FROM: Balick, M.J. , T. Swanson (Eds.) 1995.
INTELLECTUAL PROPERTY RIGHTS and BIODIVERSITY
CONSERVATION: An Interdisciplinary Analysis
of the Values of Medicinal Plants. Cambridge
University Press. New York. 45pp.

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Ethnobotany and the search for balance between use and conservation

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> One of the Lord Buddha's disciples was sent out to find a useless plant. After months and years of wandering, he came back and told the Lord Buddha that there was no such thing. Every plant has a use . . . one must only find out what that use is.

Human strategies for survival have long depended on an ability to identify and utilize plants. Generations of experience – success, failure and coincidence – have contributed to a very broad base of knowledge of individual plant species and properties which have been perceived as useful; but encroached upon by market demands and acculturation, both indigenous cultures and the diverse species to which they are tied have retreated to habitat remnants covering a fraction of their former area. It is becoming apparent that the preservation of remnants of biological diversity in large part depends on the knowledge and participation of the world's endangered cultures (Durning, 1992). The field of ethnobotany, studying the relation between people and plants, initially developed as a means of distilling and adopting valuable information founded on indigenous experience with plants. Although the research and exchange of valuable, and often profitable information, continues to be a central component of the field, applications for ethnobotanical information are rapidly expanding beyond colonial patterns of the extraction of resources and ideas. The image of a lone ethnobotanist paddling up river through the jungle in search of miracle cures no longer adequately conveys ethnobotany's increasingly relevant conservation applications: salvaging and strengthening human ties to natural ecosystems and the species they contain.

Traditional experience represents long-term associations between natural systems and their increasingly estranged human inhabitants. The conversion of land to static uses such as logging, grazing and monocrop agriculture, however, has triggered a homogenization of process and product that is rapidly eroding these ties and threatening natural ecosystems and the diversity of species they contain (Sarukhán, 1985). This trend, turning natural systems into comparatively static clearcuts, pastures or monocultures, is founded more on ignorance of biological systems than on experience (Tobin, 1990). Even if windfalls of funding and technological advances enabled the collection, documentation and screening of the remaining 99% of uninvestigated higher plants (Farnsworth, 1988) in a miraculously short time, leaps in taxonomy and phytochemistry would rapidly outstrip our ability to apply information about species regeneration and to develop more effective incentives to protect biological diversity in its natural habitats. Many historic examples of the overharvest of valued species, the latest of these being the Pacific Yew, reinforce the importance of matching our understanding of molecules with an ability to sustainably manage the larger natural systems in which they originate and flourish. Developed over thousands of years, indigenous experience provides crucial insights and incentives for conservative ecosystem management.

Ethnobotany is not the only means of counteracting the loss of biodiversity, nor the only avenue for the discovery of new medicines, but its relevance to both fields is often heralded as a means of creating incentives for conservation that will be meaningful in global markets. The global and local markets for medicine derived from plants provide some of the highest profile and perhaps most sophisticated applications from otherwise relatively poorly understood ecosystems. Intermittent discoveries of new species, new therapies and novel chemical mechanisms have served to re-seed motivation for further research into both biological and cultural diversity.

This chapter will examine relevance of ethnobotany to current conservation issues, as a source of both commercial incentives for research and as a model for the use and conservation of biological diversity. The discussion begins by looking at indigenous criteria for usefulness and several examples of how this experience has been applied. Current applications have been preceded by what amounts to many generations of trial and error which can not readily be repeated. This is followed by an outline of traditional means of preserving and perpetuating this body of information. The traditional mechanisms for conveying culture can not be frozen in a germ bank for future use but they do provide a living link between past experience and future applications. The next section explores the historical development of the discipline, as a reflection of societal and scientific values, leading to a discussion of the current relevance of ethnobotany to both conservation and natural product development.

Indigenous screens for useful species

Fewer than 1% of flowering plants have been thoroughly investigated by modern science for their chemical composition (Farnsworth, 1988). Traditional knowledge of the biology and utility of plants is vast by comparison. Thousands of years of direct dependence on plants has required the revision and perpetuation of a significant body of information regarding the value of individual species and their habitats (Johns, 1990).

Potential uses of plant fibers such as hardwoods, bamboo or jute can be readily surmised and tested, but useful chemical activity or nutritional benefits are more difficult to determine. Numerous strategies have been developed to steer the selection and matching of plant species and applications. Like a farmer who tests soil composition by taste, a sample taste can provide evidence of a plant's chemical properties; sweetness may indicate a plant is edible whereas a bitter flavor often signals toxicity or potential medicinal activity (Schultes and Rauffauf, 1992; Griggs, 1981). Other indications of potential chemical activity are based on the observation of a species' characteristics *in vivo*. When it has been noticed that mosses appear to never grow on the trunks of certain trees, or that bark heals most quickly when stripped from the side of a tree which receives the most sun, these observations are incorporated into traditional knowledge about plants and their potentially therapeutic applications.

