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INDIGENOUS KNOWLEDGE.

What is evoked in people's minds when they have the opportunity to take a look, right in the field, at the magnificent pyramids in South, Central, and North America? What thoughts pass through Westerners' minds when they arrive as tourists to the architectural marvels of Machu Picchu, Peru; the magnificent Betatakin and Keet Seel cliff dwellings of the Hisatsinom (Anasazi), Navajo Nation; or the vast and visibly complex water irrigation and road systems of the Incas? What can be learned regarding the impressive raised-bed cultivation systems used for millennia by the Indigenous Peoples of the Americas as well as in Africa and Asia, which are reportedly highly effective for soil preservation, irrigation, drainage, and control of frost and plant diseases? Is there nothing to be learned from the Aztecs, who had 10,000 hectares of *chinanpas* capable of feeding 100,000 people?

Though Westerners are often overwhelmed at the sight of such exquisite monuments of the Indigenous Peoples, they sometimes wrongly conclude that only the ancient civilizations excelled, lightly dismissing at the same time any capability or merit on the part of their direct descendants. Such observers do not realize that Native Americans of today continue to practice agriculture, medicine, architecture, and other technologies essentially in the same creative way as their ancestors did. Sometimes Westerners have such serious doubts about the Native Americans' skills and ingenuity that they prefer to believe that super-intelligent extraterrestrial beings came down to earth and built those marvels. The above-mentioned achievements are clearly not the result of magical forces but, rather, the result of the inquisitive minds of objective and pragmatic people, capable of accurately grasping the nature of things. Is this body of knowledge held by the Indigenous Peoples comparable in some ways to Western science?

Can the poorest, most illiterate, and most dispossessed people of the world generate knowledge, technology, and specialized skills good enough to solve human problems? Can an indigenous society from the Amazon, which the Western imagination views as naked and in need of everything, have an organized set of structured knowledge about nature and life that could be profitably passed on to future generations? Are they capable of generating something that could be equated to Western science? When we think of science and knowledge, we are used to expecting scientific achievements to come almost exclusively from Western, literate, wealthy nations.

In this paper we take the point of view of the Indigenous Peoples in order to answer these questions. This means an approach based on experiences, history, and pragmatism rather than unending analysis and theorization. Furthermore, we focus on the medical knowledge of the Indigenous Peoples of the Americas as one example of the achievements of the world's indigenous peoples.

The Indigenous Peoples' Medical Contributions to the World

When we are nervously seated in the waiting room in the dentist's office, wondering about the pain and discomfort we might experience, it is amazing to realize, once in the dentist's examination room, that an injection of a small quantity of the local anesthetic *lidocaine*

in our mouth can make the experience much easier! For centuries millions of people worldwide have suffered the debilitating symptoms of malaria, and many of them have experienced the curative virtues of *quinine*, recognized as essential by physicians all over the world. *Tubocurarine*, to take another example, is a strong muscle relaxant used widely in abdominal surgery. In our gratitude and admiration for these medical accomplishment, we may unthinkingly give all the credit to Western biomedicine and, regrettably, forget completely to pay proper thanks to the fathers of this knowledge, who generously allowed humanity to benefit from these medicines: the Native American healers or doctors. The following discussion details how they are the source of these formidable developments of Western biomedicine and how they have contributed to the improvement of health worldwide.

Quinine. Quinine is the most important alkaloid found in the bark of the *quinaquina*, as it is known in Quichua, a tree native to the Andes Mountains in South America. *Quinaquina* (*Cinchona* sp.), an evergreen tree 10 to 15 meters tall with glossy leaves and fragrant pink or yellow flowers, contains a mixture of more than twenty alkaloids, the most important of which are quinine, quinidine, cinchonidine, and cinchonine. Although quinine can be synthesized, the procedure is complex and costly. For this reason, quinine and the other alkaloids are still obtained entirely from natural sources. Of the thirty-eight species of *quinaquina*, four species are economically valuable for the production of quinine: *C. calisaya, C. ledgeriana, C. officinalis*, and *C. succirubra*. For nearly four centuries quinine has been used as a Western biomedicine compound to fight malaria, the world's most devastating human parasitic infection, caused by the protozoan *Plasmodium falciparum*. Although treatment modalities for malaria are diverse, quinine remains an essential drug. It is currently used to treat cloroquine- and multidrug-resistant malaria, which is highly prevalent in South America, Africa, and Southeast Asia. According to the World Health Organization, in 1994 malaria was afflicting more that 500 million people and causing 1.7 to 2.5 million deaths each year. The Indigenous People of the Andes knew the *quinaquina* and its main medicinal properties long before the arrival of Europeans to South America at the end of the fifteenth century.

