MYCOLOGICAL INVESTIGATIONS ON TEONANÁCATL, THE MEXICAN HALLUCINOGENIC MUSHROOM.[1]

PART I. THE HISTORY OF TEONANÁCATL, FIELD WORK AND CULTURE WORK

ROLF SINGER

(WITH 6 FIGURES)

1. HISTORY

The use of hallucinogenic mushrooms in Mexico was reported by European and Mexican writers (11) centuries ago, and so is not news. Nor are mushrooms unique as hallucinogens. It is widely known that peyotl, *Lophophora williamsii* (Lem.) Coulter, a cactaceous plant likewise native to Mexico, contains a hallucinatory substance, mescalin. What is new in recent developments is the serious attempt to study the organisms responsible for these curious phenomena, an endeavor logically beginning at the biological level—*i.e.*, with a study of the mycological aspect of the rather complex problem. With this goes an attempt to obtain more details on the ethnobotanical role of the hallucinogenic mushrooms in southern and central Mexico. A consequence, and, to a certain degree, also a motive, of all this renewed interest in the subject is the extraction in pure form of a substance or substances important in medical research, or at least data on the active principle in these fungi which might throw light on phenomena of practical concern, such as the symptoms commonly referred to as schizophrenic, or the question of the maturity factor in neuroses.

Before the first specimens had come to the botanical laboratories, there had been some doubt whether the *teonanácatl* of the literature, a word supposedly meaning "sacred mushroom" in the Aztec language, was actually a mushroom rather than *Lophophora*. The word *teonanácatl* is here used in the sense of Schultes (13), Heim, and in fact the majority of the authors concerned with hallucinogenic mushrooms in

[1] Published out of order as excess pagination through financial assistance of the National Science Foundation and the University of Michigan Herbarium.

Mexico (**3, 10, 11, 12, 18, 19**)—*i.e.,* as a general term for any hallucinogenic mushrooms used by Mexican Indians in pre-Columbian times and up to the present. While botanical interpretations of the word *teonanácatl* were originally based on Schultes's (**13**) paper, and referred to one single species of *Panaeolus,* we shall see subsequently that *teonanácatl* is not necessarily a single species, and that it is not—according to our present knowledge—probable that *Panaeolus* spp. are represented in the list of hallucinogenic mushrooms in Mexico.

Actually, the first correct interpretation of *teonanácatl* was published by this writer in 1951 (**16,** pp. 472, 506). This fact has not been mentioned in the current literature, although the genus *Psilocybe* as well as the species *Ps. cubensis* was mentioned by me in the place quoted. These indications were based on material collected by Dr. R. E. Schultes of Harvard University.

Schultes undoubtedly deposited the first botanically useful specimens of hallucinogenic mushrooms from Mexico in an American herbarium. These consisted of two collections, originally placed on one sheet in the Farlow Herbarium, but later separated by the present author (1941). One package containing *Panaeolus* was determined by D. H. Linder, then Curator of the Farlow Herbarium, as *Panaeolus campanulatus* var. *sphinctrinus.* If we disregard questions of nomenclature (the rules of botanical nomenclature necessitate a change in the name used by Linder, to read "*Panaeolus sphinctrinus* (Fr.) Quél."), we may say that Linder's determination is correct. Heim (**3**) came to the same conclusion. But even though the determination is correct for these specimens, it is obvious from certain data on the label of the collection [2] that there must have been some confusion of the *Panaeolus* with what later became known as *Psilocybe mexicana,* while on the other hand further inquiries show that *Panaeolus* is not one of the genera used by Mazatec Indians of the Huautla region for either religious or medical purposes.