The morphology of individual plant species has also been correlated with their medicinal efficacy. The 'Doctrine of Signatures' is based on the belief that shape, color or other characteristics serve as clues alluding to specific diseases or a particular part of the body for which a plant would be an effective remedy (Griggs, 1981). There are many historic examples which include administering the snake-like root of *Rauwolfia serpentina* as an anti-venom (Woodson *et al.*, 1957), red latex or leaves for blood disorders, milky saps (*Ficus* and *Prunus dulcis*) to encourage milk in nursing mothers (Duke, 1989) and liver-shaped leaves (*Hepatica nobilis*) to treat the liver (Lewis and Elvin-Lewis, 1977). Some examples require an active imagination and many have proven ineffective under further scrutiny. Many traditional healers, however, do not judge a plant's potential on looks alone. They attribute their knowledge of plants and medicinal applications to the plants themselves, relying on information which was conveyed to them through spiritual rather than visual senses. The applications of many traditional compounds derived from plants involve such sophisticated manufacturing processes and chemical responses that it seems difficult to imagine they were arrived at by persistent trial and error alone.

Increasingly sensitive tests and clinical trials are being developed, *in vitro*, in an effort to gain greater consistency and control over the search for useful therapeutic applications and novel compounds. Today's sophisticated screening technology has made it possible to recognize unusual chemical activity, such as is found in taxol, from among random collections that tional knowledge of the biology and utility of plants is vast by comparison. Thousands of years of direct dependence on plants has required the revision and perpetuation of a significant body of information regarding the value of individual species and their habitats (Johns, 1990).

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Increasingly sensitive tests and clinical trials are being developed, *in vitro*, in an effort to gain greater consistency and control over the search for useful therapeutic applications and novel compounds. Today's sophisticated screening technology has made it possible to recognize unusual chemical activity, such as is found in taxol, from among random collections that include thousands of species and exponentially more compounds. In considering the continued high rate of success in finding valuable bioactive compounds in plants traditionally used as medicines (Cox, 1990), capital-intensive *rational* or *empirical* screens (see Aylward, this volume) can not realistically be considered as a total replacement for 'experience-intensive' ethno-directed sampling. We suggest that a viable niche exists for ethno-directed drug discovery programs, a theory supported by the recent formation of a well capitalized company dedicated to this approach. Ethnobotanical information not only contains biochemical leads, but a history of biological acumen and sound resource management as well. As illustrated by the recent shortages created by the demand for the bark of the Pacific Yew, the search for potentially useful compounds has to be as concerned with issues of sustainable supply as it is with the discovery of new chemicals and new cures.

Today the use of products derived from plants, such as quinine and tomatoes, seems fairly widespread, but at some point in time the potential use of each rested on small scale discoveries between one person and an individual plant. Ethnobotanical knowledge has evolved over such an extended period of time that it is difficult to reconstruct the chain of events that preceded these breakthroughs in understanding. In most cases only the application remains as an artefact of the experience on which it was founded. In an effort to understand the contemporary relevance of this type of knowledge to both human and environmental health, one must consider the confluence of events that can lead to the initial recognition of a resource.

Indigenous discovery and utilization

We have selected a few examples of the complex convergences of biology, ingenuity, faith and circumstance that have led to discoveries of new species and new applications. Although this volume primarily focuses on plants and natural products that are used medicinally, we have also included several foods in this section to help illustrate the chemical sophistication of ethnobotanical information in some cases, and its surprising familiarity in others.

At some point in the history of human habitation in the Andes a connection was made between malarial fevers and an infusion from the bark of *Cinchona* trees. Before the first shipments of 'Jesuit bark' to Europe and prior to the alleged cure of the visiting Countess of Chinchón, the profound effects of *Cinchona* bark were recognized and put to use. Speculation has woven an image of a large tree downed by a storm, lying in a stagnant pool of water. Over time the water grew brown from the bark and other plants that had fallen into the pool. A traveller, feeling weak and ravaged by intermittent fevers, stopped to drink and quench his thirst. A short time later the fever went into remission. There were few enough variables and so the survivor was able to connect the disappearance of the fever with the tea-colored water and the peeling bark of a dead tree. In such a way the bark of the *Cinchona* tree gained recognition as a treatment for malaria, a disease that has caused the death of more people than any other in history (Jaramillo-Arango, 1950).