The story of how Europeans came to know the tree and later integrated it in the Western pharmacopoeia is truly captivating. It is said that in 1630 an Inca doctor known in Spanish as Pedro Leyva, who lived in what is now Loja in the southern highlands of Ecuador, revealed the medicinal uses and properties of *quinaquina* to the Jesuit missionary Juan López or, in other versions, to the Spanish Governor of Loja, Juan López de Cañizares. (Some stories have Leyva himself discovering the effects of *quinaquina* accidentally. In fact, missionaries had noticed its use by Native Americans as early as 1572.) One of the most famous legends behind the introduction of *quinaquina* in Europe is the story of Doña Ana de Osorio, countess of Chinchón and wife of the viceroy of Peru. In 1638 the countess contracted malaria; the fevers were slowly killing her. The Jesuit López or Governor López gave her the *quinaquina* that Leyva had revealed to him, and the Inca medicine cured her promptly and completely. Impressed by the virtues of the plant, she collected it and gave it to others who eventually brought it to Europe. Other historians believe that the philosopher Cardinal Juan de Lugo, also of the Jesuit order, was responsible for promoting the tree bark in Europe. This is why *quinaquina*'s many names include "Jesuit's powder" and "Cardinal's bark." Finally, in 1737 the Swedish botanist Carl Linnaeus named the tree after the Chinchón countess, and the name *quinaquina* was eclipsed in Western lore in favor of *cinchona*.

As early as 1640 cinchona began to be used to treat fevers all over Europe. The popularity and consumption of the plant increased dramatically over the following years. The virtues of the plant were constantly reaffirmed. By the end of the seventeenth century, Robert Talbor, a British apothecary, successfully cured King Charles II of

malaria. It is probably these accounts that rendered cinchona an officially recognized medicine in 1677, when it was included in the London Pharmacopoeia as *cortex peruanus* ("Peruvian bark"). Later, in 1820, the French scientists Pierre-Joseph Pelletier and Joseph-Bienaim Caventou isolated the main alkaloid of cinchona, which they named *quinine.*

The demand for cinchona rose so dramatically that, by the mid-nineteenth century, wild cinchona trees were being exploited to extinction. Charles Ledger, an early bioprospector, sent a few cinchona seeds to Europe. The Dutch became interested in the tree and initiated a plantation of cinchona trees in their colony on the island of Java in Indonesia. Subsequently, and for nearly a hundred years, they controlled nine-tenths of the world's quinine supply. No profits were shared with the Andean peoples, the intellectual owners of the splendid *quinaquina.*

During World War II, after the Dutch lost control of Java, the U.S. government immediately arranged mechanisms to obtain *quinaquina* bark from the Andes. Under a Quinine Agreement between Ecuador and the United States, the American Office of Economic Warfare supplied the administrative direction, funds, and technical resources for a massive enterprise to collect *quinaquina* bark. The Ecuadorian Cinchona Mission, a joint U.S.-Ecuador institution, was soon established with a staff of more that a hundred technicians and bureaucrats, and thousands of Quichua plants experts and laborers. It is estimated that nearly six million kilograms of dried bark were collected.

A recurrent theme in the foregoing stories and facts is the Westerners' unwillingness to recognize the contribution and intellectual ownership of the Quichuas of the Andes. Linnaeus, a botanist, thought it appropriate to identify the tree using the name of the domain of the Spanish countess, Chinchón. The Missouri Botanical Garden in St. Louis published, in 1930, a proceeding of the celebration of the three-hundredth anniversary of the "first recognized use" of cinchona! Apparently, Westerners were unwilling or unable to realize that the Indigenous Peoples of the Andes had long since recognized the tree and its most important medical uses. The European colonizers and scientists chose to deny the Native Americans' contribution and preferred to portray themselves as the discoverers of the great treatment for malaria. Had Native Americans not had the essential knowledge about *quinaquina* and shared this knowledge, however, Western biomedicine would never have identified the tree, associated it with a devastating disease, or isolated from it an active substance, quinine, for the treatment of malaria.

