted in India is poorly cited, parts of India's scientific enterprise are cognitively better related to world science (6). For example, in India, areas such as astronomy, and to some extent biochemistry and physics, are closer to mainstream science than are others. Not surprisingly, Indian astronomers, biochemists, and to some extent physicists, are also the ones who have better international connections and who "communicate beyond their boundaries" far more often than do other Indian scientists.

It should be remembered, however, that such inferences based on citation data have to be used with caution, especially in biology-based disciplines such as agriculture and medicine as distinct from physics, chemistry and related fields. This is largely due to the varying degree of compactness of the literature in these different fields, and the greater dependence of medicine and agriculture on local needs and practices. It will not, therefore, be prudent to compare the productivity, impact and communication behaviour of agricultural scientists in Thailand with those of physicists in India. The latter may be working on essentially the same problem areas or in the same genre as their counterparts in North America and Western Europe.

Alternative Systems

We have thus far seen that much as they might try the developing countries are not able to play a significant part in the international enterprise of science, and that their contribution to the growth of the world's pool of knowledge is meagre. They rarely provide the shoulders on which others can stand to see further. Much of their work is in the nature of following rather than path breaking or leading. And the flow of knowledge is essentially unidirectional, from the centre to the periphery. So far we have only looked at science as it is currently practiced in the advanced countries of the world (the growth of which is reflected in journal publications). This is not, however, the only system of scientific knowledge.

At various points in history, certain societies proved to be far more efficient than others in the production and mastery of scientific knowledge and the exploitation of technical progress. India, China, Japan and the Middle East all had well-developed scientific traditions, elaborate and firmly established theories of life and well-established traditions of education (14). In what became Latin America, the Mayan, Aztec and Incan civilizations also had equally interesting high cultures that would not have been possible without mastery over science and technology much beyond the rudimentary level.

But ever since modern science came on the scene sometime in 17th century Europe, with its basis rooted in rationality and the conception that Nature is measurable and therefore potentially controllable, it turned out to be an unprecedented "intellectual revolution", a radical departure from the past and a powerful engine of growth and progress. Its growth was so rapid and its sway so sweeping, it virtually eclipsed pre-Western scientific traditions and knowledge systems.

Ironically, modern science is now looking to those very nearly forgotten systems, albeit in a small way.

This is nowhere else so striking as in the area of plant-based scientific knowledge. Despite tremendous advances and a long list of successes, modern Western medical knowledge (based on molecular level approaches to drug development and therapy) has a long way to go before it can handle many of the diseases that continue, untamed. In addition, health care costs are becoming unaffordable for many, even in the affluent countries of the West. Together, these factors have led to a state of crisis. One of the steps taken by the scientifically advanced affluent countries towards overcoming this crisis is to look at traditional systems of medicine with a view to taking advantage of their strengths and assimilating them into the Western system of medicine.

Efforts in the United States

In the USA, government agencies and universities are taking steps to assimilate (and integrate) the best of non-Western medical systems into established medicine. For example, in 1992, the Office of Alternative Medicine (OAM) was set up under the National Institute of Health (NIH), starting with an annual budget of about $ 2 million. President Clinton raised this figure to $ 3.5 million for the fiscal year 1994. This substantial rise (even if it was only a small portion of NIH's overall budget of $ 11 billion), is an indication of the growing interest and support for research in alternative medicine in many established centres of biomedical research.

OAM held its first technology assessment conference at NIH during 11-13 July, 1994. Conferees discussed methodologies appropriate to the study of non-Western traditional medical practices with a view to assimilating all information of potential use in current Western medical practice. Needless to say, such conferences will help integration and bring about a synergy between the establishment medicine of the West and traditional medical systems of the whole world. As Salomon concluded (1), "the range of rationalities needs to be recognized by stressing the way they complement one another, rather than setting them against each other. Nor is their coexistence neutral: it leads to positive interactions and it is well known that non-Western medicine can have beneficial effects on cases of chronic and functional disorders".

The exploratory research programmes funded by OAM include, for example, the exploration of hatha yoga for illicit drug users (Harvard Medical School); examination of ayurvedic herbals for Parkinson's disease (Southern Illinois School of Medicine); investigation of music therapy for psychological adjustment after brain surgery (Pennsylvania State University College of Medicine); the study of massage therapy to counter HIV (Medical College of Ohio). Many of the techniques now undergoing scrutiny by accepted methods of Western biomedical and clinical research originate in ancient systems of Indian and Chinese medical practice (15).

While most of the research is clinical or outcomes-oriented investigation, a synergy is developing with a number of basic science disciplines, some brand new, as questions arise about the underlying biochemical mechanisms of, for example, demonstrable mind-body interactions (15).

Apart from OAM, which awarded thirty grants in 1993, and other US government-funded such as the National Heart, Lung and Blood Institute, National Institute of Drug Abuse, National Institute of Allergy and Infectious Diseases, and the National Cancer Institute, several private philanthropic foundations in the USA (such as the MacArthur Foundation in Chicago, which currently invests $ 3 million annually, and the Fetzer Institute in Kalamazoo, Michigan, with annual investment of $ 5 million) are also supporting research into alternative medicine (16). To be fair, it must be admitted that the total funding is minimal compared to the overall investment in mainstream medical research.