The uses of most plants are not as well established as *Cinchona*, but are undergoing constant revision and development. The tomato (*Lycopersicon esculentum*), now among the top 30 food crops in the world, only relatively recently overcame a reputation of being a rank and toxic weed (National Research Council, 1989). Its origins can be traced to the Andes, but there are no indications that it was used as a food there. Tomatoes were introduced to Europe by 1530, but spread more as ornamentals and curiosities than as a food. For centuries the 'love apple' was widely believed to be poisonous, it was considered suicidal to eat one raw. This probably has some founding in past experience, as many other members of the Solanaceae, jimson weed (*Datura*), tobacco (*Nicotiana*) and nightshade (*Solanum* spp.), can be highly toxic (Blackwell, 1990). The fruits first gained acceptance as a food in Italy, but northern Europe and North America continued to regard it with suspicion until the late 1800s. In a popular American housekeeping guide published in 1860, readers were still cautioned to cook tomatoes for at least 3 hours prior to their consumption (National Research Council, 1989). As recently as 1962 a species that was new to science was discovered in Peru. These tiny, green tomatoes contain twice the sugars of the commercially cultivated species. After nearly a decade of crossbreeding the genes for a high sugar content were successfully transferred into horticultural lines of the standard tomato (National Research Council, 1989). Previously shrouded in either misrepresentation or obscurity, the tomato is an example of potentially valuable plants and genes that go unknown or underappreciated.

The discovery of many ethnobotanical applications do not rest on a single experience such as a fatal bite or a miraculous cure. Often edibility or therapeutic applications can require elaborate advance preparations. Two types of manioc, for example, are widely cultivated and consumed but require specific and laborious preparations. The two varieties, 'bitter' manioc and non-toxic 'sweet' manioc, appear so similar that they are only recognized as one species, *Manihot esculenta*, by Western botanists (Schultes, 1992). Failure to recognize the difference, however, could prove fatal.

Bitter manioc, a root crop that is a staple starch for many people in South America, contains levels of cyanide that can cause death (Lewington, 1990). The Kuikuru of the Central Amazon cultivate only the more toxic bitter manioc and have developed a distinctive preparation process that renders the tuber edible.

The tubers are first washed and the outer layers, containing most of the toxin, are scraped off using shells. After being peeled they are grated into a watery pulp to remove the toxin. Other groups begin by soaking the tubers for 3 or 4 days and then mash or pound the semi-fermented mass. They then strain the pulp without rinsing, unlike the Kuikuru who rinse it thoroughly at this stage by laying the grated tuber on wood slats and pouring water over the top (Dole, 1978). The resultant leached pulp, the liquid and the starch are all used as food: soups, beverages, sauces, flour and flatbreads. When a hot soup is made from the liquid pressed from the pulp a man is designated as the formal taster, ritually taking responsibility for any toxicity on behalf of the host. Numerous accounts of its use as a poison for both suicide and homicide provide further evidence of the awareness of the toxin. At some point multiple experiments in distinguishing and preparing bitter manioc root established the necessary steps that continue to be followed daily in many parts of South America and Africa (Dole, 1978).

Some applications require combining two or more species to produce the desired result. Many types of curare, or arrow poisons, have been devised using species of *Chondodendron* vine from the forests of the western Amazon, woody *Strychnos* vines from the Orinoco basin and Guianas, and a combination of gums and resins that help adhere the poison to the tip of an arrow or dart. As mentioned earlier, taste is often one of the principal tests of the identity and potential of a plant. It is probable that the characteristic bitterness of many plants used as arrow poisons may have led hunters to discover their poisonous attributes (Schultes, 1992). The range of arrow poisons used across South America are known by many names: *curare*, *wourali*, *ourari*, *urali*. Similar sounding names may be evidence of the frequent exchange of ideas and ingredients among mobile hunters. One could deduce then that the initial discovery of efficacy, or any subsequent incremental improvements, travelled along these same channels of communication. This information has persisted in the traditional rituals of harvest, preparation and use. Over 75 different plant species are used to make arrow poisons in the Colombian Amazon alone, but the majority have been found to contain at least one of the two genera mentioned above (Schultes and Rauffauf, 1992).