The other package, originally inserted with the first, remained un-

[2] The label reads in part: "Springy meadows in rainy season. Huautla de Jiménez, Oaxaca, Mexico, July 27, 1938. Stem 1–2 mm diam., 10 cm high; hemispherical but often cuspidate; gills dark brown–black, whole plant coffee brown, black when dry. Mexican name nanacate. Indian name: she to (eruption of the earth); tso-ska (loco mushroom). Said to be poisonous in overdose of 50–60, but in moderate quantity it produces hilarity and general narcotic feeling of wellbeing for an hour. Excess doses said to produce permanent insanity. . . ." It is now evident that "springy meadows" are the characteristic habitat of *Psilocybe mexicana,* and it is this species that is "cuspidate," never *Panaeolus sphinctrinus;* dark brown lamellae would be characteristic for the former, black ones for the latter. The name *she to* is a misspelling of *xi-tjo,* which is the general word for mushrooms and fails to identify the genus.

named in the Farlow Herbarium until this author in 1941 determined it as *Psilocybe cubensis* (Earle) Sing. (at that time still as "*Stropharia caerulescens* (Pat.) Sing. = *Stropharia cubensis* Earle"). Strangely enough, this second collection by Schultes contains a note in which the local name of the species is indicated [3] as *kee-sho,* which in Huautla does not refer to the species represented by the dried carpophores in the

FIG. 1. Map of central and part of southern Mexico, between the 18th and 22nd parallels, showing Amecameca, Tenango, and Huautla in their respective states. 1:7,500,000.

package, but to *Psilocybe caerulescens* Murr., as we shall see later. The specimens and data come from the not very accessible Mazatec village Huautla, the same village where the *Panaeolus sphinctrinus* had been

[3] The label of this specimen reads: "Plantae Utiles Mexicanae. Oaxaca. Botanical Museum, Harvard University. Common name (Mexican) nanacate. Tribe: Mazatec. Indian name kee-sho. Habitat in freshets during rainy season. Locality Huautla de Jiménez, Oaxaca. Uses: From four to eight are eaten to produce a temporary narcotic state of hilarity. Said to be poisonous if taken in excess, causing permanent insanity. [Next follow descriptive data, illustrated by a drawing on the reverse side.] Coll. no. 349. Coll. Richard Evans Schultes, 27 July, 1938." Below Schultes's name that of Blas Pablo Reko is added (as co-collector). On a separate label, there is an annotation by Singer: "*Stropharia caerulescens* = *Psilocybe cubensis* (Earle) Sing.," and the Farlow label was made out correspondingly, although here the second and valid name was omitted. Thence resulted a later erroneous reinsertion in *Stropharia* when the herbarium material was shifted between 1949 and 1951, under W. L. White, curator.

collected, and where, later on, by Wasson, Heim, and Singer, *Ps. caerulescens* was likewise found (FIG. 1). If we assume that *Ps. mexicana* was originally confused with *Panaeolus sphinctrinus,* and *Ps. caerulescens* with *Ps. cubensis,* by Schultes's source of information, we already have all three important hallucinogenic mushrooms of the Mazatecs, or rather traces of them, in the first two records. These psilocybes will later be treated in more detail.

This was the status of the mycological knowledge of *teonanácatl* when in 1952 Dr. Sam I. Stein became interested in the psychiatric implications of certain reports on the action of such dark-spored agarics as *Psilocybe* and *Panaeolus* (**1, 2, 6, 9, 10, 11, 12, 13, 16**). He then began to prepare the organization of a research program on fungus toxicology as related to neuropsychiatric problems. One of the first steps planned was the collection of dried material and cultures of the respective species, and of botanical observations made on the spot. These were not only to help in solving the basic problem from a biological point of view, but to produce sufficient knowledge to grow fruiting bodies of these species in the United States, or to grow mycelium in sufficient quantities to satisfy the demands of further investigations. The origin of these cultures had to be carpophores from the now classical village of Huautla de Jiménez, since obviously only a mushroom population known by previous tests and observations to be hallucinogenic should become the starting point of the production of carpophores destined to be the raw material for further experiments—particularly bio-assays and biochemical analyses—in the investigation on hallucinogens. This localization does not exclude further search for different species used in some remote valley of Mexico or Guatemala, or elsewhere.

The first author to publish data on chemical analysis and animal tests was Santesson (**12**), who unfortunately was handicapped by lack of thorough botanical study of the material he used, and by the application of inadequate chemical and experimental procedures. He had two samples, one "probably belonging to a *Panaeolus,*" and the other supposed to be *Armillariella mellea* (although that was neither clear from the text nor at all probable). It is more likely that the material consisted of *Psilocybe mexicana* and *Ps. cubensis,* but it may conceivably have been a mixture of numerous elements. It was referred to as *teonanácatl.* Chemical reactions supposedly showed that no alkaloid was involved. According to the Fehling reaction, Santesson's material seemed to contain a glucoside as the active principle. Subcutaneous injections of 2.12 g and 1.57 g of the drug per kilogram body weight of *Rana temporaria* resulted in a "semi-narcosis" of the frogs, with a nega-

tive "turning test" (the classical inhibition effect of morphine on the rotation reflex of frogs).

