COMMENTARY

Ancient medicinal plants of South America

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Many archaeologists suggest that shamanic practices are ancient, starting at least 30,000 y ago (1–3). As an analytical concept, anthropologists define shamans as religious practitioners who interact directly with the spirit world to help their people. Shamans in each culture have their own practices and are called by different names (e.g., *chayanyi*, *curanderos*, or *vegetalistas*). Shamanic practices are found in indigenous groups all over the globe, from Australia to the Arctic. The core of these practices is altered states of consciousness (ASC), during which the shaman is able to perceive and interact with the spirit world. However, the rituals used to initiate ASC greatly vary, from Australians walking into their Dreamtime to Siberian shamans drumming into trance states (4). There are many purposes for these states, but ultimately, they are the gateway to spirits and deities who help cure the sick, bring rain, find lost objects, or otherwise help people medically, physically, emotionally, and/or spiritually (4, 5). Human neurology and physiology enable people to enter trance states, which can range in intensity and duration from a sort of daydreaming-like state to having powerful hallucinations while catatonic (6). Hallucinations can be initiated using various methods, including fasting, chanting, drumming, sensory deprivation, extreme pain, and consuming psychoactive plants. Often, shamans combine these various methods and will sometimes use psychoactive plants when they are available. These psychoactive agents can be consumed in a variety of ways, including simply eating them [e.g., the Huichols of west Mexico eat fresh and dried peyote buttons (7)], inhaling them as snuff [e.g., the Yanomamo of Venezuela inhale yakoana powder (8)], using enemas [e.g., the Maya used ritual enemas laced with various psychoactive plants (9)], and brewing them (8). South American shamans brew a tea called ayahuasca, which is the focus of Miller et al.'s (10) paper in PNAS. Miller et al. provide enticing evidence that the key alkaloids found in ayahuasca occur in a 1,000-y-old bundle found in Cueva del Chileno from South America, but rather than being made into a tea, it appears that the plants were inhaled as a snuff. Their article focuses on the result of liquid chromatography tandem mass spectrometry analyses of an animal-skin pouch, a headband, and 2 pieces of dried plant materials, but they provide a photograph of the bundle and its amazing artifacts, which include bone spatulas, snuffing tables, an effigy snuffing tube, and a headband (figure 2 of ref. 10).

There are 2 common recipes for ayahuasca, but at least 2 alkaloids must be present: harmine (derived from *Banisteriopsis* spp.) and *N*,*N*-dimethyltryptamine (DMT or *N*,*N*-DMT) (from *Anadenanthera* spp. or *Psychotria viridis*). By themselves, *Anadenanthera* seeds can be ground to make a mildly hallucinogenic snuff (8), and the alkaloids of *Banisteriopsis* are used as a mood-altering medicine but are not particularly hallucinogenic by themselves (Table 1). When these 2 plants are combined, however, they create vivid, dynamic hallucinations. These plants are consequently valued by shamans across South America and are considered "ancient teachers" that transcend time (11). Despite ayahuasca's importance in many Amazonian cultures, anthropologists and other researchers have been uncertain about the origin and prehistoric/early historic importance of ayahuasca. Archaeologists have found little evidence of these plants occurring together. As Miller et al. (10) note, Ogalde et al. (12) examined hair from 32 Andean mummies from northern Chile. Based on their gas chromatography/mass spectrometry analysis, they suggest that an infant and an adult male tested positive for harmine (*Banisteriopsis*), but none of the mummies tested positive for DMT (*Anadenanthera* spp.) (10, 12). *Banisteriopsis* was likely consumed as a medicinal tea, but the lack of the second alkaloid suggests that ayahuasca was not consumed, and by extension, that ayahuasca may not have been present between AD 800 and 1200.

The importance of Miller et al.'s (10) discovery goes beyond simply saying that a hallucinogen commonly used today was also used in the past. Archaeological and historic records indicate that people use

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Table 1. Five chemicals found in a 1,000-y-old bundle associated with snuffing tablets and an effigy snuffing tube and their possibly related plants and common purposes

Chemicals	Plants	General purposes
Cocaine	*Erythroxylum coca*, leaves brewed as a tea or chewed	Mild stimulant, helps minimize altitude sickness, easies stomach aches
Benzoylecgonine (metabolite of cocaine)	*Erythroxylum coca*, leaves brewed as a tea or chewed	Mild stimulant, helps minimize altitude sickness, easies stomach aches
Bufotenine	*Anadenanthera* seeds, *Brosimum acutifolium* bark, ground into a snuff or brewed as a tea	Stimulant, *Brosimum acutifolium* helps minimize headaches and stomach aches
DMT	*Psychotria viridis*, trace amounts in *Anadenanthera* spp. seeds, ground into a snuff or brewed as a tea	*Psychotria viridis*, shamanic rituals; *Anadenanthera* seeds, mildly hallucinogenic, used for general aches
Harmine	*Banisteriopsis* spp. brewed as a tea	Nonhallucinogenic, general aches
DMT + harmine	*Anadenanthera* and *Banisteriopsis*, brewed together as ayahuasca tea	Powerful hallucinogenic mixture, shamanic rituals and curing ceremonies