Another combination of lianas, or vines, is used to make an intoxicating drink manufactured for ritual healing and 'enlightenment'. Traditional stories about the origins of this powerful tonic weave together ancestral guidance, communication with the spirits of the plants, and the protection of visible and invisible guardians. Known by a variety of names including *caapi*, *yajé*, *sainto daime* and *ayuhuasca*, the drink is produced using the bark of the jaguba vine (*Banisteriopsis caapi*). The vine's three visible guardians, a grasshopper, the chicua bird and a snake, and invisible guardians must be appeased before harvesting (Luna, 1991). Despite these protective beliefs, traditional healers need to travel greater and greater distances to gather the bark from older, more potent vines. Increasing scarcity makes it often more practical to invest the time and effort in cultivation instead (Schultes, 1992). The vine of *B. caapi* can be readily grown from cuttings which contributes to the belief that each tendril and leaf is part of one continuous vine stretching back through time, described as an umbilical cord linking people to the past (Hugh-Jones, 1979).

The bark most commonly harvested from *Banisteriopsis caapi* (also collected from other forest vines or lianas in the same family) is peeled and boiled for several hours or pulverized in cold water to make a less concentrated batch. The resultant beverage is believed to be an effective treatment for many ailments, and is widely used in the Amazon. The type of hallucinogenic effects of the drink depends on many variables, including the time of day it was harvested, the preparation, the setting in which it is consumed and the addition of other plant species. The most frequent additives, used to both strengthen and prolong the experience, are leaves from 'oco-yajé' (*Diplopterys cabrerana*) and 'chacruna' (*Psychotria viridis*) (Schultes, 1992). They contain tryptamines which are usually inactive when taken orally, except when monoamine oxidase inhibitors are present. Not coincidentally the compound, harmine, found in *B. caapi* is this type of inhibitor. The colors and the entire experience induced by the drink appear to correlate distinctly to the quantity and combination of the various additives (Schultes and Hofmann, 1979). The recognition of such chemical fine tuning and its physiological results indicates a very sophisticated science. This leaves one wondering how traditional cultures arrived at such an unusual synergistic combination. As with the collection and production of curare, the preparation of the drink *ayuhuasca* has become highly ritualized. The adherence to ritual serves to both conserve the requisite plant species and standardize the end product, strictly replicating the original recipe generations after its first assemblage.

Despite thousands of years of human experience coupled with botanical variety, the intersections of diversity and human resourcefulness that produce new applications are unusual events. A vine in the family Bignoniaceae, found from Mexico to Argentina, is only known to be used by people in one place of its range. In a community in northern Colombia, several fishermen and their families were recently observed using a product from the vine to capture sand crabs. They manufacture a powder which they leave outside the crab's burrow. The crabs then eat it and are temporarily paralyzed, forced to wait until someone returns to collect them the following morning. The compound appears to be biodegradable as the crabs recover by the time they arrive at the local market and have been consumed with no apparent ill effects (Gentry, 1992). Perhaps this limited use for capturing crabs is an indication that it is not far from the time and place where it originated, but even from this proximity we are left with a single specific application as a record of a long and largely obscured past.

Information dispersal and perpetuation

The key to the quality and vitality of ethnobotanical information is not the static end result, but the biological and cultural dynamic that fuels a cycle of discovery, use and proliferation (Johns, 1990). Ethnobotany, like most scientific endeavors, is perpetually adapting old ideas to new information, but few fields are losing their resource bases as quickly. Ethnobotanical knowledge is rapidly eroding, caught between the loss of species and the habitat that provide new material on the one hand and the loss of the cultural legacy of experience on the other. As mobility and markets mix people and traditions, the efforts to find common ground detract from individual experience and cultural distinction. Botanical knowledge which sustained our predecessors is being converted to memory within one or two generations, and entirely forgotten by the next (Messer, 1978). The information and values which are replacing this knowledge often obscure the impetus for conservation of natural systems and the species they contain.

Yet locally developed and managed systems of knowledge and its use continue to be the richest source of information available regarding the use and conservation of species and habitats (Durning, 1992), in addition to being a source of new drug leads and other potentially marketable products. In order to find new means of counteracting these processes of dissolution and acculturation, and strengthening this connection, it is necessary to build on the languages, traditions and institutions that have protected and perpetuated the knowledge of plants and their uses for generation (Sheldon and Shanley, 1991).

In cultures with written language, revered ethnobotanical traditions have been transposed into elaborate volumes on ethnomedicine, horticulture, famine foods and other compilations. Ayurvedic doctors trained in Ayurvedic schools, for example, rely on a vast body of reference material, botanical gardens and collegial support in their practices. The same is true in Chinese traditional medicine where an extensive network of institutions are devoted to the study of plants and their uses. In countries such as Thailand and Tibet, monasteries have provided an educational structure for a large percentage of the population, and a sanctuary for traditional practices. This was also true, ironically, of European monasteries in the Dark Ages, which protected folk knowledge of herbs at a time when anything that might be mistaken for witchcraft went underground (Griggs, 1981).