At the time I reached Mexico—*i.e.*, one year after Heim had accompanied the Wassons there—the former had already published three short communications (**3, 4, 5**) on specimens of Mexican species believed to be used in Indian ceremonies, and a preliminary article on his own observations. The name *Psilocybe mexicana* was then proposed for the first time, although not validly published before the second half of 1957. For what we consider to be *Ps. caerulescens* Murr., Heim proposed a new name, *Ps. mazatecorum*,[4] and having traveled to regions further south and northwest, he added a number of new entries on the list of species which collectively may be termed *teonanácatl*. Among them was *Ps. zapotecorum* Heim, from the Sierra Costera, and *Ps. aztecorum* Heim, from Popocatépetl. Fair to excellent illustrations of these species were provided by Heim for the Wassons' article (**19**) and in their book (**20**). In both of these latter publications as well as in other articles, ceremonies conducted by local curanderos (and a curandera) and experiences under the influence of hallucinogenic mushrooms were described by the Wassons and Roger Heim. No results of chemical analyses or animal tests have been published as this is written. Nevertheless, the attention given the mushrooms in the press has created—far beyond Mexico—an extraordinary interest and expectancy. Whether this attitude is justified by the research now in progress remains to be seen.

2. FIELD AND CULTURE WORK IN 1957

My journey from Mexico City to the Mazatec country was undertaken in the company of two young Mexican botanists, M. A. Palacios, who worked as my assistant, and G. Guzmán H., an ardent student of agarics. There could not have been better traveling companions, or ones who better served the purpose of the trip.

We reached Huautla the first week of July and were there the guests of an Indian family. The head of the family, Isauro Nava García, an exceptionally intelligent and cooperative man who could express himself well in Spanish, and equally well spell the words of his native Mazateco, turned out to be a keen observer of fungi. He recognized easily and almost infallibly the different species of *Psilocybe*, knew where they could be found and when, and pointed out the interesting features of their re-

[4] After having been advised by Dr. Alexander H. Smith of the probable identity of this fungus with Murrill's type of *P. caerulescens*, Heim changed the name to *P. caerulescens* var. *mazatecorum* Heim, because, as he explains, of the high variability of these fungi.

spective habitats. He was of course completely familiar with the mushroom lore of his valley and had eaten hallucinogenic mushrooms before. Either he or his brother-in-law accompanied us in many of our collecting trips. Everything he said was checked by comparison with information obtained elsewhere. All the data obtained from him were corroborated with the exception of an opinion about the activity of a mushroom called "nčhe-je nčhe-je" (now known as *Ps. candidipes*), which was variously called inactive and poisonous. This, by the way, is the only species of the taxonomic group to which the hallucinogenic psilocybes belong that was not likewise reported by Wasson and Heim from the Mazatec region. On the other hand, the species said to be hallucinogenic and not belonging in the same taxonomic group as *Ps. cubensis, mexicana,* and *caerulescens* were not confirmed as hallucinogens by our own inquiries and observations. These unconfirmed data (**3, 4, 16**) refer to *Conocybe siligineoides* Heim, two species of *Panaeolus* (*P. sphinctrinus* and *P. fimicola* sensu Heim), and those psilocybes not reported to show any blue discoloration or stain (*i.e., Ps. cordispora* and *Ps. macrocystis*). I may add that there are a *Psathyrella* and copelandias from Santa Cruz which Guzmán, who collected them there, is inclined to think may be hallucinogenic. When we met Mr. Wasson in San Andrés near Huautla, he suggested that among these species the chances of finding real hallucinogens are rather good in *Conocybe.* So they are also in *Panaeolus* and related genera, since species of these have been shown to be poisonous or inebriating, and to be active in animal tests—*e.g., Panaeolus venenosus* Murr. (**9**), which is apparently a synonym of *P. subbalteatus,* and species of the same genus or related genera determined in the past as *Panaeolus papilionaceus* and *P. "campanulatus."* Unfortunately, some of these determinations (**1, 2, 6**) may not be accurate and may just as well refer to other related genera (*Anellaria, Copelandia*), or at least to other species. We must insist, however, that the phenomena which belong in the class of "cerebral mycetisms" in the terminology of Ford (**2**) are not fully identical—although comparable—with the hallucinatory-euphoric and lasting effect described for the psilocybes. Aside from that we feel certain that *Panaeolus sphinctrinus* is not used as a drug by present-day Indians in Mexico.

