PLANTS, PEOPLE, AND CULTURE
The Science of Ethnobotany

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Plants That Heal

Walk into any pharmacy in the United States, Canada, or Western Europe and ask to examine any bottle of prescription medicine chosen at random. There is a one in four chance that the medicine you hold in your hand has an active ingredient derived from a plant. Most of these plant-derived drugs were originally discovered through the study of traditional cures and folk knowledge of indigenous peoples—the ethnobotanical approach. The pharmacognosist Norman Farnsworth, of the University of Illinois, estimates that 89 plant-derived drugs currently prescribed in the industrialized world were discovered by studying folk knowledge.

Consider again William Withering’s discovery of digitalis in the eighteenth century. Withering’s discovery depended on the same sequence of steps that lead to success in modern ethnobotanical drug discovery programs: (1) folk knowledge of a plant’s possible therapeutic activity accumulates; (2) a healer
This interior of an Ayurvedic medicine shop in the town of Kottakkal, Kerala State, in southern India, shows the vast array of products available for this system of traditional medicine.
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uses the plant for her patients; (3) the healer communicates her knowledge to a scientist; (4) the scientist collects and identifies the plant; (5) the scientist tests extracts of the plant with a bioassay (a preliminary screen for the desired pharmacological activity); (6) the scientist isolates a pure compound by using the bioassay to trace the source of the activity in the plant extract; and (7) the scientist determines the structure of the pure substance.

In the case of digitalis, knowledge concerning the use of the foxglove accumulated in the traditional healing systems of the British people as recorded in Gerard's herbal of 1597. In the eighteenth century a healer (the “old woman” in Shropshire) used the plant to treat dropsy, an ailment caused by inadequate pumping action of the heart. Hearing of the therapy's success, Withering interviewed the healer, who shared her remedy with him. Withering identified and collected foxglove and then tested extracts of its leaves by the only means of bioassay available to him: he gave it to his patients. Today it is considered unethical to screen untested substances on human populations, but in the eighteenth century Withering had no access to laboratory animals with dropsy. By the end of the nineteenth century, chemists were able to separate the components of the foxglove leaves through extraction with solvents (a process known as fractionation) and show that the observed cardiotonic effect was largely due to the cardiac glycosides. They determined the structures of the glycosides and named two of the most active ones digoxin and digitoxin.

Although William Withering is usually credited with the discovery of digitalis, there was a long interval between his record of the folk use of foxglove leaves and the production of pure digoxin and digitoxin on an industrial scale. This gap, extending nearly a century and a half, was bridged by the work of many other chemists, pharmacologists, and medical workers. Modern ethno-botanical research programs are designed to compress a process that once took centuries. Yet many factors far removed from scientific considerations influence the rate at which drugs are discovered and produced. Few, if any, drugs, are produced merely as research curiosities. Strong economic, social, and even political incentives are needed to fuel the arduous processes of discovering and developing drugs. The spread of new diseases, often as a result of human colonization of new habitats, and restricted access to drug supplies in time of war have often spurred innovation and resourcefulness. The power of social, political, and economic conditions to provide strong incentives for drug production can be clearly seen in the history of a drug very different from digitalis: quinine.
"Peruvian Bark" and the Discovery of Quinine

Quinine is an odorless white powder with an extraordinarily bitter taste. It is useful against malaria, the disease caused by mosquito-borne transmission of the protozoan *Plasmodium*. It is also used to treat cardiac arrhythmias. Although we often think of malaria as a tropical disease, it once was a serious health hazard in such temperate cities as Washington, St. Louis, London, and Rome. (Miasma, a nighttime vapor that rises from swamps and other wet places, was believed to cause malaria before mosquitoes were found to be the vector.)

Quinine is valued as a flavoring agent as well as a medicine. Most quinine imported into the United States is used to flavor tonic water. Yet the taste for the flavor of tonic water can be traced to the use of quinine as an antimalarial compound by British colonial forces in India. Since the blood serum level of quinine needed to protect against malaria is rather low, a daily gin and tonic may indeed have some small medicinal value in malarial regions.

The story of the West’s discovery of quinine begins in the late sixteenth and early seventeenth centuries, during the conquest of the Inca empire in Peru. The Spanish invaders became aware of a montane rain forest tree used by the Indians to treat fevers. A Spanish legend says that a soldier who was suffering from a bout of malaria in the wilderness drank the dark-brown water in a pool into which quinine trees had fallen. He then went to sleep, and when he awoke, he found that his fever had disappeared. Concluding that the bitter brown water was a “tea” made from the steeped stems and bark of the tree, he spread the word about its power to reduce his fever. Another Spanish legend tells of Indians who observed that sick animals came to drink at the tepid pools around which great stands of quinine trees grew.

In 1633 a Jesuit priest named Father Calancha described the healing properties of the tree in *The Chronicle of St. Augustine*:

> A tree grows which they call the fever tree in the country of Loxa, whose bark is the color of cinnamon. When made into a powder amounting to the weight of two silver coins and given as a beverage, it cures the fevers and . has produced miraculous cures in Lima.

Jesuits throughout Peru began using the bark to prevent and treat malaria. In 1645 Father Bartolome Tafur took some bark to Rome, where its use spread among clerics. Cardinal John de Lugo wrote a leaflet to be distributed with the bark. Because the miraculous “Peruvian bark” was so widely used, not a single
participant in the papal conclave of 1655 died of malaria—the first time in recorded history that a Roman convocation had been so spared. Peruvian bark was introduced to England as early as 1654, but British Protestants were reluctant to try a Catholic concoction. Oliver Cromwell, who refused to be “Jesuited” with the bark, died of malaria in 1658.

In 1670 a young apothecary named Robert Talbor gained fame in London by curing malaria with a secret formula. Talbor belittled the Peruvian bark, warning the public to “Beware of all palliative Cures and especially that known by the name of ‘Jesuit’s powder’.” After Talbor’s secret formula cured Charles II’s malaria, the king sent him to the French court, where he successfully treated the ailing son of Louis XIV. The French king paid 3000 gold crowns for Talbor’s secret, which Talbor stipulated could be published only after his death. It was then discovered that the “secret” was Peruvian bark.

Despite the fame of Peruvian bark, its botany remained unknown: no botanist had ever published a description or drawing of the tree from which it came because it grew in high rain forests in the Andes. In 1735 a French botanist named Joseph de Jussieu traveled to South America and after many travails found and described the tree, a small member of the Rubiaceae, or coffee family, that grows in the understory. In 1739 the Swedish taxonomist Carl Linnaeus named the genus Cinchona, a misspelling of the name of a Spanish countess who, legend claimed, had been healed by the bark.

In 1820 the French chemists Joseph Pelletier and Joseph Caventou isolated the alkaloid quinine from the bark and were awarded 10,000 francs by the Paris Institute of Science. Yet, although the purified alkaloid quinine had been discovered, no one could synthesize it. Quinine producers therefore continued to rely on massive supplies of bark collected from wild Cinchona trees. In 1880 Colombia alone exported 6 million pounds to Europe, all collected from undomesticated forest trees. The export value of Cinchona bark was so great that Bolivia, Colombia, Ecuador, and Peru attempted to maintain a tight monopoly on production by prohibiting the export of seeds or living plants. But the temptation to break the South American monopoly proved irresistible, and in 1852 Justus Hasskarl, the director of a Dutch botanical garden in Java, began a secret mission to smuggle Cinchona seeds out of South America.