Important, however, is the growing realization in the West that alternative medicine is based on an integrative approach to human health that has been lost in much of Western medical practice, and that it can provide a corrective whole-body view to the conventional (Western) specialized approach of biomedical science. Such recognition has led several top medical schools in USA to introduce alternative medicine components into their curricula, with a view to helping tomorrow's biomedical professionals broaden their awareness of the healing arts and to inform them of approaches to research that had not been a normal part of their curriculum. For example, students of Columbia are taught nutritional medicine, hypnosis, biofeedback, mind body medicine, etc. Researchers at the University of Maryland School of Medicine, Baltimore, are examining new ways of looking at acupuncture and pain studies with support from the Maurice Laing Foundation, London.

The West no longer dismisses sciences based on a different rationality from that of Western science (1). For instance, Deepak Chopra's books (17-20) on total health emphasising the virtues of ayurveda and meditation have sold tens of thousands of copies. According to Chopra (20), there are more than 6,000 doctors in the USA, who have integrated ayurveda and Indian meditation techniques in their practice. Today, American and European supermarkets and specialty herbal shops stock dozens of herbal teas, most of them learnt from traditional societies, says Michael Balick, Director of the Institute of Economic Botany, New York (21). Dr. Balick was recently in India to learn about the ancient Indian medical system of ayurveda. He and other ethnobotanists are more like anthropologists; they travel to distant lands and live with traditional healers (most of whom live in poverty) and learn from them as students would from their teachers (22). This awakening has come at a time when the cellular and molecular technology has developed to such a level that it can be used to gain deep understanding of how alternative medicine works. Interestingly, all this is happening at a time when Americans are examining their own culture and are becoming increasingly aware that "all cultures influence and borrow from one another", that "traditional" American culture has always been multicultural and that "mainstream" and "margin" may no longer make sense (23).

Of central importance here is the methodical process employed to assimilate traditional into established medicine: beginning with a determination of the strengths of traditional systems to its absorbtion, after careful scrutiny and research, into established medicine. This process, which has just only begun, is best evident in the way the West uses ethnobotany, an area in which both academic researchers and the pharmaceutical industry are collaborating (24-27).

Ethnobotanical Alternatives

Until recently, the dominant mode of drug development was to synthesise a large number of chemical compounds and test them through a very elaborate procedure to determine their efficacy. A major advance in this process occurred with the introduction of powerful computers. For example, a consortium of ten pharmaceutical companies – most of them German, with one or two Japanese, was established about a decade ago. This was accomplished with funds from the participating companies (in proportion to the number of doctorates employed in their R&D Divisions) and a matching grant from the German government to develop new drugs for a variety of diseases. The consortium, led by Hoechst, used the analytico-synthetic method to identify molecules having a high curative potential. They used what can be called computer heuristic procedures; thus saving on the cost of synthesising and testing a very large number of chemical compounds. Since then, rational drug design based on state-of-the-art techniques in pharmacophore model generation, data base search strategies, computer aided compound selection, prediction of relationships between biological activity and molecular structure, and pseudo-receptor model generation, has gained importance. Pharmaceutical companies such as Merck and BioCad and computer-oriented companies such as Hewlett Packard and Molecular Simulations Inc. are active in this area. This entire development is well within the Western pradigm of biomolecular science.

In contrast, in recent years, some major players in the pharmaceutical industry are trying to take advantage of the medical wisdom available in traditional societies (in, for example, Latin America, India, Africa and China) (28-30).

Of course, plant-based medicines are not new to the Western pharmacopeia. Although much of the plant wealth and traditional societies having the wisdom to use this wealth reside in the developing countries, particularly in the tropical rain forests and the mountain ranges, many parts of the advanced world have also their share of the plant wealth and wisdom. For example, as early as 1597 John Gerard wrote his treatise entitled *The Herbal...* (31), perhaps the first comprehensive ethnobotanical study of the Northern European tribe (32). In this book, Gerard described all the herbal remedies used by apothecaries of his day. In 1775 the English physician William Withering had recorded the powerful cardiotonic effect of the leaves of *Digitalis purpurea* on patients suffering from dropsy. And, as early as in 1897, Bayer, the German pharmaceutical major, first marketed aspirin, which is nothing more than a derivative of an extract of willow bark *(Filipendula ulmaria)* that has traditionally been known as a herbal cure for fever and inflammation. Since then the interest of drug companies in plant-based medicines has waxed and waned (33). During the 1930s and 1940s there was considerable research on plant-based drugs, but this was phased out as the pharmaceutical companies placed more faith in their ability to synthesize the necessary drugs. In addition, the discovery of antibiotics, derived from fungal and other micro-organisms, pushed the search for plant-based drugs to the backburner.

It was at this juncture that the synthesis of therapeutic molecules (based on structure/property/biological activity relations of chemical compounds, arrived by using computer heuristic procedures) looked like a serious possibility. This route to synthetic drugs is still being pursued and the increasing capabilities of desktop computers and

3D-visualization equipment and improvements in the software should make this approach to drug discovery even more attractive. But pharmaceutical industry sources say that "synthetic methods are extremely interesting from a scientific point of view, but from a commercial point of view they probably won't be very competitive". On top of it we do not yet know how to synthesize many complex molecules. It is against this background the pharmaceutical industry is re-discovering a rich resource which has been waiting for millennia to be exploited, viz. the plant wealth in the forests of Asia, Africa and Latin America.