As for *Conocybe siligineoides*—which would be the only forest-inhabiting, or even xylophilous, species among those indicated by any author, it will be well to take into consideration a statement made to us by Isauro Nava. He said that there was, growing at a certain distant locality and not fruiting at the time of our visit, another hallucinogenic mushroom, as small as "pajaritos" (*Psilocybe mexicana*) and of the same shape and also staining blue, but differing in its habitat—wood in

the forest rather than soil of meadows. Just such a species (*Ps. yungensis*) had been collected by me a year earlier in the ecologically very similar Bolivian Yungas, also a tropical-montane forest, and a similar but different one (*Ps. pelliculosa*) by Alexander H. Smith in the Pacific Coast area of the United States in coniferous forests of a temperate type. It is therefore quite possible that the missing forest-inhabiting hallucinogenic mushroom is not the species described by Heim as a *Conocybe,* but another representative of the section in which all the other hallucinogenic psilocybes belong.

How can such errors—if indeed errors they are—be explained? The growing demand for hallucinogenic mushrooms in the Huautla area has brought everybody, children and adults, many certainly much less expert than Isauro Nava, into the mushroom business. The younger generation of Indians tends to ridicule the use of mushrooms in ceremonies and is inadequately familiar with the characters of the mushrooms. Nevertheless, all these collect to fill the sudden demand at relatively high prices, and so inactive mushrooms are often mixed with active ones either by mistake or as conscious adulteration. I have witnessed the impurity and possible falsification of the product sold in Oaxaca, not easily discovered by anyone but a mycologist, especially if the material has been dried crudely for use between seasons. If substitution is discovered, the natural reaction of the seller is to claim that these different mushrooms are also used as hallucinogens.

As a result of the foregoing discussion, we may consider as established hallucinogens the following species of the Huautla region: (1) *Psilocybe cubensis* (Earle) Sing., (2) *Ps. caerulescens* Murr., and (3) *Ps. mexicana* Heim, and may add tentatively (4) *Ps. candidipes* Sing. & Smith (**17**).

By the end of July a further trip was organized by the National Autonomous University of Mexico, Institute of Biology, which took us by automobile to the region of Tenango del Valle (FIG. 1) southwest of Mexico City. A species of agaric is prescribed there by a "curandera" of a small village above Tenango and at times sold in the market at Tenango; it is currently collected by many local inhabitants of the region for storage, to have ready in case of illness, especially stomach troubles. The specimens come from a place called Piedras Blancas on the slopes of Cerro de Toluca. From our investigation on good specimens obtained at Piedras Blancas, and from observations on pure cultures made from them, we believe that they are an independent species, and not a variety of any known species, as suggested by Heim (**4**). We add therefore (5) *Ps. muliercula* Sing. & Smith (**17**), "mujercitas."

A similar trip, a week earlier, was made to San Pedro de Nexapa

near Amecameca (FIG. 1) in the Distrito Federal and at the borderline with Puebla. This trip in search of the species previously described (from purchased specimens) by Heim as *Psilocybe aztecorum* yielded no specimens, and we had to rely for the moment on material which did not produce cultures. The information about the use of the mushroom was, however, obtained from the informant in Nexapa interviewed by Heim, and the exact habitat of Heim's *Ps. aztecorum* was carefully studied. Since the fruiting bodies appear only later in the year, G. Guzmán followed this exploratory trip with a second one in September, from which good specimens were collected at their natural habitat, and cultures were taken from the lamellae of these. The use made of *Ps. aztecorum* seems to be exactly the same as that made of *Ps. muliercula*. Consequently we list (6) *Ps. aztecorum* Heim.