Hasskarl’s plan was exposed by a German newspaper, but the following year he entered South America under an assumed name and traded a bag of gold to an official for Cinchona seeds. Returning to Java with his botanical bounty, he was immediately knighted by the Dutch government. As the trees matured, however, jubilation changed to dismay, for the quinine content of their bark proved to be disappointingly low. Clearly Cinchona trees differed
from strain to strain in the amount of alkaloids they produced. A second attempt to collect Cinchona seeds would be needed to produce a viable industry in Java.

Another opportunity to establish a Dutch quinine industry was inadvertently provided by an Australian, Charles Ledger, in 1861. Ledger had tried on several occasions to collect Cinchona seeds but was bewildered by the diversity of this genus—there are 40 species, and each species has countless strains. As it happened, seeds that Ledger had sold the British government produced trees with very low quinine content. However, Ledger eventually prevailed upon an Aymará Indian, Manuel Incra, to smuggle seeds from a species of Cinchona tree in Bolivia that was reputed to have high quinine content. Upon discovery of this infringement, the Bolivian government tortured Incra to death. Ledger traveled to Europe and attempted to sell his seeds to the British government. Because of the low alkaloid content of the Cinchona plants Ledger had provided earlier, the British government refused to buy any, but a pound of Ledger's seeds eventually found their way to the Dutch government. The Dutch paid the equivalent of $20 for them and sent them to Java to be planted. It was arguably the best $20 investment made in history.

As the trees matured, the Dutch were astonished to discover that their bark had a record alkaloid content of 13 percent. As the new alkaloid-rich strain came into production in Java, the harvesting of wild plants, which typically had lower quinine content, in South America waned. By 1930 the Dutch plantations in Java produced 22 million pounds of bark, yielding 97 percent of the world's quinine.

Yet eventually, this Dutch near-monopoly on quinine inadvertently threatened the stability of Western democracy. In 1940 the German army seized the entire European repository of quinine when it captured Amsterdam. When the Japanese conquered Indonesia in 1942, the United States and its allies were virtually without quinine supplies. There was a small Cinchona plantation in the Philippines, but it, too, fell to the Japanese only weeks after they annexed Java. The last Allied plane to leave the Philippines before the islands capitulated to the Japanese contained a singularly precious cargo: together with key Philippine personnel, the aircraft carried 4 million tiny Cinchona seeds. These were flown directly to Maryland. When they had germinated, they were sent to Costa Rica for planting. Although the evacuation of this Cinchona germplasm (genetic material) from the Philippines was carried out with considerable foresight and valor, there was little hope that the resultant trees could mature quickly enough to meet the urgent wartime need for quinine. More than 600,000 U.S. troops in Africa and the South Pacific had contracted malaria, and the average mortality
rate was 10 percent. Since more U.S. soldiers were dying from malaria than from Japanese bullets, the lack of Cinchona bark immediately became a serious national security issue.

A few weeks after the fall of the Philippines, the botanist Raymond Fosberg received an unusual delegation in his office at the Smithsonian Institution. As one of the few North American tropical biologists, he was asked by the U.S. Board of Economic Warfare to carry out a mission of highest priority. Together with several other U.S. botanists, he was to travel immediately to South America, recollect all known Cinchona species, secure a massive supply of Cinchona bark for shipment to the United States, and establish local plantations of Cinchona trees. Fosberg was to obtain, if possible, millions of pounds of bark for immediate shipment to the Merck pharmaceutical plant in New Jersey.

Fosberg was placed in charge of the survey in Colombia. So that chemical assays of any bark collected could be carried out quickly, the U.S. government set up field laboratories in Bogota, Colombia; Quito, Ecuador; Lima, Peru; and La Paz, Bolivia. Since the exact locality of the original sixteenth-century collections was unknown, Fosberg traveled for months with local assistants through remote forests interviewing Indians and searching for Cinchona species. When he located a large stand of the trees, he had to arrange for local people to harvest the bark, dry it under difficult tropical conditions, and then transport it down a mule or foot trail to the nearest road or river. If no trail was available, Fosberg worked with the Indians to cut an airstrip in the jungle so that the bark could be flown out.

In the course of these expeditions, Fosberg and his colleagues learned a great deal about Cinchona biology. In time they were able to project how much dried bark a tree of a particular size would yield. A tree whose stem measured 2 inches in diameter was found to yield 1 pound of bark; a tree whose stem measured 26 inches in diameter yielded 255 pounds.

The emergency explorations had mixed success. In 1943 and 1944, Fosberg and his colleagues secured 12.5 million pounds of Cinchona bark for the Allies’ war effort. Yet they never did locate the quinine-producing species, Cinchona ledgeriana, that had made the Java plantations so productive. Meanwhile, Allied chemists searched for quinine substitutes, but synthetic antimalarial drugs lacked the efficacy of real quinine and produced such unpleasant effects as nausea, diarrhea, and yellowing of the skin, which made them unpopular with American soldiers.

As the war continued, Fosberg persisted in his search for Cinchona species but soon had to confront a problem far more serious than the elusiveness of a tree: he became aware that he himself was being hunted. As Fosberg tells the
story, he had just checked into a run-down hotel in a remote Colombian outpost when he heard German voices coming from the room below. Late that night a knock came at his door. Fosberg opened it to find himself staring into the faces of two Nazi agents, who explained they knew who he was and what he was doing there. They had been on his trail for several weeks. Would the U.S. government, they asked, be interested in buying a large quantity of pure quinine that they had smuggled out of Germany? Relieved, Fosberg struck a deal and returned to the United States with German quinine, which quickly and quietly found its way to the Pacific theater.

After the war, synthetic antimalarial drugs such as Maloprim and Fansidar reduced the need for quinine. But the utility of quinine to treat certain heart arrhythmias and its commercial value as a bitter flavoring agent suggest that this bark, which first made its way from Peru to the royal courts of Europe, will remain an important botanical commodity for years to come.

A Successful Approach to Drug Discovery

As the discoveries of digitalis and quinine bear witness, the ethnobotanical approach to drug discovery has been spectacularly successful. The table on pages 34-35 lists 50 drugs prescribed in North America and Europe that were derived...
from ethnobotanical leads. Most of them were discovered from leads known to Western science for decades. We think of William Withering as the pioneer of cardioactive drugs with his discovery of digitalis, for instance, but in 1597 Gerard noted that the sea squill (*Drimia maritima* [Liliaceae]) “is given to those that have the dropsie.” Since then, the cardiotonic drug Proscillaridin has been derived from *D. maritima.*

Aspirin is yet another drug developed from a plant. The European herb called queen of the meadow, *Filipendula ulmaria* [Rosaceae], which is referred to in some older literature as *Spiraea ulmaria,* has long been used in folk medicine to treat pain and fevers and as an antiseptic. In 1597 Gerard wrote that the roots of this plant, “when boiled in wine and drunken, are useful against all pains of the bladder.” In 1839 salicylic acid was isolated from the flower buds of *F. ulmaria.* The pure compound rapidly came into widespread use as a pain reliever, but it frequently caused gastric upset. Then in 1899 the Bayer company began to market a synthetic derivative, acetylsalicylic acid, which had higher pharmacological activity and fewer side effects. They called their new compound “aspirin”-“a” for “acetyl” and “spirin” for *Spiraea,* the plant from which salicylic acid had originally been derived. Salicylic acid also occurs in members of the willow family, the Salicaceae. The ancient Greeks and North American Indians used the bark of the willow genus *Salix* to relieve pain.