A small but growing group of ethnobotanists – researchers who study the relationships between plants and people – is making a significant contribution to drug discovery by bridging ancient wisdom of the tribes around the world and modern Western medical practice.(32-35) Among the notable contributors are Gunnar Samuelson and Lars Bohlin of the University of Uppsala, both students of the distinguished Swedish ethnobotanist Finn Sandberg, Richard Evans Schultes of Harvard University, Paul Alan Cox of the Brigham Young University and Michael J Balik of the New York Botanical Garden at Bronx, both students of Schultes, Brent Berlin of the University of California at Berkeley, Walter H Lewis of Washington University, along with several French Institutes, Orstom being one wellknown among them.

The vigorous search for medicinal compounds through the ethnobotanical route that began in the early 1980s led to the identification of many medicinally useful plants. For example, working in Colombia, Schultes (38) alone studied more than 1500 species of plants which are valued by the aboriginal population for their biological activity. Of these more than 1500 species, 44 are employed in the preparation of arrow poisons, 40 as fish poisons, 59 for treating fevers, 13 as sacred hallucinogens, six as stimulants, four as oral contraceptives, seven for treating cardiovascular problems, 74 for dealing with dental problems, 28 as purgatives, 31 as insecticides and insect repellents, and 36 as vermifuges. Many of the lead compounds derived from these searches exhibit potent antiviral, antifungal or anticancer effects.

Some important developments include prostratin extracted from the Samoan rain forest tree *Homalanthus nutans,* for possible anticancer use, a flavanone with anti-inflammatory properties isolated from the bark of the Samoan tree *Erythrina variegata,* a new compound that kills parasitic worms in the stomach, which was extracted from a relative of the ginger plant grown in Thailand, called *Curcuma comosa,* and taspine isolated from a Peruvian tree sap for hastening the healing of wounds. Balick has isolated a substance from a plant in Belize, which could eventually find use in the treatment of AIDS. A partial list of drugs derived from ethnobotanical leads is given in Table 2 (39)

To assist in the correlation of knowledge of natural products, Professor Norman Farnsworth (40) of the University of Illinois at Chicago has constructed NARPALERT, a database drawing on more than 100,000 scientific articles with references to more than 43,000 species of plant or animal and more than 100,000 chemical compounds. One good thing is this database is available free of charge to scientists in developing countries.

The Royal Danish School of Pharmacy, Copenhagen, is collaborating with the Tropical Botanical Garden and Research Institute, Thiruvananthapuram (TBGRI), on a research programme on plant-derived drugs and on the construction of a database on ethno-

Table 2. Fifty Drugs Discovered from Ethnobotanical Leads

Drugs	Medical use	Plant source
Ajmaline	For heart arrhytmia	*Rauvolfia* spp.
Aspirin	Analgesic, antiinflammatory	*Filipendula ulmaria*
Atropine	Pupil dilator	*Atropa belladonna*
Benzoin	Oral disinfectant	*Styrax tonkinensis*
Caffeine	Stimulant	*Camellia sinensis*
Camphor	For rheumatic pain	*Cinnamomum camphora*
Cascara	Purgative	*Rhamnus purshiana*
Cocaine	Ophthalmic anaesthetic	*Erythoxylum coca*
Codeine	Analgesic, antitussive	*Papaver somniferum*
Colchicine	For gout	*Colchicium autumnale*
Demecolcine	For leukaemia, lymphomata	*Colchicium autumnale*
Deserpidine	Antihypertensive	*Rauvolfia canescens*
Dicoumarol	Antithrombotic	*Melilotus officinalis*
Digoxin	For atrial fibrillation	*Digitalis purpurea*
Digitoxin	For atrial fibrillation	*Digitalis purpurea*
Emetine	For amoebic dysentery	*Psychotria ipecacuanha*
Ephedrine	Bronchodilator	*Ephedra sinica*
Eugenol	For toothache	*Syzygium aromaticum*
Gallotanins	Haemorrhoid suppository	*Hamamelis virginia*
Hyoscyamine	Anticholinergic	*Hyoscyamus niger*
Ipecac	Emetic	*Psychotria ipecacuanha*
Ipratorium	Bronchodilator	*Hyoscyamus niger*
Morphine	Analgesic	*Papaver somniferum*
Noscapine	Antitussive	*Papaver somniferum*
Papain	Attenuator of mucus	*Carica papaya*
Papaverine	Antispasmodic	*Papaver somniferum*
Physostigmine	For glaucoma	*Physostigma venenosum*
Picrotoxin	Barbiturate antidote	*Anamirta cocculus*
Pilocarpine	For glaucoma	*Pilocarpus jaborandi*
Podophyllotoxin	For condyloma acuminatum	*Podophyllum peltatum*
Proscillaridin	For cardiad malfunction	*Drimia maritima*
Protoveratrine	Antihypertensive	*Veratrum album*
Pseudoephedrine	For rhinitis	*Ephedra sinica*
Psoralen	For vitiligo	*Psoralea corylifolia*
Quinine	For malaria prophylaxis	*Cinchona pubescens*
Quinidine	For cardiac arrhythmia	*Cinchona pubescens*
Rescinnamine	Antihypertensive	*R. serpentia*
Reserpine	Antihypertensive	*R. serpentia*
Sennoside A, B	Laxative	*Cassia angustifolia*
Scopalamine	For motion sickness	*Datura stramonium*
Sigmasterol	Steroidal precursor	*Physostigma venenosum*
Strophanthin	For congestive heart failure	*Strophanthus gratus*
Tubocurarine	Muscle relaxant	*Chondrodendron tomentosum*
Teniposide	For bladder neoplasms	*Podophyllum peltatum*
Tetrahydro-cannabinol	Antiemetic	*Cannabis sativa*
Theophylline	Diuretic, antiasthmatic	*Camellia sinensis*
Toxiferine	Relaxant in surgery	*Strychnos guianensis*
Vinblastine	For Hodgkin's disease	*Catharanthus roseus*
Vincristine	For paediatric leukaemia	*Catharanthus roseus*
Xanthotoxin	For vitiligo	*Ammi majus*

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pharmacology of Indian medicinal plants (Personal communication from Dr. Pushpangadan, Director, TBGRI).