In oral traditions, cumulative knowledge is often harbored by respected individuals such as healers or hunters, and transmitted through apprenticeships with younger members of the community. Much of ethnobotanical literature is based on interviews with only one principal informant. In the Colombian Amazon, the role of shaman is not a hereditary position; there are certain qualities that are sought out. The candidate must be interested in myth and tradition, have a good memory, a strong singing voice and above all their 'soul should shine with a strong inner light rendering visible all that is hidden from ordinary knowledge and reasoning' (Schultes, 1992). Embodied in individuals, this type of information is more vulnerable to mortality and acculturation than the printed word.

In other cultures, without the benefit of human or literary repositories, ethnobotanical information has been dispersed in a thinly spread residue of folkloric knowledge, as is the case in many communities disconnected from their ethnobotanical heritage by colonialism or other fragmentation. On a recent trip, a reporter from the USA was trying to capture and document the importance of biodiversity in the Brazilian Amazon. After 3 days of interviews, looking for exemplary species he had become frustrated; each time he asked a new person which plant they thought was the most important, he got a different answer (P. Shanley, personal communication). Knowledge that is conveyed orally is more adaptable to new information but is also perhaps more vulnerable to the distortions of individual experience than the printed word.

Traditional means of preserving and perpetuating ethnobotanical knowledge are being undermined by larger market demands and the values they foster (Durning, 1992). Loss of cultural ties to place, combined with habitat destruction, make it continually necessary to develop more effective methods of protecting what still exists. Numerous efforts are being made, but their numbers are small relative to the rapid and irreversible loss of information. One such example is a collaborative effort between the Ix Chel Tropical Research Foundation in Belize and the New York Botanical Garden, which focuses on the collection, documentation and study of traditional medicine (Balick, 1991*a*, *b*). The project strives to work on several different levels simultaneously; learning from groups of elderly healers who for the most part do not have apprentices, teaching the community's children through school programs, building nurseries with the Belize College of Agriculture, building cooperation with the Belize Association of Traditional Healers and contributing to Western medical research collecting for the Developmental Therapeutics Program of the National Cancer Institute. One of the most exciting developments is the recent donation of 6000 acres of old growth forest to be managed by the Belize Association of Healers for teaching, extraction and conservation (Belize Association of Traditional Healers, 1993). Extractive reserves, plant nurseries, college curricula, herbaria and other institutional harbors can provide much needed temporary shelter for both information and species.

The development of ethnobotany through the prism of academia

Although all the academic twists and turns of this interdisciplinary and applied science are not relevant to this discussion, it is important to sketch the changing perspectives on indigenous knowledge as a backdrop for current attitudes and applications. The direct dependence on plants has historically given the knowledge of how to identify and utilize individual species a place of central importance, but as markets grow, many people have become removed from a personal stake in this connection. This increasing distance gave rise to academic studies in aboriginal botany, ethnology and eventually in ethnobotany. The fledgling field of ethnobotany initially focused on the transfer of plant uses employed by 'primitive' people, but changes in cultures, markets and the availability of resources have broadened both the topic and its potential applications (Ford, 1978).

Even though it was not recognized as ethnobotany at the time, the search for new plants and new uses drastically escalated as explorers of the fifteenth and sixteenth century spread out around the globe (King, 1992). Many expeditions were spurred on by visions of gold and other treasures, but the most valuable cargo they often returned with was a satchel of seeds, a sack of bark or Wardian case filled with seedlings (Jaramillo-Arango, 1950). The crews often included an illustrator or a naturalist in an effort to document and absorb all that they encountered. As a means of documenting vast areas in a single sweep, this early form of ethnobotany constituted list-making occasionally punctuated by large rewards, such as *Cinchona*, chocolate (*Theobroma cacao*), tobacco (*Nicotiana*), maize (*Zea mays*) and potatoes (*Solanum*) (National Research Council, 1989). This approach defined the early colonial perspective on cultural and biological diversity.

As the emphasis on list-making became more earnest and abstract, taxonomy and compilations on practical use diverged. The study of useful plants was not regarded as a thoroughly respectable scientific subject. Even Linnaeus, who established the binomial system for scientific nomenclature, expressed the opinion that useful plants were unworthy of study (Wickens, 1990). By the eighteenth century, an awakening interest in the natural and cultural treasures of the New World fueled numerous publications on the traditional lives and livelihoods of Native Americans and a surge in botanical information about the New World (Bye, 1979).