Queen of the meadow, *Filipendula ulmaria,* was long used in folk medicine to treat pain and fevers and as an antiseptic. It is the original source of salicylic acid, the precursor of modern aspirin.
The fifty ethnobotanically derived drugs listed in the table on pages 34-35 pose an interesting question: Can folk wisdom still point the way to new drugs? A decade or so ago, the story of Withering’s discovery of digitalis might have been regarded as a historical anecdote of little relevance to contemporary drug discovery programs, even though such discoveries have continued well into the twentieth century. Perhaps the most significant discovery was that of the vinca alkaloids, vincristine and vinblastine, in the rosy periwinkle, *Catharanthus roseus* [Apocynaceae]. These alkaloids are used around the world for the treatment of pediatric leukemia and Hodgkin’s disease. The rosy periwinkle was discovered in a collection of 400 medicinal plants that scientists at Eli Lilly screened against cultures of P-38 mouse-cell leukemia. In the laboratory, rosy periwinkle killed leukemia cells. The active components, vincristine and vinblastine, occur in such low concentrations that more than 250 kilograms of leaves are needed to make a single 500-milligram dose. Although the plant is unlikely to be useful against leukemia in a folk setting, it was indeed a healer’s claim that the plant was effective against diabetes that led scientists to investigate it.

More recently the effort to make use of folk knowledge in the search for novel pharmaceuticals has increased throughout the world. The task is daunting. Modern searches for bioactive molecules typically make use of expensive

A healer’s apprentice in Belize, Bertha Waight, examines rosy periwinkle, *Catharanthus roseus*, as part of her studies. The rosy periwinkle originated in the forests of Madagascar, but is now found growing wild in many areas of the tropics. Two potent chemicals derived from the leaves of this plant, vincristine and vinblastine, are the drugs of choice to treat certain cancers.
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### Fifty Drugs Discovered from Ethnobotanical Leads

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molecular biology assays in attempts to identify specific interactions along biochemical pathways of particular disease targets. Often an entire biochemical pathway depends on a key enzyme; if the enzyme can be inactivated by a drug, the pathway will be blocked and the disease averted. Once the underlying biochemistry is understood, automated screens of thousands of substances, including plant extracts, can be rapidly conducted. Should activity be found, scientists then work to isolate, purify, and determine the structure of the bioactive molecule. Since the funds available for such searches are limited, it is clear that not every one of the 250,000 different species of flowering plant species can be carefully examined. Indeed, since the beginning of modern pharmacology, less than $\frac{1}{2}$ of 1 percent of the species of flowering plants have been exhaustively studied to determine their chemical composition and medical potential.

A problem more difficult than the financial one has been a deep-rooted prejudice in the pharmacological community against ethnobotanical searches. Although ethnobotanical approaches to drug discovery are of historical significance, pharmaceutical firms in the 1960s and 1970s believed that new approaches, incorporating techniques from molecular biology and computer-assisted drug design, had superseded folk knowledge as a potential source of new pharmaceuticals. Ethnobotanical approaches such as that employed by William Withering came to be regarded as antiquated in comparison with computer-assisted design of pharmaceuticals.

A deeper reluctance to explore indigenous knowledge systems may be attributable to cultural prejudice dating to the years when the Western powers reigned over colonies. During the period of colonial expansionism, Western medicine “was taken as a prime exemplar of the constructive and beneficial effects of European rule,” writes David Arnold, a historian of science at the University of Manchester. “Thus Western medicine was to the imperial mind . . . one of its most indisputable claims to legitimacy.” Since Western medicine was regarded as prima facie evidence of the intellectual and cultural superiority of Europeans, the figure of the medicine man or shaman was often viewed as inimical to social and cultural progress. Indeed, the pejorative term “witch doctor” has come to stand for savagery, superstition, irrationality, and malevolence.

Why, then, should scientists spend considerable time and effort to seek out and study with the very healers that Western culture has so long held in contempt? As often occurs in science, the pendulum is beginning to swing back. Plant-based pharmaceuticals are again considered worth pursuing, for several reasons. First, we are becoming increasingly aware of the loss of biodiversity throughout the world, a loss that may preclude future discoveries of plant-based pharmaceuticals. Second, new molecular tools for screening novel sub-
stances have greatly accelerated the pace of research. Not long ago individual laboratory animals had to be injected with plant extracts; today an automated bioassay can screen hundreds of extracts in a few hours. As a result, both the amount of plant extract used and the time needed to determine any bioactivity have been reduced significantly. Third, appreciation of the sophistication of indigenous knowledge systems has grown. Claims that a traditional remedy really works are no longer dismissed out of hand—there are simply too many historical precedents of major drug discoveries rooted in folk medicine. One new pharmaceutical company, Shaman Pharmaceuticals, Inc., was established in 1989 to prospect for therapies based entirely on ethnobotanical leads.

Not all plant-derived pharmaceuticals, however, are products of ethnobotanical research. Traditionally, two different approaches, random and targeted, have been attempted in the selection of plant species for investigation. In random plant selection programs, a broad net is cast and plants are collected from a given region and screened without regard to their taxonomic affinities, ethnobotanical context, or other intrinsic qualities. Such searches have had consistently low success rates, although the National Cancer Institute (NCI) discovered taxol, an important drug used to treat breast and ovarian cancer, during a random screen.

Targeted selection programs can be of several types. In phylogenetic surveys, the close relatives of plants known to produce useful compounds are collected. In ecological surveys, plants that live in particular habitats or have certain char-

Medical doctor Thomas Carlson, on the left, and ethnobotanist Steven King, on the right, conducted field ethnobiomedical research in southeast Nigeria. Here, they are listening as Ester Madu, a traditional healer of Igbo culture, describes the use of a species for treating non-insulin-dependent diabetes mellitus, or type II diabetes. Ethnobotanist/physician teams are necessary to understand the range of information presented by traditional healers, who have extensive knowledge of both botany and medicine.
Strategies for collecting plants in the search for medicinal compounds include: (top left) taking samples of plants at random, (top right) taking samples from plants in families already known to contain plants with bioactive compounds, and (bottom) taking samples from plants used by traditional healers. The plants selected in the ethnodirected survey represented by the bottom panel were recommended by a Maya healer in Belize.

Characteristics, such as immunity to predation by insects or molluscs, are selected. And in ethnobotanical surveys, plants used by indigenous peoples in traditional medicine are chosen for study.

The history of drug discovery and development seems to confirm that ethnobotanical screens of floras are far more likely to succeed than random screens. The ethno-directed sampling approach, as this methodology is called, has two primary components. The first is the cultural prescreen, in which indigenous peoples experiment with the plants in their environment, often over
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hundreds of generations, and identify those that are bioactive. The second component is a screen that the ethnobotanist consciously or subconsciously employs to determine which plants warrant further study. For example, claims of blowgun poisons or the mood-altering effects of plants in the dogbane family [Apocynaceae] are likely to arouse any ethnobotanist's interest, since many plants in this family are known to exhibit potent cardiotonic or psychoactive activity. Particular disease targets may also predispose the researcher to pay close attention to certain types of claims. In this age of AIDS and other viral diseases, any indication of possible antiviral activity for a plant used in traditional medicine is likely to be carefully evaluated.