It is indeed surprising that despite the fact that 25% of all prescription medicines are derived from plants, hardly 10% of the world's plants have ever been looked at by modern screening methods, says Peter Hylands of ESCAgenetics Corporation, San Carlos, California. Today plant extracts from Brazil arrive at ESCAgenetics laboratories at the rate of 10,000 per year. Each one of these extracts is subjected to screening involving 20 to 30 tests for activity against various forms of cancer, AIDS, auto immune diseases, fevers, inflammation and many other conditions. Indeed ESCAgenetics scientists have succeeded in producing taxol from such plant sources, taking advantage of the plant's natural metabolism. In fact, as Georg Anders-Shonberg, Executive Director for natural products chemistry at Merck Sharp & Dohme Research Laboratories, points out, the discovery of taxol in the bark of the Pacific yew tree gave a new stimulus to screen plants for new drugs. Merck has sealed a $ 1 million deal with Costa Rica's National Institute of Biodiversity to screen plants, insects and microorganisms for medicinal compounds. Costa Rica contains more biodiversity per acre than any other country. Merck has trained local Costa Ricans as parataxonomists to collect plants. ESCAgenetics has entered into an agreement with several institutions in Brazil to search the vast Amazon Basin and the Mata Atlantica for therapeutic compounds. G. D. Searl & Co. and Pfizer Inc. have similar agreements with the US botanical gardens.

Learning from Traditional Healers

Other companies have followed a more innovative and less expensive path. They take advantage of the traditional knowledge of plant-based medicines resident in the population of many developing countries. For example, Pharmagenesis based at Palo Alto, California, is investigating compounds used in Asian traditional medicine. As many of the Asian drugs are prepared from water extracts at high temperature and consumed orally, these therapeutic compounds should be stable, unlike proteins, and should be easily delivered in the body. Pharmagenesis also has compounds in clinical and preclinical testing as treatments for lupus and rheumatoid arthritis. Shaman Pharmaceuticals, South San Francisco, California, is tapping into the knowledge of traditional healers (known as shamans) of Ecuador and neighboring countries. Shaman was founded in 1989 on the premise that native healers' knowledge of medicinal plants could help unearth curative compounds and profits. Till now the company has made a huge net loss, but it has two compounds in clinical trials: Virend, a topical antiviral product for the treatment of herpes and Provir for a childhood ill called respiratory syncytial virus, both drugs retrieved from a South American croton tree. Currently Shaman's men are looking for leads in Ecuador, Peru, Papua New Guinea and West Africa and are searching for plants bearing chemical compounds against diabetes, nonaddictive painkillers, antivirals and antifungal compounds. For this purpose they are talking to medicinemen who are well known in their localities. Scientists of this company believe that not even 1% of the world's plants have been tested for therapeutic value.

Several decades ago, Ciba had devoted considerable resources to the work done on the isolation of reserpine, an antihypertensive, from the Indian snakeroot *(Rauvolfia* *serpentina)* obtained from India. Today Ciba-Geigy has an ongoing collaboration with the Beijing Institute of Botany and the Chinese Academy of Sciences in Shanghai, the two leading institutions in the field of Chinese herbal medicine. The company has also employed more than 40 men in Africa whose sole job is to talk to elderly men and women and find out how they deal with illness in the family and their community (Personal communication from Juan Rada of the Club of Rome and Digital Europe).

According to Michael Balick (21), ethnobotany is serious business and many more pharmaceutical companies would try to learn from traditional healers. The Institute of Economic Botany he directs has more than 5.7 million preserved plants in its herbarium! Needless to say, most of these were collected from outside the United States. Large quantities of *Rauvolfia serpentina, Vinca rosea* and other plant materials are being exported from India to pharmaceutical firms in Europe. Table 3 gives statistics on the export of medicinal plants from India.

Table 3. India's Exports of Plants and Parts of Plants Including Seeds and Fruits, Used Mostly in Pharmacy and to Some Extent in Insecticides, Perfumery, etc.
(Not an exhaustive list; only selected items are included)

Plant material	**Apr. 1990-Mar. 1991** (kg)	**Apr. 1991-Mar. 1992**
Ginzeng roots*	1,809,787	1,445,515
Psyllium (Isabgol)busk	13,781,969	14,393,015
Psyllium (Isabgol) seeds	2,866,525	3,151,394
Sandalwood chips & dust	3,525,055	3,011,717
Sarsaparilla	3,250	240
Senna leaves & pads	3,721,405	5,121,222
Tukmarla	337,932	359,042
Ayurvedic & Unaniherbs	2,633,604	3,350,562
Unab (Indian jujube)	18,847	8,668
Vinca rosea (herbs)	365,999	270,770
Total value of exports of this category of plant material	Rs 1217 million	Rs 1300 million

(*) Includes all varieties of the Ginzeng family, such as galangal, serpentina and zedovary. Data obtained from Government of India's official publications.