Cocaine and Local Anesthetics. Local anesthetics such as the lidocaine mentioned at the beginning of this section are due to another significant medical contribution from the Indigenous Peoples of South America to the world. The coca shrub, *Erythroxylon coca,* is a small tree native to the mountainous tropical regions of the Andes. For centuries, if not millennia, the chewing of coca leaves has occupied a central role in the lives of the Indigenous Peoples of northwestern South America. There is abundant material evidence of coca use as far back as 3000 B.C. Many figurines of coca chewers have been found in the coastal region of Ecuador, where the Valdivia people lived. The Carchi people of the northern highlands of Ecuador left many chewers' ceramics, including ash containers today called *iscupurus.* Mummies almost 2000 years old from the Nazca region of Peru customarily carry bags of coca leaves, now called *chuspas,* around their necks. Coca was so present and important that a wonderful Inca legend tells us that *Cocamama* (Mother Coca) was a beautiful goddess full of grace, health, and joy. All is not charm, and Cocamama, to the distress of many, was a promiscuous woman who was cut in half by her many lovers. Having no other means of survival, she managed to grow into the first coca plant. Coca leaves were consumed daily by the Indigenous Peoples of the Andes as both a food and a medicine. Coca was used to gain physical strength and endurance, to decrease fatigue, and to control pains such as toothaches and headaches. With the arrival of the Spaniards

to South America, the coca plant entered the scene of the Western pharmacopoeia.

In the early years of contact, the Spaniards dismissed the claims made by the locals about the coca leaves. Soon enough, the Catholic clergy and colonial officials began to consider the practice of chewing coca leaves inappropriate. In 1551 the Bishop of Cuzco banned coca use, under pain of death by burning alive, believing that it was an evil agent and a distraction to the Church's evangelization work. Eighteen years later, however, King Philip II of Spain, wishing to protect the life and productivity of the enslaved Indigenous laborers, decreed coca not evil. As often occurred with indigenous natural resources in colonial times, coca then became one of the most important sources of revenue for the Catholic Church and the colonizers. Ironically, in the following years, the church distributed coca to their enslaved Quichuas in order to improve productivity in mines and crop fields. Jesuits are claimed to have said, "The Devil's coca will now be used to assist God's work."

By the mid-nineteenth century, coca was intensely studied and became an extremely popular product in Europe. The young German scientist Albert Niemann at Göttingen University first isolated cocaine in 1860. Then Karl Koller, a Vienna ophthalmologist, found cocaine to be very useful as an eye, nose, and throat anesthetic. By 1884 cocaine was quickly integrated and used widely by the medical community as a local anesthetic. Coca may have been introduced to Dr. Koller by Sigmund Freud, who studied coca enthusiastically and was a great advocate of its medicinal properties. He believed that coca could be used for depression and other mental conditions, and he used it to relieve its own social anxiety. Later, coca was present everywhere. The French druggist Angelo Mariani's mixture of wine and coca, called Mariani's Coca or Dr. Mariani's French Tonic, became a symbol of a miracle drink and medicine all over Europe and the United States. Even Pope Leo XIII sponsored Mariani's coca wine! It was during this wave of coca enthusiasm that in 1886 John S. Pemberton invented Coca-Cola, which contained an extract of coca leaves (it still does, but the cocaine has been removed). By the end of the nineteenth century the U.S. pharmaceutical company Parke-Davis marketed cocaine as cigarettes, powder, a drink called Coca Cordial, and even a cocaine mixture that could be injected intravenously; the needle was included. Regrettably a history of misuse and abuse of coca followed, and cocaine addiction put a restraint to all the past fervor.

At the beginning of the twentieth century, concerns were raised about the toxicity and addictive properties of cocaine. In 1905, the work of Alfred Einhorn, who was searching for an alternative drug to cocaine, resulted in the synthesis of procaine, a prototypical local anesthetic. Procaine has the advantage of being less toxic than cocaine and nonaddictive. Since then, other closely related compounds inspired by the structure of cocaine have been synthesized. Among the most used in surgery and dentistry are procaine, lidocaine, bupivacaine, and tetracaine.