This approach has been shown to increase the number of hits produced by in vitro studies (those carried out in test tubes) in comparison with the random approach. In broad-based in vitro screens, for example, Paul Cox, Rebecca Sperry, Lars Bohlin, and other colleagues at the University of Uppsala found 86 percent of the medicinal plant species in Samoa to show significant levels of pharmacological activity. Michael Balick, testing plant samples in a National Cancer Institute screen for anti-HIV activity, found that a small sample of "powerful plants" from an individual healer in a village in Belize, in Central America, initially gave four times as many hits in an HIV screen as a random collection. Steven King of Shaman Pharmaceuticals found that the type of pharmacological activity identified in vitro bioassays corresponded with the activity identified by the indigenous healers 74 percent of the time. For many biological activities that have a corresponding folk use-antifungal, antibacterial, or hypoglycemic activity, for example-it appears that selecting plants that traditional healers use to treat these conditions will give higher levels of positive activity in the biological screens.

It is important to note, however, that not all indications of pharmacological activity lead to the discovery of new compounds. Many times this approach results in the isolation of compounds already known. It now appears that several plants that aroused Balick's interest in Belize, for instance, contain compounds that were already known to enhance the body's immune system. Because drug development programs like the one at the NCI are directed toward discovering new compounds, these plants, though active in the test tube studies, were not considered for further evaluation. The NCI's tests did make it clear, however, that healers were indeed able to identify plants with beneficial properties.

Still, the likelihood of success by the ethnobotanical approach may vary from culture to culture. Not all cultures are equally likely to use plants with significant pharmacological activity. Ethnobotanists tend to focus drug searches on cultures that have three characteristics: a cultural mechanism for the accu-
rate transmission of ethnopharmacological knowledge from generation to generation, a floristically diverse environment, and continuity of residence in the area over many generations. Ethnobotanical data derived from cultures that display all three of these characteristics can be somewhat analogous to human bioassay data, particularly if people have been dosing themselves with the same plants for many generations. These people are likely to have identified any problems of lack of efficacy or acute toxicity over the years.

**Ethnobotanists at Work in the Field**

The drug discovery process, beginning with a plant used by a traditional healer and ending in a medicine used in a clinical setting, involves many disciplines and often takes many years to complete. Unlike the techniques used by pharmacologists or natural-product chemists, the skills required by the ethnobotanist are difficult to articulate in a book or classroom; for whereas a chemist’s personality has little effect on the outcome of an experiment, the ethnobotanist’s demeanor can have a direct impact on the success of the study.

Before a drug search can begin, the ethnobotanist must first obtain permission to conduct research from the national government. If the research is to be conducted in a foreign country, certain international protocols must be scrupulously observed. Under the Rio Treaty on Biodiversity, each signatory nation has sovereignty over all biodiversity within its boundaries. No plant sample that might result in discovery of a novel pharmaceutical compound can be removed without the country’s written permission. Today Charles Ledger’s smuggling of Cinchona seeds would be a crime punishable in the source country, Bolivia; in his home country, Australia; and in the recipient country, Indonesia.

Once the national government has given permission for the research, the ethnobotanist must obtain the permission of the village leaders. Because of issues of intellectual property rights, the ethnobotanist should negotiate in advance a fair and equitable return to the local people on any commercial development of a plant used in traditional medicine. The ethnobotanist must then meet and establish rapport with the village healers. The ability to secure and maintain the healers’ trust is the single most important skill the ethnobotanist can have. Ethnobotanists establish rapport in several ways. Their first task is to learn the language of the people they study with. The use of an interpreter is seldom satisfactory, because healers employ special concepts and terms that most members of their culture do not know. “If you want to understand fully the ideas of sickness and health that underlie your healer’s practices, his cate-
categories of disease, and the specialist vocabulary of his profession, you must work in his language, not yours,” the anthropologist Bruce Riggs says, “because while you may, eventually, get to understand what he tells you in his language, and translate it into something that can be compared with Western ideas on the same topic, there is no way that your informant, perfect though his English may be, can do that for you. His very use of English will mask and obscure your topic of investigation.” Formal instruction in an indigenous language is seldom available, so ethnobotanists assemble word lists, study published grammars, dictionaries, and translations of Western texts (often the Bible), and listen very carefully to indigenous speakers to learn their language.

Second, ethnobotanists must establish their own personal working ethnography, an understanding of the culture, of the group they are studying. The ethnographer James Spradley defines cultural knowledge as the “acquired knowledge people use to interpret and generate behavior.” Some cultural knowledge, such as how to tie a knot or relate a legend, are explicit types of knowledge, knowledge that can be easily and quickly communicated to someone else. But many important types of cultural knowledge are tacit, outside the normal awareness of most members of the society: the amount of personal space that one maintains in interacting with other members of the culture; how to stand, sit, or position oneself in relation to others; when to speak and when

In Belize, Silviano Camberos S., a physician from Mexico, works with Kekchi Maya herbalist and bushmaster Jose Tot, on the left, to learn about local disease concepts and herbal treatments. Only after such discussions will he undertake ethnobotanical collections for pharmaceutical evaluation.
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not to speak, how loud to speak in the presence of village elders; and so forth. One can quickly and easily learn explicit cultural knowledge, such as modes of dress and types of food, by studying books or hearing the experiences of others, but tacit cultural knowledge can usually be obtained only by direct experience. Tacit cultural knowledge is much more important than explicit cultural knowledge in establishing rapport with healers. The best ethnobotanists are those who most rapidly learn and employ tacit cultural knowledge.

Most scientists formulate hypotheses, design research instruments, gather data, and then analyze the data, but this linear method is of little use to ethnobotanists in search of tacit cultural knowledge. They must work in an iterative, cyclical fashion, collecting tacit cultural information, employing it in their own behavior, interpreting the response to their efforts, and then refining their knowledge of cultural information before using it again. To do all this, ethnobotanists change their lifestyles to conform with that of the indigenous culture. Yet superficial changes in language, diet, and dress, while helpful, are seldom sufficient. Indigenous peoples are extraordinarily adept at sensing insincerity; it is our experience that genuine interest and clearly stated, respectful intentions help communicate to indigenous peoples the humility, trust, and respect that are so crucial for establishing rapport. If these efforts to establish rapport are successful, the ethnobotanist obtains a preliminary understanding of the culture’s healing tradition.

Many earlier ethnobotanical studies, whether of healing techniques or other plant uses, simply produced a list of plants deemed “useful” by the people of an area. The ethnobotanist often made little effort to understand how the indigenous people viewed the plants in their own culture. Although these older-style surveys contain much useful information, particularly since we still know so little about the world’s plant diversity, they are now in need of being repeated using newer techniques. These techniques have proven their value in studies of all kinds of plant uses.