The combination of practical application and botanical discipline marked efforts such as the Lewis and Clark expedition in the early 1800s and the later work of Edward Palmer and Stephen Powers in the 1870s (Wickens, 1990). This unspecified discipline was inadvertently advanced by an American anthropologist while conducting research in Mexico. Palmer planned to collect anthropological information and his colleague, a botanist, would collect the botanical specimens. Shortly after their arrival to begin field work in 1878 his partner fell ill and had to return to the USA. Palmer continued the research, collecting and describing useful plants in conjunction with his anthropological work, for the rest of the expedition and the remainder of his career, making the initial collections and ethnobotanical documentation of many plant species culturally important to North America. Palmer's collections reflected his focus on practical applications and the cultural context of a given plant, often including plant parts such as roots or seeds which were valued by the indigenous people, but may have been overlooked by a collector with a purely taxonomic background (Bye, 1979). Powers, working among the Neeshenam Indians of California (1875), used the term 'aboriginal botany' to describe 'all forms of the vegetable world which the aborigines used for medicine, food, textiles fabrics, ornaments, etc.' (Ford, 1978). For approximately the next 20 years this term and its definition were accepted by those working in the field (Wickens, 1990).

The term 'ethnobotany' was initially inspired by an archeological collection exhibited at the 1893 World's Columbian Exposition in Chicago. Professor John Harshberger, of the University of Pennsylvania, captured the essence of the exhibit in a lecture entitled, 'The Purposes of Ethnobotany' delivered to the Archeological Association in Philadelphia in 1896 (Harshberger, 1896). Harshberger outlined the following reasons for the importance of ethnobotanical study:

1. To define tribal cultures and their methods of husbanding resources.
2. To shed light on the distribution of plant species.
3. To help trace former trade routes.
4. To suggest new lines of manufacture.

At this point in time expanding settlements and exploration were encountering many indigenous cultures and languages. The primary focus on finding and transferring valuable applications was an outcome of an historical search for new resources coupled with a lack of experience with native languages and indigenous systems for classifying the natural world (Ford, 1978). The field of economic botany has continued in this vein, searching for new ways to incorporate useful plants into other commerces and cultures, usually into those economies that have several layers of transactions between the harvest of a plant and its consumption or utilization (Ford, 1978). The field of ethnobotany, on the other hand, has become increasingly cultural in orientation, considering plant use in the context of human needs, values and beliefs. Although the differences between the fields of ethnobotany and economic botany are continually being reinterpreted, the semantics seem to represent not such drastic topical differences as different frameworks for valuing plants: a cultural versus a commercial measure of import.

The current role of ethnobotany

As the complexities and relevance of ethnobotany gain a broader audience, its applications have reached beyond the documentation of a new therapy or fiber to provide models and incentives for cultural and biological conservation. Long-term experience with plant biology, habitat preference and regenerative capacity can provide useful models for a balance between the use and conservation of resources (Redford and Padoch, 1992). Cultural experience provides a living link to complex natural systems, without which each successive generation would be left to their own devices.

Three important applications are emerging from the changing role of ethnobotany. The first is using ethnobotany as a means of recognizing the essential role of culture as a conveyor of relevant experience (Ford, 1978). Direct dependence on natural systems and traditional medicines continues to be a way of life for a large part of the world's population. Over 80% of people in developing countries, for example, continue to rely on traditional plant-based medicines for primary health care (Farnsworth, 1988). Ethnobotany grew out of basic human needs and it is in these localized contexts that applications are primarily reinforced and perpetuated (Jain, 1990). This is the critical link between the continuation of knowledge of plants from the past and potential applications in the future. Whether motivation stems from short-term market potential or long-term ecological survival, no strategy for the conservation of biological diversity can succeed without the support of indigenous people and subsistence farmers (Castillo, 1992).

Second, indigenous approaches to ecosystem management, based on a detailed knowledge of a plant's uses and biology, can provide invaluable long-term models for sustainable use (Redford and Padoch, 1992). Although perhaps more motivated by necessity than altruism, many cultures have developed beliefs and practices that have proven sustainable over time (Posey, 1992). As most studies of ecosystems and species occur in a short time frame relative to the processes they are trying to describe, ethnobotanical experience provides invaluable perspectives on the long-term sustainability of any given practice. A solid understanding of the biology of a plant often underlies cultural beliefs about wild collection and cultivation, as exemplified by the three guardians of ayuhuasca vines.