different plants for different purposes, much like we ingest different compounds in our modern medicine. For example, the Huichols are aware of the hallucinogenic proprieties of *Datura*, morning glory, and other plants, but almost exclusively use peyote. *Datura* in particular is instead associated with sorcerers who wish to harm others (6). The famous Mazatec *curanderas* (female healers) of Oaxaca, Mexico, primarily use *Psilocybe mexicana* during their curing ceremonies (8). Of course, people in the past made "drug mixtures" just like people today do by mixing tobacco, alcohol, and medicines as they deem useful. For example, the *curanderos* of Peru are known to mix tobacco into their ayahuasca (8). Lethal mixtures may even be provided to sacrificial victims. For example, 3 frozen Inca child sacrifices were found in Argentina in 1999. The children were given *chicha* (maize beer) and coca (cocaine) at such high dosages that they probably produced altered states of consciousness, which likely gave them sacred visions at the end of their lives (13, 14). The use of ayahuasca 1,000 y ago may indicate the ancient presence of other cultural features, including healing ceremonies and divination that have been documented ethnographically. Thus, Miller et al.'s article will stimulate much research in Amazonia to see if there are additional lines of evidence for ayahuasca and other evidence for the curing ceremonies with which it is associated.

Don José Campos, a practicing Peruvian *vegetalista*, reports that consuming ayahuasca as a snuff is painful but quickly provides a short-lived vision (11). As a result, many modern Peruvian shamans prefer to drink ayahuasca as a tea. However, the ritual bundle discussed by Miller et al. (10) seems to indicate that the processed plants were snuffed, not used for tea, as evidenced by the associated snuffing tablets and snuff tube. If this is correct, snuffing of ayahuasca might predate the brewing of the tea, which raises additional questions: When did they begin to use tea? Are there different ritual/religious contexts for consuming tea versus snuff? Did different cultures or different people in each culture use ayahuasca in different ways? To answer these questions, future archaeologists could look for ayahuasca residues in ancient pottery. As an aside, I also wonder if the different methods might (consciously or unconsciously) encourage different uses/interpretations of the subsequent hallucinations. Perhaps the pain associated with consuming snuff encouraged "negative" hallucinations and might therefore be associated with war, conflict, and sacrifice, whereas drinking the tea, which is described as causing a peaceful, calm response, might correspond to "positive" visions. Additional ethnographic and archaeological analyses will help evaluate these sorts of questions.

Miller et al. (10) also find evidence of *Erythroxylum coca* (cocaine) and possibly mushrooms (psilocin). They seem to have found an ancient pharmacopeia, complete with tools for administering the medicines. Obviously, the bone spatulas and snuffing tablets were used to prepare the plants. Once processed, the snuff could be consumed through the tube. One wonders what residues might be present in the snuffing tube. Was the polychrome headband part of the insignia of the shaman? What are the contexts for other, similar headbands across the region and through time? Were they associated with specific contexts, say curing rituals? Or could the headband have a more specific use, such as helping to ease the sinus pain that likely resulted from snuffing the plants? These and similar questions might lead to unforeseen insights regarding the cognitive and cosmological structures of these past societies.

Finally, it warrants stressing that there is a practical importance to Miller et al.'s study. People everywhere identified medicinally useful plants (including hallucinogenic plants), presumably through a process of trial and error, and then passed this knowledge through generations of people. Traditional medicine has produced many useful insights and combinations that have helped advance modern pharmacology. While modern chemistry is unraveling the complex alkaloids in many of these plants, their full potential remains unknown. Even now, researchers are working on better understanding how marijuana reduces pain, which is important as America wrestles with its opioid crisis (15). Current research is addressing how psilocybin (magical mushrooms) might treat mental illnesses (16). Undoubtedly, additional research into these and other plant alkaloids will aid modern medicine to help humans with their aches and pains, whether these are physical, mental, emotional, and possibly even spiritual. Given that numerous groups used ayahuasca historically and we now have tantalizing evidence for it being present for at least 1,000 y, and given the complexity of the interaction of 2 different plants used to make ayahuasca, there are likely mysteries about how these plants work that may benefit modern people. Others have not missed this observation, and in fact there is debate in the pharmacology literature as to whether the various alkaloids in *Banisteriopsis caapi* might be effective in treating neurodegenerative disorders (17). It is good that research such as Miller et al.'s (10) could further encourage medical science to reassess ayahuasca's role in healing.

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