This collision of two worlds, the Western and that of the Indigenous Peoples of the Americas, exemplifies how traditional medical knowledge appropriation occurs. The persistent preference for recognizing a Westerner as a "discoverer" for simply bringing a plant to the Western public arena reflects the colonialist view that Indigenous people are nearly nonhuman, incapable of being owners or generators of knowledge, not entitled to respect for it. Even such a prestigious and sober textbook as Goodman and Gilman's *The Pharmacological Basis of Therapeutics* affirms that the anesthetic property of coca was "serendipitously discovered" in the late nineteenth century. It cannot be overemphasized that the Quichuas of the Andes had already been using coca for centuries to control pain!

Curare. In contrast to quinine and coca, curare did not attract the attention of the European masses. It remained a mysterious plant known only by medical experts. Curare is a poisonous resin used by the Indigenous Peoples of the Amazon River basin to hunt.

The preparation of curare is in the expertise of knowledgeable healers and hunters. The curare solution is coated onto small hunting arrows, which are shot with a blowgun to effectively paralyze animals. The most used species are *Chondrodendron tomentosum* and *Strychnos toxifera*. The poisonous nature of curare is due to the biological actions of its alkaloids: tubocurarine and the toxiferines. Curare acts as a neuromuscular junction—blocking agent, producing paralysis of skeletal muscles. The toxin causes death by paralysis of respiratory muscles.

Walter Raleigh is believed to have taken samples of curare to Europe in the late sixteenth century. Without the Native American source, he could never have noticed or come into contact with curare, made from a few of the thousands of plant species of the Amazon. Later, Charles Marie de la Condamine introduced curare to the French Academy, and Alexander von Humboldt, in 1805, stimulated the botanical investigation of the plant. The interest in curare re-emerged when doctors successfully used purified curare to treat patients with tetanus and spastic neurological disorders. When Richard Gill brought curare to the United States in 1940, the true clinical and surgical applications began. In 1942, Harold Griffith and Enid Johnson from McGill University, in Montreal, Canada, used curare, which until then had been considered as only a poison, to produce muscle relaxation. Tubocurarine is used today as a complement to general anesthetics in abdominal surgery. The severe muscle relaxation it produces, which would otherwise require dangerously large amounts of anesthetics, is beneficial in the operating room because it enables the surgeon to access and manipulate the internal organs. The use of smaller quantities of general anesthetics renders surgical operations safer, decreases anesthetic-related complications during surgery, and promotes quicker postanesthesia recovery. Without the original contribution of the Indigenous People of the Amazon, a substance some have dismissed as "a poison prepared by the savages of South America," Western biomedicine could hardly have achieved this breakthrough in surgery.

From Colonialism to Equitable Partnership?

The contribution of the Indigenous Peoples of the Americas to the world has been vast. It has touched almost every single aspect of modern life, including food, land, medicine, architecture, mathematics, federative politics, education, and ecology, to name a few. *Quinaquina*, coca, and curare are only a small fraction of what Native Americans know and have shared. According to John Borchardt, the hundred Native American nations have altogether contributed 220 indigenous drugs to the pharmacopoeia of the United States of America. In a wonderful book edited by Nestor Foster and Linda Cordell, *Chilies to Chocolate: Food the Americas Gave the World*, we can find 128 species of plants and crops that the Indigenous Peoples of the Americas shared with the world, including maize, potatoes, tomatoes, cacao (chocolate), chili peppers, avocado, beans, rubber, peanut, pecan, and vanilla. Undoubtedly, the indigenous knowledge and science has been practical and extremely useful for humanity.

Because the Indigenous Peoples are dominated and dispossessed by stronger nations in America, and colonialist practices against them persist today, rarely do they benefit materially from the use of their knowledge. They are unable to exercise cultural ownership or independently defend their intellectual properties and heritage. Despite all the abuses of the past and present, however, a period of recognition of the Indigenous Peoples, of their culture, territorial and human rights, and of their valuable science appears to be beginning.