Lastly, traditional resource management, formed in this cultural context, reinforces a dynamic system that both conserves and exploits biological diversity (Alcorn, 1994). Indigenous communities and relatively unscathed ecosystems overlap with marked regularity for two reasons. First, because both native peoples and unique plant and animal species tend to have been relegated to remnant parcels of land, areas that contain the highest species diversity are often homes for endangered cultures, and second, because indigenous peoples have consciously fostered genetic diversity within species compared with the modern propensity for monocultures of vulnerable hybrids (Durning, 1992). Large-scale cultivation, transportation and regulation of plants and the manufacture of their derivatives all contribute to the shrinking number of species recognized as valuable. Less than 4% of the 80 000 plants known to be edible are widely cultivated, and only seven species provide three-quarters of human nutrition (Tobin, 1990). This relative handful of domesticates partially obscures the diversity and value of the wild plants that we are only just re-discovering (Griffin, 1978). In the meantime, direct ethnobotanical experience is one of the most tangible means of differentiating and utilizing the diversity of species in any given habitat (Jain, 1990) and countering the simplifications of 'economies of scale' seemingly inherent to development.

This new relevance for *old* experience focuses on the conservation of cultural and biological diversity, but as incentives based on direct experience and dependence erodes, it is necessary to find additional means of ensuring a vested interest in the conservation of diversity. It is becoming apparent that unless economic values can be assigned to natural products and to the people who know how to propagate, prepare and use them, the prospects for preserving species diversity and indigenous cultures look increasingly tenuous (Posey, 1992).

The role of ethnobotany in pharmaceutical prospecting

Plants have been the cornerstone of medicinal therapies for thousands of years and continue to be an essential part of health care for much of the world. The traditional origins of many current pharmaceuticals have been obscured by the process of drug development, such as aspirin from willow bark (*Salix* spp.), reserpine for hypertension from the Indian Snake Root (*Rauwolfia serpentina*) and D-tubocurarine, widely used as a muscle relaxant in surgery, from arrow poisons (*Chondodendron tomentosum*, as discussed earlier), but the plants used in traditional medicine continue to supply the industry with raw materials and new ideas. Of the frequently quoted 25% of prescription drugs sold in North America that contain active principles derived from plants (Farnsworth, 1988), three-quarters were initially recognized by the industry because of their use in traditional medicine (Farnsworth, 1990). The current directions in the industry, however, are not so much determined by swashbuckling histories, as by which screening methodologies generate the best new drug leads.

Ethnobotany is just one strategy for discovering new compounds, but the pharmaceutical businesses that have chosen to focus on leads from traditional medicines have not based their decisions on altruism alone. To test this approach a theory of species sampling described as the *ethno-directed sampling hypothesis* was proposed. It maintains that using the combination of indigenous knowledge and ethnobotanical documentation as a pre-screen will allow the researcher to obtain a higher number of leads in a pool of plant samples compared with a group of plants selected at random (Balick, 1990). In an initial test of the hypothesis, plant samples from Belize and Honduras were subjected to an human immunodeficiency virus (HIV) screening by the National Cancer Institute (NCI). Six per cent of the random collections indicated activity, whereas 25% of the ethnobotanical collections were active (Balick, 1990). More recent studies using *in-vitro* and *in-vivo* screens with traditional pharmacopoeia continue to show high rates of pharmacological activity. In a screening of plant species used as medicine by indigenous communities in Samoa, over 86% displayed significant chemical activity (Cox, 1990). Screening results from a newly established company, Shaman Pharmaceuticals, have revealed that of the samples that displayed promising chemical activity, 74% directly correlated with the original ethnobotanical use (King, 1992).

The NCI recently re-embarked on medicinal plant research in the mid-1980s, initiating species collection in many different parts of the world. In a sample of NCI's latest screenings for activity against HIV, less than 2% of the random species collections showed *in-vitro* activity worth pursuing further in the laboratory, whereas over 15% of the ethnobotanical collections indicated preliminary chemical activity against the virus (M.J. Balick, unpublished data), later attributed to other compounds with previously known anti-viral effects such as tannins and polysaccharide. These were not pursued as this search was limited to 'novel' compounds.

The depth and breadth of ethnobotanical research to date has been conducted almost as spottily as the research on biological diversity. Explorers and field researchers have not systematically and consistently targeted the most likely leads first. The focus of research has been shaped by many external factors including geographic access, funding stipulations, language barriers and chance. Hence, it seems unlikely that the potential of future discovery has been significantly diminished by the subtraction of each new compound from the pool of information. With the increasing importance of supply issues, in concert with the pursuit of new products, it is probable that ethnobotany will continue to provide as valuable leads in the future as it has in previous decades and centuries.