Most commonly, the modern ethnobotanist adopts the role of participant-observer, living with the people under study, observing their daily life and customs, and learning about their lifestyle, foods, disease systems, and myths and legends. In true participatory ethnobotany, the indigenous person becomes a teacher, a colleague, and a respected and valued friend. These close relationships are not without some liability, however. Ethnobotanists may have trouble maintaining objectivity. Even more serious, formal interview techniques, which are designed to prevent an investigator from unconsciously directing the flow
and nature of the conversation ("leading" an interviewee), are difficult to maintain during participant observation. Because ethnobotanists consciously reduce the formal distance between observer and subject, they are vulnerable to the criticism that they move too deeply into indigenous paradigms. It should not be a surprise that many ethnobotanists become passionate advocates for indigenous rights, playing major roles in establishing indigenous-controlled reserves and ensuring that indigenous peoples share in the benefits of new discoveries such as medicines derived from plants.

The practitioners of another style of ethnobotanical research ask their indigenous colleagues to re-create events, perhaps those that were once more common. Ethnobotanists may ask to see how a limb is splinted with a palm leaf or commission aged shipwrights to build seaweed under a researcher's watchful eye.

Samoa, Seumanutafa and her apprentice instruct ethnobotanist Paul Cox (left) and pharmacognosist Lars Bohlin (right) on different types of medicinal plants.
eye. Although the information gained is valuable, the situations are by definition contrived: the patient is not actually in pain; a cross-oceanic migration is not imminent. The investigator is thus able to take notes in great detail. As more ethnobotanical research is carried out among Westernized peoples, the recreation of past events becomes of greater importance.

Applying the “artifact/interview” method, pioneered by Brian Boom of The New York Botanical Garden, the scientist queries local people about an item constructed from plants. The investigator gathers information on where plants used to produce the object come from, then makes a trip to collect samples of the species used. Or the investigator may simply discuss the use of plants for food, medicine, or magic, without an artifact being presented.

Immersion ethnobotany, another new approach, reduces the distance between subject and observer still further, for the ethnobotanist using this method submits to being treated by an indigenous practitioner. For example, while in India studying the traditional medicinal system known as Ayurveda, Michael Balick was interned in a local hospital and given traditional Ayurvedic treatment by four practitioners, who applied a series of herbal massages and chiropractic manipulation, and also prescribed internal medicines. As a patient in treatment, Balick had, in effect, turned over control of the study to the traditional healers, in order to experience first-hand the very profound effects of the system in such a way that it could be described in detail.

Indigenous healing systems are often complex, but they incorporate at least three basic components: (1) a cosmological view of the universe that can help explain the cause, diagnosis, and treatment of disease; (2) a cultural context within which health care is given; and (3) a repertoire of pharmaceutical substances. We are unaware of any culture that does not possess such an indigenous pharmacopoeia. To keep track of an unfamiliar and often complex belief system, ethnobotanists document interviews with healers with copious notes, audio recordings, videotapes, and film. As they learn from the healers, they begin to see plants through the healers’ eyes. Only then can they begin to accumulate a contextually significant collection of plants.

Specialist Healers in Belize

Many traditional healers in Belize are generalists, yet they have developed areas of specialization. Michael Balick and his colleague Rosita Arvigo have studied extensively with Hortense Robinson, a specialist in midwifery and other health
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Left: Hortense Robinson, a traditional healer from Belize specializing in midwifery, prepares a poultice from species in the genera *Bursera* and *Hibiscus* to be used in the treatment of headache. Right: Andrew Ramcharan, a traditional healer specializing in the treatment of snakebite, collects roadside plants in northern Belize. A surprisingly large number of plants along roadsides and in secondary forests are valued for their medicinal properties in Central America, as well as elsewhere in the tropics.

care issues involving women and children. She uses a specific set of plant species, including some powerful species she considers too toxic for use by non-specialists. One plant used by midwives is the castor oil bush (*Ricinus communis* [Euphorbiaceae]). A leaf of this plant placed on a lactating mother’s nipple is said to reduce or stop the flow of milk. Other plants are used to treat irregular menstruation or heavy menstrual bleeding.

Andrew Ramcharan, of Ranchito, a village in the north of Belize, specializes in the treatment of snakebite in an area where the agroecosystem consists primarily of sugar cane and harbors many venomous snakes. His family came to Belize from India. His grandfather, a well-known snakebite healer in Calcutta, had learned his skills from his father, and they served him well in Central
As forests are destroyed, so are vast repositories of plants used in traditional medicine. This graph shows the time required for a Belizean healer, Don Elijio Panti, to reach the secondary forest sites where he collects medicinal plants. Whereas in 1940 these sites were an average of 10 minutes from his house, by 1988 Don Elijio had to walk 75 minutes to reach an adequate site.

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America. The Ramcharans found only some of the therapeutic plants they knew in Belize and experimented until they identified local species that could substitute for the taxa they had used in India. They also exchanged information with the local Maya Indians on plants they used. In such a manner, traditional medical systems evolve and adapt to local environments.

Both Hortense Robinson and Andrew Ramcharan provide primary health care services to the residents of their villages and surrounding areas, and, like many other traditional health care providers in Belize, they depend largely on medicinal plants that grow in the forest. As these forests are destroyed, increasingly greater levels of energy must be expended to locate and collect the plant medicines the healers use. Hortense Robinson often walks nine miles from her home to a remnant of a once-vast forest to collect plants she commonly uses in her practice. This sacrifice, she says, strengthens her spirit and ability as a healer, and increases her patients’ faith in her work.

In addition to the loss of potential drugs far into the future—a loss that affects Western medicine as well as the indigenous population—an immediate consequence of deforestation is the degradation of the traditional primary health care system in the area. For many conditions, traditional medicine is effective, while also being less expensive, more widely available, and more culturally acceptable than Western medicine. Besides, traditional healers in Belize recognize and treat such diseases as susto, viento, and envidia—fright, wind, and envy. Western medicine cannot replace the medicine these healers practice.

Understanding these indigenous healing systems is not easy. Michael Balick, for example, asked people in Belize about plants that might be useful in treating cancer. He then collected individual species and provided bulk samples to a pharmacological laboratory for screening. Surprisingly, no more biological activity was observed in these plants than in another group that had been collected at random. Only later did Balick realize that “cancer” in Belize means a condition characterized by weeping, open wounds that are chronic, spreading, and difficult to heal—not what he had intended to research at all.

The Collection of Herbarium Specimens

Ethnobotanists are careful to document all the plants they collect with well-prepared voucher specimens that they deposit in herbaria. The importance of adequate herbarium voucher specimens cannot be overstated: if any question or
Left: Douglas Daly, a botanist specializing in the flora of the Amazon basin, is shown here identifying herbarium specimens of plants in the Frankincense family (Burseraceae). The specimens serve as vouchers for his ethno-botanical and floristic studies in the extractive reserves of Brazil. Right: Cases in the herbarium of The New York Botanical Garden hold preserved plant specimens. Modern, climate-controlled storage facilities ensure that dried plant vouchers can be kept in collections indefinitely, for study by later generations of botanical scientists.

Dispute should arise concerning the identity of the species involved, examination of a properly collected voucher specimen can unequivocally settle the matter. A properly documented voucher specimen should supply the ethno-botanical information, the names of the people interviewed, and a detailed description of the place where the plant was found so that the plant population can be located again if necessary.