Indigenous Peoples themselves are strongly voicing their concerns about the appropriation and use of traditional knowledge. The Indigenous Peoples of the Americas, Africa, Asia, Australia, Europe, and the Pacific, united at the World Conference of Indigenous Peoples on Territory, Environment, and Development (May 25–30, 1992), endorsed the Kari-Oca Declaration and the

Indigenous Peoples Earth Charter, which states:

> our collective responsibility to carry our indigenous minds and voices into the future, that traditional knowledge of herbs and plants must be protected and passed onto future generations, and the usurping of traditional medicines and knowledge from indigenous peoples should be considered a crime against peoples.

Governments and international organizations are responding, sporadically, in positive terms. It is extremely encouraging to see that the Government of Peru passed Bill 27811 in August 2002 to protect Indigenous Peoples' rights and ownership over their ancestral knowledge. According to the bill, companies seeking to use Peruvian Indigenous knowledge must allocate no less than 10 percent of their profits to the Indigenous People's Development Fund of Peru. Panama legislature also passed Law 20 on June 26, 2000, addressing the same issue. Another Latin American country, Brazil, did the same with the enactment of Presidential Provisional Measure 2.186-16 in August 2001. In New Zealand this trend is in advanced stages of implementation concerning Maori knowledge; changes have been approved to trademarks legislation and to the Patents Act. Another exceptional development occurred with the approval by the South African parliament of the Traditional Health Practitioners Act in August 2004 to regulate the work of traditional healers. This national initiative was expected to affect an estimated 200,000 traditional healers, and the interest and enthusiasm was expected to continue for the next several years. The World Intellectual Property Organization (WIPO), through its Intergovernmental Committee on Intellectual Property and Genetic Resources, Traditional Knowledge and Folklore, proposed mechanisms to promote the recognition of traditional knowledge within the patent system and "reduce the practical likelihood that patents will be allowed that incorrectly claim inventions that make use of traditional knowledge and genetic resources" (WIPO).

The new appreciation of the Indigenous Peoples' culture and knowledge is reaching the Western scientific community as well. In the summer of 1999 the International Council for Science (ICSU) and the United Nations Educational, Scientific, and Cultural Organization (UNESCO) adopted the Declaration on Science and the Use of Scientific Knowledge. The declaration acknowledges that traditional and local knowledge systems are "dynamic expressions of perceiving and understanding the world that can make, and historically have made, a valuable contribution to science and technology" (UNESCO).

In America it took more than five centuries to go from the belief that Indigenous Peoples were savages and soul-less creatures, to the acknowledgment that they are peoples or nations with rights to be respected. Fortunately, we are at the dawn of a process of recognition and appreciation. The Indigenous Peoples' knowledge protection is being legislated, and early considerations on benefits sharing are proposed. Worldwide respect, protection, and recognition of the Indigenous Peoples' knowledge and rights could result in a more just world, the end of an era of colonialism, and a more equitable global human society.

See also **Grassroots Science; Science in History: Latin America; Technology in History: Latin America**

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INFORMATION TECHNOLOGY.

We are currently witnessing the birth of a new information infrastructure as powerful in its own right as the printing press. This new medium is helping us express knowledge in new ways and connect with each other across time and space in ways previously unimaginable, and it is having a huge social, economic, and political impact. Rather than in the proclaimed age of the Internet, however, we are continuing to live, as we have been living since the early nineteenth century, in the age of the database: Our ability to use information technology to marshal and analyze data has continued to rise in areas of government, science, and the economy.

Building an Information Infrastructure

There are many models for information infrastructures. The Internet itself can be cut up conceptually a number of different ways. There is over time and between models a distribution of properties between hardware, software, and people. Thus, one can get two computers "talking" to each other by running a cable between them or by dedicating a given physical circuit (hardware solutions) or by creating a "virtual circuit" (software solution) that runs over multiple different physical circuits, with each small piece of a message possibly taking a different route. One can also (and this is still the fastest way of getting terabits of data between two cities) put a disk on a truck and drive it over. Each kind of circuit is made up of a different stable configuration of wires, bits, and people; but they are all (as far as the infrastructure itself is concerned) interchangeable.

Infrastructural development and maintenance requires work, a relatively stable technology, and communication. The work side