Natural products and individual cultures pose significant obstacles for industries which are striving to maintain consistent levels of quality and supply on a large scale. The costs involved in finding and isolating useful compounds, developing a product and out maneuvering the competition often seem to outweigh the potential benefits of any therapy short of the cure for cancer. Many of the major pharmaceutical companies were founded on the commercialization of products derived from plants, but most have largely converted to synthetic production and cut back on natural product research (Farnsworth, 1988). More recently the limitations of the ability of modern medicine to cure and the growing specialty markets for herbals and alternative medicines (Angier, 1993) have reversed this trend and many companies are again investing in the search for interesting natural products (Shaffer, 1992).

Pharmaceutical companies have developed mass screening programs to accommodate a large volume of botanical samples. These screening processes are capital intensive and usually rely on spotting chemical actions that have been previously recognized in the laboratory and are already understood. A recent departure from this approach is an effort currently underway at Shaman Pharmaceuticals, located in San Francisco, California. Shaman's strategy is to develop more efficient discovery processes by focusing on plants with a history of human medicinal use (Shaman, 1993), species whose activity has been recognized in a traditional context. They hope thereby to significantly increase their rate of success and cut the investment of time and capital required to prove a drug successful and to take it to market. In their initial charter, Shaman established a parallel non-profit-making company called The Healing Forest Conservancy to address the needs and rights of the communities in which they conduct ethnobotanical research. This effort to recognize the value of wild species, ecosystems and traditional knowledge is aimed at bridging the seemingly divergent interests of both traditional people and Western consumers (Shaman, 1993). Although driven by shareholders' interests, the company has consciously linked their success as a business to their ability to protect the resources on which their business is founded.

Even though industry's interest in the potential of biological diversity and traditional knowledge may stimulate a new wave of investment in ethnobotanical research, there are many historic examples of demand overrunning formerly abundant natural resources, as well as the cultural practices that once protected them (King, 1992). Developing markets for natural products, particularly those that are harvested from the wild, can trigger a demand that cannot be met by available or legal supplies (Ehrenfeld, 1992). Although *sustainability* is widely used to describe management practices which do not damage the distribution and genetic integrity of a plant population over the long term, what these practices actually are must be determined on a species basis (Foster, 1991). Since most industries have more experience with marketing than with determining levels of sustainability, levels of sustainability are often developed more according to levels of demand than to actual population dynamics of a natural supply. It is probable that many more so-called *green* products are sold than could potentially be 'sustainably' harvested (Shaffer, 1993). Developing a better understanding of resource availability and renewability is an essential aspect to the development of truly *green* products (Toledo *et al.*, 1992).

Conclusion

Ethnobotany is not the only avenue for new drug discovery, nor the only source of models for conservation, but the body of knowledge it represents is founded on long-term experience with both subjects. The divisions created by expanding economies and advancing technologies have served to separate the demand for natural products or traditional knowledge from the protection of their sources. There is still so little known about biological diversity and the chemical activity it contains, hence random or rational screening will continue to uncover new species and new compounds. For the same reason, the magnitude of what remains unknown, scientists will continue to improve our understanding of the biological requirements of individual species; but responding to complex social and biological issues, such as those presented by new drug development, must incorporate multiple approaches.

Recent events and issues such as the UNCED conference, the controversy over the transfer of germplasm across international borders, new initiatives in pharmaceutical development and manufacture, the debate over intellectual property rights and the assignment of royalties have all helped focus global attention on the balance between the conservation of biological diversity and economic development. As stated previously, it is not a coincidence that the areas of greatest biological diversity are most often home to endangered indigenous cultures. These traditional links between people, habitats and the species they contain have served to transmit information and protect species for thousands of years. We may not have the luxury of time to re-establish the neurological effects of arrow poisons or the timing for harvesting medicinal roots that encourages regeneration, but it is critical to find new avenues for utilizing and valuing this body of knowledge.

A glance at the strategies used in both commercial and academic drug discovery programs indicate that, in the past decade, the ethno-directed approach is occupying an expanding niche in the field of new drug development. The discovery of new applications and new compounds from traditional medicine has the potential to elevate the recognition of the value of that diversity in the global markets; but to preserve the possibility of new options and continued expansion we need to reach for new levels of informed management of biological resources (Wilson, 1990). Far from being outdated or irrelevant to the search for valuable natural compounds, the field of ethnobotany continues to offer invaluable experience with both useful plants and the management of natural resources, and can contribute significantly to the creation of effective conservation initiatives in both indigenous and industrial cultures.

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