Because of their scientific value for years to come (sophisticated bioassays of the future may require only micrograms of plant material), voucher specimens should be deposited and preserved in a well-curated herbarium and duplicate specimens should be deposited in geographically distant herbaria, including
Preparation of Herbarium Specimens

Preparation of an herbarium specimen begins with the selection of a plant representative of the population. The ethnobotanist collects all parts of the plant—the leaf, fruit, flower, and every other part a botanist would require to identify it. Plants in flower are not necessarily in fruit, and vice versa. For a good portion of the year, many plants are found in a sterile condition, especially those in tropical locations where the growing season is year round, or those in dormancy in the temperate region. And without a flower or fruit—what botanists call the “fertile” portion of the plant—it is often difficult to identify the species. If the plant is small, such as an herb, the entire organism can be collected and pressed for preservation.

The photo at the bottom of this page shows a poor herbarium specimen. It is described as coming from a plant 2 meters tall in the primary forest and as having a yellow flower. Unfortunately, the flower has not been collected, and only leaf fragments are present on the herbarium sheet. One specialist who examined it could not place it in the proper family; another could say only that it was definitely not a palm. The species is used in Ecuador to thatch roofs and tie bundles, but as far as the ethnobotanist is concerned, the specimen is unidentifiable.

The photo of the herbarium specimen at the top of this page shows a medicinal plant used to treat skin burns. It is identified as a vine that grows to 2 meters tall and has purple tubular flowers and green fruits that turn red at maturity. Note that both fruits and flowers are present on the specimen, as well as a good section of the vine and numerous leaves. This plant can easily be

Top: An example of a well-prepared herbarium specimen, containing fruits and flowers, that can be identified as *Lycianthes lenta*, in the tomato family [Solanaceae]. Bottom: An example of a poorly prepared herbarium specimen. The collector has gathered only a few fragments of the leaf, with no flowering or fruiting material. Since it is impossible to identify this plant from the material present, making the ethnobotanical research that is based on this specimen is of little value.
Herbarium specimens are produced by pressing and drying plants that have been collected in the field. A plant press, left, is a standard tool. A plant sample, typically of leaves, flower, and fruit, is placed flat inside a sheet of folded newspaper, then pressed flat by placing it within a sandwich of blotter paper (red), cardboard, and corrugated aluminum. Many such sandwiches are placed between wooden endboards that are tightly clamped by buckled straps. The entire press is placed in a plant drier, as shown on the right. This dryer consists of a box with a screened bottom to prevent leaf and paper fragments from falling into the flames; the box rests on a larger wooden frame with slots or short legs that allow air to enter at the bottom—there the air is heated by a propane or kerosene burner or by lightbulbs or a small heater if electricity is available. The warm, dry air rises upward and moves through the plant press via holes in the corrugates, allowing moisture to be removed from the blotters and plant specimens. Most plants, except those with fleshy parts, can be dried in 6 to 24 hours using this apparatus.
identified as belonging to the family Solanaceae, specifically as *Lycianthes lentu*. Both of these plant specimens were made to document an ethnobotanical use by indigenous people, but only the one on the top of page 48 can be properly identified.

'It is important to accompany each specimen with careful notes that tell where it was collected—the latitude and longitude, the village, the state or county, and the country. The notes should also provide as complete a botanical description as possible—the size and shape of the plant, the colors of flowers and fruits, any fragrance especially if the plant is too large to be completely preserved on the herbarium sheet. A palm, for instance, may be 30 meters tall; the leaves alone can measure 8 meters. In this case, representative pieces of flower, fruit, leaves, and stem sections can be taken. The notes should also describe how the plant was collected, and the process is often documented by photographs. The date when the plant was collected and the names of all members of the collection team should be provided in the lower portion of the label. Finally, the contributions of institutions and foundations that have supported the research must be acknowledged.

Usually plants are pressed in sheets of folded newspaper and preserved for a time in an alcohol bath if they cannot be dried in the field. An alcohol bath (usually less than 50 percent alcohol) compromises the chemical integrity of the herbarium specimen, but if a botanist cannot manage to carry a heater, sheets of cardboard and corrugated paper, ventilators, wooden presses, and straps into the area, immersing the plant in a fluid preservative until it can be dried is the best thing to do.

Once the material is delivered to the institution where it is to be studied, the plants are sewn or glued to high-quality acid-free rag bond paper and stored in steel cases in an environmentally controlled area—an herbarium. Under proper storage conditions, herbarium specimens will retain their scientific value almost indefinitely.
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To prepare plant samples for pharmacological testing, a botanist first collects 1 to 2 kilograms of plant parts in the field and preserves them by drying or by placing them in a fluid preservative. In the laboratory, the plant materials are macerated, placed in a solvent, and shaken for 24 hours. The solvents are removed in a rotary evaporator, and the plant extract is then freeze-dried. The process yields 0.5 to 1 gram of crude extract, which can be tested in various bioassays.

Ethnobotanists are responsible for preparing not only voucher specimens but also materials for pharmacological testing. They must note carefully ones in the countries where the material was collected. Ethnobotanical data on the diseases treated, the mode of formulation, and the methods of administration should be copious in order to guide later investigations. The collection number of the specimen should be used to label all subsequent pharmacological fractions and residues so that any new discovery or question can be immediately referred to the original herbarium sheet.
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the parts of the plants the healers use, since flowers, leaves, shoots, and roots often differ significantly in their chemical composition. Dried samples ranging from 0.5 to 2 kilograms have traditionally been supplied for testing, but drying may not always be the best method of preservation, for heat can destroy some classes of chemicals. Storage in alcohol or freezing are splendid ways to preserve plant materials, but in many parts of the world it is not very practical. In general, the best ways to collect and preserve plants are the ways the healers use.

The ethnobotanist collects an initial sample of approximately 0.5 kilogram of plant material along with an herbarium specimen and takes them to the laboratory. There fractions of the sample containing different components are extracted with a variety of aqueous and organic solvents. The extracts are then tested against various bioassays to identify promising pharmacological leads and novel activity.

Bioassay procedures have evolved from recording observations of live animals that have been dosed with plant extracts, to high-volume, sophisticated in vitro procedures that determine if the plant extract inhibits specific enzymes, binds to certain molecular receptors, or exhibits other types of highly specific biologic activity. If the extract shows bioactivity, the botanical team is then directed to return to the area where they first collected the plant to retrieve a bulk sample, often 50 to 100 kilograms of material. At that time the botanists compare the new specimens with the original material and verify the botanical identification. Sufficient plant material is gathered to permit fractionation and structural elucidation of the chemical components responsible for the identified activity. Scientists compare the chemical structure with known structures to see if the entity has been previously discovered. After they have isolated the chemicals and determined their structure, they decide whether or not to attempt to synthesize the compound. Various factors—cost, the quantity needed, the availability of the natural resource—impact this decision.

The compound is then entered into clinical trials in which its effects on human subjects are observed. In Phase I clinical trials, researchers watch for any toxicity of the compound when it is administered to human volunteers. In Phase II trials, they determine the efficacy of the compound against the disease in a small group of people. In Phase III trials, they study a much larger population of patients under rigorous clinical conditions. After the efficacy and safety of the substance have been demonstrated, a new drug application (NDA) can be submitted to the Food and Drug Administration for the use of the compound as a therapy in the United States.
### Examples of Samoan Disease Terminology

<table>
<thead>
<tr>
<th>Samoan Term</th>
<th>English Translation</th>
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<tbody>
<tr>
<td>Anufe</td>
<td>Intestinal worms</td>
</tr>
<tr>
<td>Ate fefete</td>
<td>Swollen liver</td>
</tr>
<tr>
<td>Malaga umete</td>
<td>Head ulcerations</td>
</tr>
<tr>
<td>Failele gau</td>
<td>Complications of maternity</td>
</tr>
<tr>
<td>Fe'efe'e</td>
<td>Untranslatable internal disease</td>
</tr>
<tr>
<td>Lepela</td>
<td>Leprosy</td>
</tr>
<tr>
<td>Lafa</td>
<td>Ringworm</td>
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</tbody>
</table>

Samoan disease names are derived in a variety of ways. *Anufe*, for example, means “worms”; the disease takes its name from the cause. *Ate* (liver) and *fefete* (swollen) provide an anatomical origin for a disease name, while *malaga umete* (*umete* = bowl) refers to the shape of the ulceration. New mothers are vulnerable to *failele gau*, and *fe'efe'e* (octopus) summons a vision of tentacles crawling inside one’s intestines. *Lepela* is a transliteration of the word “leprosy.” *Lafa* is an irreducible term for ringworm.