Even in non-medicinal applications such as pesticides, and fungicides, the developed world is waking up to the wisdom of the South. The enormous potential of the neem tree, known to Indians for millennia, was discovered in US only recently. But US firms have already taken several patents on neem products and are making huge profits. Indeed, the National Academy of Sciences of USA commissioned a panel of experts a few years ago to bring out a monograph titled *Neèm: A Tree for Solving Global Problems.* Recently, Duncon and Company of US has carried out research on neem, turmeric and ginger and has isolated the active ingredients. Another American firm, W R Grace has taken a patent for a neem extract which it calls as Margoson-O. Rohm and Haas Co. has taken both a European and a US patent on an insecticide based on hydrogenated neem extract. Terumo Corporation of Japan has taken several Japanese patents on neem-bark based polysaccharides that demonstrate antitumour and antimicrobial properties as well as enhance antibody formation. In contrast, Indian scientists are reluctant to patent their work, perhaps because the bulk of the work had already been accomplished by generations of anymous experimenters.

Thus, we see in their efforts to identify and absorb what is good and useful in other systems of knowledge the academia, the Government agencies and industries in the West act in a concerted manner. Also it is not merely an act of mere borrowing but value addition through research and the application of tools of Western system of knowledge. A case of true synergy.

The enormous biodiversity of the developing world and tremendous wisdom of the native tribes (both of which are in danger of rapid extinction) can, if properly tapped, lead to a plethora of drugs to combat many diseases. It is for this reason ethnobotanists and scouts of pharmaceutical firms in the West are fanning out into the jungles of Africa, Asia and Latin America. They full well realize that theirs is a race against time, as both plant species and the cultures which know about their medicinal value are both vanishing fast. It is indeed possible that millions of plant species which have not yet been phytochemically studied may vanish along with their medicinal values without us ever coming to know of them, thanks to afforestation, encroachment and processes of natural extinction (41). According to World Wide Fund for Nature, of the estimated 250,000 flowering plants believed to be in existence, tens of thousands remain undiscovered and only some 5,000 have been tested exhaustively for their pharmaceutical attributes. Most of these plants thrive in the warmth and wetness of tropical rain forests. But these forests are being destroyed at the rate of 40 hectares a minute – an area the size of Austria every year. Five plants become extinct everyday! "Who knows what weapons against cancer, AIDS, or afflictions yet to come were lost forever in today's batch of five?" WWF has many ongoing ethnobotanical projects in many countries.

Traditional Medicine in Developing Countries

It is not as if the traditional societies themselves are totally unaware of the richness of the flora and its tremendous potential in today's context. For example, Chinese researchers have recently come up with a treatment for malaria based on *Artemisia annua* known for more than 2000 years, which is shown to be far superior to quinine by WHO. The new preparation has been tested in China, Brazil, Vietnam, Thailand and Africa.

There is a resurgence of interest in traditional medicine in India, where several plant products are currently being evaluated in various stages of development, standardisations and clinical trials. Notable among the plants being tested are *Picrorhiza kuroa,* a perennial herb found in alpine Himalayas in the Kashmir-Sikkim region and *Withania somnifera* (known as Ashwagandha). Central Drug Research Institute, Lucknow, has found *P.kurroa* to have curative effect in liver diseases. Preliminary results have shown that its activity is even better than hepatoprotective drugs used in Europe. Researchers at Kasthurba Medical College, Manipal, have found that the extract of Ashwagandha root kills tumour cells on its own and hastens cure in combination with conventional radiotherapy. A third plant product – this one from *Curcuma longa* – has been found to be more effective

Table 4. Plants Used in Indian Ethnomedicine

For Intestinal diseases		
Acacia catechu	*Combretum roxburghii*	*Ludwigia adscendens*
Acalypha alnifolia	*Crinum pratense*	*Micromelum minutum*
Achyranthes bidentata	*Delphinium vestitum*	*Morinda angustifolia*
Alnus nepalensis	*Flacourtia indica*	*Nelsonia canescens*
Begonia palmata	*Glossogyne bidens*	*Neptunia triquetra*
Blumea fistulosa	*Hedyotis scandens*	*Picrasma japonica*
Boehmeria macrophylla	*Hybanthus enneaspermus*	*Pyrrosia adnescens*
Boerhaavia diffusa	*Hymenodictyon orixense*	*Sterculia villosa*
Careya arborea	*Indigofera linnaei*	*Tectaria coadunata*
Chromolaena odorata	*Knema linifolia*	*Tragia involucrata*
For Liver complaints		
Achyranthes porphyristachya	*Combretum pilosum*	
Alcea rosea	*Costus speciosus*	
Allamanda cathartica	*Cyperus rotundus*	
Barringtonia acutangula	*Euphorbia ligularia*	
Bauhinia purpurea	*Gouania tiliaefolia*	
Begonia palmata	*Hedyotis scandens*	
Berberis kumaonensis	*Helminthostachys zeylanica*	
Bergenia liguloto	*Hymenodictyon orxense*	
Betulo utilis	*Leea alata*	
Cissampelos pareira	*Lygodium flexuosum*	
Cochlospermum religiosum		
For skin diseases		
Aerva lanata	*Calotropis procera*	*Martynia annua*
Ampelocissus barbata	*Clematis buchananiana*	*Premna barbata*
Anogeissus latifolia	*Cheilanthes farinosa*	*Quercus leucotrichophora*
Arisaema jacquemontii	*Euphorbia nivulia*	*Ranunculus arvensis*
Artemisia japonica	*Euphorbia uniflora*	*Rhamnus triquetra*
Blepharispermum subsessile	*Flacourtia indica*	*Skimmia laureola*
Blumea laciniata	*Holarrhena antidysenterica*	*Strychnos nuxvomica*
Boehmeria macrophylla	*Holoptelia integrifolia*	
Caesalpinia pulcherrima	*Manihot esculenta*	
For joint diseases (gout and rheumatism)		
Ailanthus excelsa	*Chlorophytum arundinaceum*	*Hymenodictyon orixense*
Argemone mexicana	*Chrysanthemum pyrethroides*	*Laportea interrupta*
Aristolochia tagala	*Clerodendrum colebrookianum*	*Lindera pulcherrima*
Barringtonia acutangula	*Datura innoxia*	*Orthosiphon rubicundus*
Biophytum sensitivum	*Dillenia pentagyna*	*Pholidota imbricata*
Capparis sepiaria	*Fagopyrum esculentum*	*Polygala arvensis*
Cassia auriculata	*Gerbera piloselloides*	*Skimmia laureola*
Cassia tora	*Holarrhena antidysenterica*	*Strychnos nuxvomica*