### Isolation of the Anti-HIV Drug from a Samoan Tree

Except for a group of basic remedies that nearly all Samoans know, herbalism is a specialty practiced by healers called *taulasea*—herbalists—nearly all of whom are women. They have learned their craft from their mothers or other female relatives. Some Samoan *taulasea* use more than 100 species of flowering plants and ferns. The number of Samoan herbalists has dwindled. Those still practicing are very old and few have apprentices.

Samoan medicine differs significantly from Western medicine in its descriptions of disease etiology. As in Belize, many diseases recognized in Samoa are not directly translatable into Western terminology.

Samoan healers refuse payment for their services, arguing that the plants are a gift of God. Yet their knowledge is formidable: a typical healer can identify
The late Samoan healer Mariana Lilo prepares a tea used to treat hepatitis from *Homalanthus nutans*. To produce the remedy, she immerses the macerated bark of *H. nutans* in boiling water. Her patient will ingest only the tea containing the water-soluble fraction of the bark.

Over 200 species of plants by name, recognize over 180 disease categories, and compound more than 100 remedies.

Samoan healers may treat ailments with massage, special diets, or incantations. When a healer diagnoses a disease that requires an herbal treatment, she immediately begins to collect the necessary plant materials, since only fresh plants are used. Most Samoan remedies are formulated from flowering plants. Formulation techniques are specific to the plant part used. Most remedies are water infusions, some are oil infusions, and a few are ignited and inhaled. Many remedies, including those for internal ailments, are applied externally. Most treatments are prepared using a combination of several species of plants gathered in the wild, but some remedies are prepared from a single species.

Consider the treatment that Epenesa Mauigoa uses for *fivasamasama* (*fiva* = fever; *samasama* = yellow), the clinical manifestation of acute hepatitis. After confirming a diagnosis of *fivasamasama*, Mauigoa has one of her children journey to the forest for the wood of the *mamala* tree (*Homalanthus nutans* [Euphorbiaceae]). But not any type of *mamala* will do; botanists recognize one species of *Homalanthus*, but Mauigoa recognizes two. "Only the *mamala*
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with long white petioles is used," she explains. The mamala with red petioles on the leaf is reserved for abdominal complaints called tulita suuu.

After her daughter returns with Homalanthus wood, Mauigoa scrapes away the outer cork and epidermal tissues of the wood and extracts the "inner bark," or cambial tissue, by scraping it with a knife. She places the scrapings in a cloth, ties it like a tea bag, and immerses the bag in boiling water for half an hour. After removing the bag and discarding its contents, she filters the liquid through a cloth and gives it to the patient to drink.

In 1984 Epenesa Mauigoa and other healers told Paul Cox about this remedy for fiva samasama. Gordon Cragg of the Natural Products Branch of the National Cancer Institute had agreed to evaluate the pharmacological efficacy of medicinal plants that Cox might find in Samoa, and among the materials he collected were stem wood samples of H. nutans. Attempting to simulate traditional preparation techniques, he chose not to use the standard method of air drying to prepare samples for analysis, but instead returned to his laboratory in the United States with the samples preserved in aqueous alcohol in aluminum bottles. In his lab he removed the alcohol in a rotary evaporator and placed the extracts in a freeze drier. Cox then carried the freeze-dried samples to the NCI in Maryland, where a team including Michael Boyd, John Cardellina, Kirk Gustafsson, Peter Blumberg, John Beutler, and other researchers tested them for activity against the HIV-1 virus—the virus associated with acquired immunodeficiency syndrome (AIDS).

The NCI team soon found that the stem wood extracts exhibited potent in vitro activity against the HIV-1 virus, both stopping the virus from infecting healthy cells and preventing infected human cells from dying. Bioassay-guided fractionation resulted in the isolation of prostratin (12-deoxyphorbol13-acetate).

The identification of prostratin, which belongs to a group of compounds known as phorbols, as the active component in H. nutans caused some concern: phorbols are known tumor promoters. Research conducted by a team led by Peter Blumberg at NCI demonstrated that prostratin does not promote tumors, even though it activates protein kinase C, a typical indicator of tumor promotion. Indeed, the NCI team found that prostratin functions as an antipromoter: it stops mutant cells from developing into tumors. The NCI is currently soliciting bids from drug companies to license prostratin for drug development. Since prostratin stops cells from becoming infected with the HIV-1 virus and prolongs the life of infected cells, it may prove to be effective as part of a combination therapy in tandem with proteases and other antiviral compounds. Yet toxi-
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Ethnobotany and the Future Discovery of Drugs

How many and what types of drugs remain to be discovered through the ethnobotanical approach? Is there any way to estimate the probable success of the ethnobotanical approach in the future?

Some estimate of the prospects can be gleaned from an analysis of maladies for which healers administer treatments prepared from plants. A review of published accounts of plant uses in 15 widespread geographical areas—Australia, Fiji, Haiti, India, Kenya, Mexico, Nepal, Nicaragua, North America, Peru, Rota, Saudi Arabia, Thailand, Tonga, and West Africa—makes it possible to categorize the plants according to the ailments for which they are used. The categories found include diseases of the nervous and cardiovascular systems, obstetrical and gynecological ailments, treatment of neoplasms (cancer), gastrointestinal ailments, skin diseases, inflammation (including fevers), microbial diseases, renal ailments, hydration therapy, parasitic diseases, immunotherapy, blood diseases, and poisons. We can compare these indigenous uses of plants with the Western drug uses reflected in the United States Pharmacopoeia. A similar approach allows us to categorize the 50 ethnobotanically derived drugs listed on pages 34–35.

Such an analysis shows a striking difference between the mean percentages of disorders treated with indigenous plants and Western drugs. Indigenous plant remedies are focused more on gastrointestinal (GI) complaints, inflammation, skin ailments, and obstetric-gynecological disorders, whereas Western drugs are more often used to treat disorders of the cardiovascular and nervous systems, neoplasms, and microbial ailments. Why these differences? There are several possible answers:

1. Perceived peril. Cardiovascular illness, neoplasms, microbial infections, and nervous system ailments are the biggest killers in Western cultures. Indigenous peoples, who do not have the lifestyles or predicted life spans associated with cardiovascular disease and cancer, see diarrhea, complications of maternity, and inflammation as more perilous.

2. Salience. Indigenous peoples can easily detect inflammation, skin diseases, and GI ailments, but most cancers and cardiovascular disease are difficult
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to diagnose by traditional methods. In fact, few indigenous languages have a word for cancer, leukemia, lymphoma, or hypertension.

3. Toxicity Indigenous peoples are likely to avoid plant medicines that are highly toxic in low doses. Most cardiovascular and anticancer drugs, as well as those that act on the central nervous system, have extremely narrow dosage windows and thus are not likely to be acceptable to indigenous peoples. (Withering’s dosage problem with digitalis demonstrates this problem.)

4. Economic incentives. The discovery of drugs in the Western world is driven by market considerations. When we analyze the amount of money spent in the United States for research in the various treatment categories, we find that cardiovascular illness, neoplasms, nervous system disorders, and microbial diseases receive 72 percent of every research dollar. Such economic pressures are unique to Western scientists; they do not affect indigenous healers. Thus the percentages of drug types discovered by the ethnobotanical approach more closely represent funding opportunities than indigenous use categories.

On the basis of this analysis, we can predict success for properly designed ethnobotanical surveys for gastrointestinal, anti-inflammatory, OB/GYN, and dermatological drugs. But does this mean that no new cardiovascular, anticancer, or antimicrobial drugs are likely to be found by the ethnobotanical method? Are new anticancer drugs such as vincristine and new cardiac drugs such as digitalis still waiting to be discovered?

An analysis of the table on pages 34-35 suggests that new drugs in these categories indeed await discovery by the ethnobotanical approach. Of the 50 drugs listed, 22 percent are cardiovascular substances (compared to 2 percent of indigenous plant remedies), 20 percent are used for the nervous system (compared to 10 percent of indigenous plant remedies), and 10 percent are used for neoplasms (compared to only 1 percent of indigenous plant remedies). Ethnobotanists’ success in finding drugs at a rate far higher than predicted bodes well in general for this approach to drug discovery. “Seek and ye shall find” seems to be the operative principle.

Ethnobotanical Research and Traditional Health Care in Developing Countries

So far we have focused largely on ethnobotanical research in efforts to discover new drugs for Western medicine. Yet according to recent estimates by the World Health Organization, more than 3.5 billion people in the developing world rely
Don Elijio Panti, the late Maya traditional healer from Belize, is shown treating one of the thousands of patients that come to him each year. A vital part of their country’s health care system, specialists in traditional medicine provide health care to a large portion of the world’s population. Unfortunately, there are few in the younger generation who are being trained to take the place of people such as Don Elijio.

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on plants as components of their primary health care. Just as many Europeans know of the use of Aloe vera [Aloaceae] to treat burns, many indigenous peoples know of some common plants that have medicinal uses. Ethnobotanical research should not be limited to discovering new pharmaceuticals for Westerners; it can also be of some benefit to peoples in developing countries.

An increasing number of nations, including China, Mexico, Nigeria, and Thailand, have decided to integrate traditional medicine into their primary health care systems. In these systems, ethnobotanical research plays a crucial role in documenting the traditional health care practices of the country. Medicinal plant lore often recedes or completely vanishes in the wake of rapid Westernization. In some countries, careful ethnobotanical studies have become invaluable records of ancestral ways. In areas where the people are moving away from traditional lifestyles, particularly in rapidly growing urban populations, careful ethnobotanical documentation can provide the needed foundation for educational programs. Workers at Mahidol University in Bangkok, for example, have prepared a series of slide presentations and pamphlets to teach schoolchildren about traditional Thai uses of plants.

Ethnobotanical research can also help in the discovery of crude drugs. Only pure compounds with known structures and pharmacological activities are
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permissible as drugs in Western medicine, but in many developing countries
the price of such pure substances puts them beyond the reach of all but the af-
fluent. Careful clinical studies can document the safety and efficacy of crude ex-
tracts or tinctures of plants that can be dispensed at far less cost. Carefully de-
signed clinical trials of crude botanical drugs have been conducted in Mexico
and Thailand. The trials in Thailand have resulted in certification of a tincture
of the beach morning glory, *Ipomoea pes-caprae* [Convolvulaceae], as an anti-
inflammatory treatment.

An area of ethnobotanical drug discovery that has yet to be developed is that
of “gray pharmaceuticals”-drugs of proven safety and efficacy that are not
marketable in the Western world. Decisions concerning marketability in the
Western pharmaceutical industry are not driven solely by proof of safety and
efficacy. To be marketable, a drug candidate must affect only one point on a
biochemical pathway: compounds that affect multiple points of the same path-
way are unlikely to be marketed because only “magic bullets” (single-activit
drugs) are viable in today’s legal and economic environment. Drug candidates
must also show superiority over competing drugs in the same market. Thus
some plant-derived drugs that are not marketable as Western pharmaceuticals
may still be acceptable in the country of their origin, particularly if they can be

Throughout the South Pacific and South-
east Asia, an extract of the beach morning
glory, *Ipomoea pes-caprae*, is used on the
skin to treat inflammation. In Thailand, a
tincture of this plant is now sold in drug-
stores after first being proved safe and ef-
fective in rigorous clinical trials.
produced cheaply. The transfer of information (sometimes costing millions of dollars) concerning the safety and efficacy of such gray pharmaceuticals from Western firms to developing countries, along with the appropriate patent rights and technologies to enable the developing countries to produce them, should be encouraged.

Safeguarding Indigenous Intellectual Property Rights

We do not know what compensation, if any, Withering offered the old woman in Shropshire who guided him in his discovery of digitalis. The Aymará Indian, Manuel Ñcra, who collected the seeds of the quinine-rich Cinchona ledgeriana in Bolivia for Charles Ledger paid for his generosity with his life. Such treatment of indigenous peoples was not unusual. Historically, the intellectual property rights of indigenous peoples have not been recognized. The use of information supplied by indigenous peoples in the discovery of commercially marketable pharmaceuticals raises the question of those people’s intellectual property rights and the ownership of biodiversity.

The indigenous healers we work with offer significant intellectual guidance and input into our research programs. Thus we prefer to call them “colleagues,” “guides,” or “teachers” rather than “informants,” the term favored by anthropologists. In view of their significant intellectual contributions to our research, we believe that indigenous peoples are entitled to the same intellectual property rights enjoyed by other investigators. In the case of prostratin, for example, the National Cancer Institute and Brigham Young University have guaranteed that a significant portion of any royalty income will go to the Samoan people.

Yet in many cultures, the preservation of important habitats is equally urgent. In Samoa, four village-owned and -managed reserves totaling 50,000 acres, beginning with the Falealupo Rain Forest Reserve (where the tree that produces prostratin was first collected), have been created with donated funds. And in Belize, the world’s first extractive reserve for medicinal plants has been created on 6000 acres of tropical rain forest by the local government working with the association of traditional healers with significant international support. This effort seeks to demonstrate that conservation and the use of forests as sources of locally consumed medicines are compatible objectives. Elsewhere, as in India, medicinal plant reserves are being established to ensure a continued supply of plants for traditional health care practitioners and their patients.

Cash disbursement of royalty income most closely approaches the Western concept of equity, but this approach fails with peoples who have no monetary...
For many indigenous peoples, the right to live unmolested and undisturbed on their ancestral lands is the greatest value. Establishment of nature preserves that protect both biodiversity and indigenous cultures is of tremendous importance to indigenous peoples. And this need can be most clearly seen in those societies that depend neither on commerce nor on agriculture for their sustenance: the hunter-gatherers.