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than phyenylbutazone against rheumatic arthritis and with less side effects. Researchers at Banaras Hindu University have found Brahmi, an ancient ayurvedic drug, to be effective in the management of mental deficiency and to possess neurotropic properties. They have already received proposals from the USA and Germany for joint research into the efficacy of ayurvedic preparations based on plants such as Sankhpushpi *(Canscora decussata)*, Jatamansi *(Nardostachys jatamansi)* Brahmi *(Centella asiatica)* and Ashwagandha *(Withania somnifera)*. They have not yet made any commitments in view of the uncertainties on patent and intellectual property rights following the signing of the GATT agreements. Other drugs based on ayurveda are under trial for kala-azar and infectious diseases of various kinds (42).

The All India Coordinated Research Project on Ethnobiology has identified several thousands of plants used routinely by about 400 tribes across India. At least 4000 of these plants were not known to possess any medicinal value, says Dr Pushpangadan, Director of the Tropical Botanical Garden and Research Institute, Thiruvanathapuram (TBGRI), which coordinates tribal medicinal plants research and conducts follow-up studies on such plants. Recently Dr. Pushpangadan's laboratory has helped Thiruvananthapuram Medical College conduct clinical trials of *Trichopus zeylanicus* used by the Kani tribes in the Western ghats region of Kerala, to combat fatigue (43).

India's Department of Biotechnology has set up three national gene banks, at Thiruvananthapuram, Lucknow and New Delhi, to gather and store rare, threatened and important species of medicinal and aromatic plants. India is also the coordinator for an international programme of the G-15 nations to set up a network of gene banks in member states. India's Council of Scientific and Industrial Research has produced a multi-volume series under the title *Wealth of India* which gives in-depth articles on India's plant and mineral wealth. This agency is also the publisher of the very useful secondary service *Medicinal and Aromatic Plants Abstracts* which is available in print and in CD-ROM forms.

Plants used in Indian ethnomedicine for intestinal diseases, liver complaints, skin diseases and joint diseases are listed in Table 4 (44). Some plants used in Nigeria are listed in Table 5, together with the constituents and potential applications (45). Considerable amount of research on medicinal plants has been carried out in India in the last five decades and a number of publications on Indian medicinal plants have also appeared in print (46-48).

In view of the recent wave of interest shown by the Western firms in developing, patenting and marketing plant-based products, India and other Third World countries should act quickly if they wish to take maximum advantage of their plant wealth. Developing countries should not abandon their traditional knowledge base, says Salomon (2). As the French title of his book indicates, the scribe in the town square still has his uses despite the advent of the most powerful computer. For that matter, the advent and rapid development of quantum mechanics have not rendered classical mechanics irrelevant!

Despite awareness of the tremendous potential of their plant wealth, especially its medicinal value, many Third World countries are unable to transform them into value-added marketable products, as well as the West does. Like in the days of old, develop-

Table 5. Nigerian Medicinal Plants with Potential Applications in Primary Health Care

Plant	Constituent(s)	Activity/Indications
Aframomum melegueta	Essential oil, shagoal, gingerol	Antimicrobial, rubefacient
Ageratum conyzoides	Ageratochromone	Wound healing
Azadirachta indica	Nortriterpenoids	Antimalarial, antipyretic, seed insecticidal
Balanites aegyptica	Steroidal glycosides, furanocoumarines	Laxative, antiinflammatory
Bridelia ferruginea	Coumestans, flavonoids	Antifungal, mouth infections
Butyrospermum paradoxum	Fatty acids	Emmollient, antiinflammatory
Cajanus cajan	Amino glycosides, phenylalanine	Management of sickle-cell anaemia
Carica papoya	Proteolytic enzymes (volatile oils in leaves)	For fevers, antidiabetic
Cassia spp.	Anthraquinone, glycosides	Laxative
Cola nitida	Caffeine, aromatic acids	Tonic
Cymbopogon citratus	Volatile oils	Diuretic, tonic
Dorstenia multiradiata	Leucoanthocyanidins	Antifungal, antiviral
Dracaena mannii	Saponins	Local antifungal, antiprotozoan
Eucalyptus globulus	Essential oil	Local antiseptic, colds, rubefacient
Garcinia kola	Biflavonoids	Antihepatotoxic, antiviral, adaptogen, plaque inhibitor
Morinda lucida	Anthraquinones	Antimalarial, jaundice
Ocimum gratissimum	Terpenes, xanthones	Antiseptic, coughs, fevers
Picralima nitida	Indole alkaloids	Antimalarial, broadspectrum antiprotozoan
Piper guineense	Lignans, alkaloids	Antimicrobial, insecticidal, tonic, antiinflammatory
Psidium guajava	Essential oils, vitamins	Carminative
Sabiaceae calycina	Alkaloids, flavonoids	Wound dressing, laxative
Schwenkia guineensis	Steroidal glycosides	Oral hygiene
Sclerocarya birrea	Catechins, flavonoids, amino acids	Antidiabetic, tonic
Tamarindus indica	Ascorbic acid, citrates	Laxative, nausea
Tetrapleura tetraptera	Saponins, coumarins	Antiinfective, tonic
Uvaria chamae	Chalcones, terpenes	Antimicrobial
Vernonia amygdalina	Sesquiterpenes, saponins	Tonic, antidiabetic
Xylopia aethiopica	Diterpenes	Tonic, carminative, antiviral
Zanthoxylum xanthoxyloides	Aromatic acids	Management of sickle-cell anaemia
Zingiber officinale	Terpenes	Antihypertensive, antihistamine

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ing countries export their plants as raw material to Western pharmaceutical firms which add value and make huge profits. According to a recent report in *Business World*, an Indian fortnightly, export of medicinal plants from India has shot up from around Rs 1,210 million in 1990-1991 to about Rs 1,630 million in 1994-1995. Of course, within the Third World there is a wide spectrum. At one end, we have the Ka'apor people of Brazil who do not have any recorded knowledge and whose entire knowledge base survives only through oral tradition.(32) Obviously, their knowledge base cannot be large and it cannot survive for long. It can at best be excellent knowledge for short term processes. In contrast, India has an extremely well-developed and integrated system of knowledge encompassing not only medicine, but the full range of human endeavours, going back to a few thousands of years. Even so, India is not able to take full advantage of the knowledge base in translating her herbal wealth and ancient medical wisdom into modern Western cures. The Indian pharmaceutical industry has made a beginning and is making and exporting drugs based on ancient Indian wisdom. The four leading companies producing traditional medicines, Himalaya, Charak, Zandu and Dabur, however, account for less than 2 % of the total pharmaceutical sales in India, which is dominated by allopathic medicines, but are now investing modest sums on research and are hoping to increase both their volume of business and profits substantially before the end of the decade. Even here, the West is far ahead. Says Dr. Pushpa Bhargava, one of India's leading life scientists: "The country has all the expertise to do what is required in this connection [converting India's plant wealth into drugs]. What, however, the country lacks is the tradition of doing the right things at the right time. People do the right things at the wrong time, generally far too late. If the present apathy continues, it would not be a surprise if in the next century India would be marketing its indigenous drugs under the licence of multinationals". Says Prof. C. R. Babu of the Delhi University's Department of Botany, "in spite of numerous conferences and resolutions, precious little has been done (in India] to discover new medicinal plants from unexplored areas. The North East (of India] is the centre for diversity of medicinal plants. Yet almost 75 percent of the rain forests remain unexplored. In fact, the active component in many plants of proven utility is yet to be identified and isolated. For most, there is no accepted method of extraction for utilization on a commercial scale". Objectively viewing the tremendous success of the West in exploiting the plant wealth and wisdom of the developing countries and the inability of the developing countries to take full advantage oftheir own resources and traditional knowledge base, one is reminded of Nobert Wiener's narration of the fight between the mongoose and the snake. Although there is not much difference between the two in terms of their physical strength, in every encounter, the mongoose emerges victorious because of its ability to plan and organize its strategy better.

Implications

There are many implications of the West's new-found interest in the knowledge systems of the traditional societies. The most obvious is the threat to biodiversity. Plant species can become extinct through overexploitation. For instance, *Prunus africana* is virtually eliminated from the forests of Cameroon, as its bark was found useful in treating prostate problems. In Brazil, various species of *Pilocarpus* are now endangered through their overexploitation for pilocarpine for the treatment of glaucoma. Promoting sustainable use of different plants in which useful products are discovered is vital. But profit-oriented pharmaceutical companies may not be inclined to devote time and money to promote afforestation and sustainable development.

The second problem concerns acculturation and introduction of "alien" civilization leading to destruction of ethnic and cultural diversity. The local traditions may surrender to the invading Western culture and modes of thought and behaviour. This happens even in societies which have a long history of learning and high intellectual attainments. For instance, the way in which science is taught in Indian schools today leaves much to be desired. The poor imitation of the Western mode of teaching science in Indian schools makes it difficult for children, if not impossible, to think of alternative approaches or answers to a given problem. With their stereotype image of science as knowledge gained under controlled conditions, often in illequipped classrooms and laboratories, they are bereft of a questioning spirit and the desire to seek personal verification of given knowledge. What is more, according to Prof. Krishna Kumar of the Delhi University, ayurveda, unani, siddha, traditional folk medicine and other alternative systems have no chance of appreciative mention in school literature, let alone application in the fundamentalist universe of school science. This is indeed unfortunate, especially when the West is trying to take full advantage of such traditional systems.

Says Indian environmentalist Vandana Shiva (49): "I see Science as a pluralistic enterprise which refers to different 'ways of knowing'. For me Science is not restricted to modern western science, but includes the knowledge systems of diverse cultures in different periods of history". This is precisely what will be lost in the process of acculturation.

Organic farming is gaining more and more adherents in the United States and elsewhere. But in India, the birthplace of organic farming, hardly any school, college or agricultural university teaches the ideas of the Japanese naturalist Masanobu Fukuoka, who has sharply criticised modern agricultural practices and has advocated a search for alternatives.

The third problem concerns the goals of the Western pharmaceutical companies. They are, naturally, keen to develop drugs for the ailments common to the advanced countries, such as AIDS, cancer, cardiovascular and nervous system disorders and microbial diseases, and not the diseases that are of great concern to the areas where the plants are collected, such as gastrointestinal and tropical diseases, leprosy, schistosomiasis, malaria and leishmaniasis (39). This tendency to concentrate on First World diseases has percolated to the Third World also. For example, in a recent study on medical research in India (50), I found that there was very little overlap between diseases which are prevalent in India and the areas in which Indian medical research was active. For example, there are nine million blind in India – more than in any other country – but India has hardly contributed anything to research in ophthalmology. However, there was some interest in cardiovascular and cancer research, although these are not among the major causes of mortality or morbidity in India.

The fourth question concerns the compensation received by the traditional societies from the advanced countries for the transfer of knowledge and material. For example, Western agriculture has benefited considerably from the germplasm collections made in the countries of the South, where most of the important food crops were developed. Powerful companies in industrialized countries are busy patenting indigenous knowledge built up over generations by farmers in developing countries (51-52). Indeed scholar-activists like the American sociologist Jack Kloppenburg have argued that this transfer of knowledge should attract the provisions of the Intellectual Property Rights and the West should be made to adequately compensate the old world for all gains (53). The Ottawa-based Rural Advancement Foundation International (RAFI) estimates that developing countries and their indigenous people are cheated to the extent of $ 5.0 billion a year through "biopiracy" (54). In another paper, RAFI has estimated that medicinal plants and microbials from the South contribute at least $ 30 billion a year to the North's wealthy pharmaceutical industry (55). This is the amount they would be entitled to in royalty payments if multinational food and drug companies paid for their plant varieties and knowledge. But what any company has paid so far is a pittance.

The current laws and international regulations are heavily loaded in favour of the developed countries and are scarcely designed to protect the interests of the traditional communities. The world's patent system provides protection only to private and corporate knowledge and not to community knowledge (56). The need of the hour is to evolve legislation that will ensure the rights of the people to their biological knowledge. Cox and Balick (29). believe that the indigenous peoples are entitled to the same intellectual property rights enjoyed by other investigators. Agarwal and Narain go one step further and suggest that the entire rural communities, not just the few participants in a programme, should get the benefit (56). It is important for developing country governments to enact legislation to control access to both wild and cultivated biodiversity. Agarwal and Narain (56) suggest that urgent steps should be taken to undertake documentation of traditional knowledge – just like documentation in a patent office.

Conclusion

To sum up, many developing countries are trying to do mainstream research, i.e. in the same paradigmatic genre as the scientifically advanced countries of the West. But it is becoming increasingly difficult for them to get fully assimilated as equal partners in this endeavour. The chances are even the better-endowed of them will continue to remain insignificant players. The West has now directed its attention to explore the scientific traditions of the developing societies, especially in the area of medicine and agriculture, and is poised to accomplish its goals with relative ease. In this effort it may even do better than the developing societies. Thus, the centre is not merely doing well, as is to be expected, in mainstream science which had its origin in Europe a few centuries ago, but also doing well in and deriving greater benefit than the periphery from the "sciences (of the periphery) based on a different rationality from that of Western science." Yet another example of the operation of the Mathew effect – the better endowed cornering a greater share. There are important moral and political implications to the West's exploitation of both the biodiversity and the accumulated knowledge of the traditional societies. The countries of the South have a strong case for adequate compensation.

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Correspondence should be adressed at: Lakshmi Vilas, 9 Vattanam Road, Devakottai 630 302, India.

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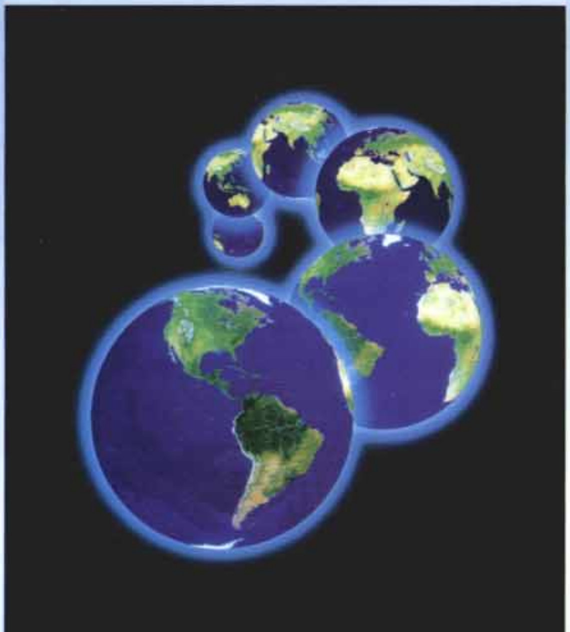

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