All six species enumerated have a number of important characters in common—first of all the diagnostic characters of the genus as defined by Singer (**16**). They are devoid of chrysocystidia, do not show a glutinous or viscid veil on the stipe, and have the stipe centrally attached. The spore print is fuscous sepia or dark purple brown (often more deep lilac when quite fresh), as is usual in the entire subfamily Strophariodeae of which *Psilocybe* is a genus. The spores are smooth and have a germ pore. Some species have rather strongly longitudinally compressed spores, although with few exceptions the compression is not strong enough to be the same as that observed in the true deconicas,[5] and the spore size is variable from species to species (4–17μ long). The upper layer of the pileus is a cutis, with a more or less individualized epicutis which often takes the appearance of a pellicle. A veil is present in all these species but the extent of development of the veil in adult specimens varies according to, and to a certain degree even within, the species. Some species have a persistent although never furrowed ("lamellar") thin repand annular veil. *Psilocybe candidipes* has an abundant veil development, but the annulus is narrow and not persistent. *Psilocybe caerulescens, Ps. aztecorum,* and some other species still have a well developed veil, but it is obliterated in age and never forms an annulus. In *Ps. mexicana,* on the other hand, is reached the extreme situation in this group, where the veil consists merely of a number of fine silky hyaline fibrils connecting the apex of the stipe with the margin of the pileus when the carpophore is young, collapsing on the stipe to form appressed scattered silky fibrils which disappear completely in age.

[5] Dr. A. H. Smith thinks that species with strongly lentiform rhombic spores of small size should not be generically separated from *Psilocybe*. It is possible, and even probable, that the study of a large number of species not yet analyzed will corroborate this opinion when the genus is finally monographed.

Aside from the generic characters indicated above, all the species that enter our list of Mexican hallucinogens have a very interesting and striking chemical character, one that is very constant in young and fresh material, but becomes lost in old and dried material, especially where the climatic conditions provide relatively high temperature. When the fruiting bodies are scratched or handled, or dried out, they stain blue or (in superposition on a yellowish pigment) green. This is apparently an enzymatic oxidation or autoxidation which may be comparable with that of *Russula* sect. *Nigricantinae* (where tyrosinase is the enzyme active in producing through the oxidation of tyrosine a melanin-like blue or pink and eventually blackening substance), or of the bluing boletes like *Boletus luridus* (with boletol, the pigment resulting being blue). The reaction is certainly identical with that observed in related genera of Agaricales like *Copelandia* and in certain species of *Pholiotina*. Some reagents such as guaiac solution accelerate this reaction in the few cases where I could make the test, but the action of guaiac is said to be nil by other authors in other cases. However, a chemical character which accompanies the bluing phenomenon is that of metol, which gives a constant strongly positive reaction with the context of the stipe in the bluing psilocybes, becoming deep purple after a few minutes (Singer **15**, **16**). Furthermore, it appears that the odor and taste of the whole group are sometimes distinctive: the odor of fresh carpophores is that of fresh flour or cucumber, or more rarely absent, or raphanaceous; while the taste is either hardly distinctive or more or less astringent or unpleasant. Heim (**5**) also indicates, among the characteristics of the hallucinogenic group, the fact that the spores show a light ocher pigmentation. It should not be denied that a very large number of Strophariaceae—Stropharioideae may show a light ocher color when seen under moderate magnifications in strong light or when not fully mature. However, my findings, corroborated by other observers, do not support the generalization that this particular light ocher color is characteristic for the Mexican hallucinogenic psilocybes or for the section of *Psilocybe* in which they belong.

Ecologically, however, all these species (even though not all the species which taxonomically belong with them) are adapted to conditions brought about by either cattle raising or agriculture, or else by natural but violent and profound disturbances of the equilibrium of the soil flora. Although not one of the species is carbonicolous or ruderal, the specific ecology of the Mexican species has apparently much in common with the ecology of anthracophilous and ruderal agarics.

With the characteristics indicated above, the hallucinogenic mushrooms enter quite naturally a taxonomic subdivision proposed by this author in 1948 (**15**) as the section *Caerulescentes* Sing., with *Psilocybe*

cubensis as the type species. This section consisted even then of one annulate and several exannulate species. The fact that both annulate and non-annulate species enter the section now, having in common, in addition to their anatomical and chemical characters, the physiological activity referred to as "hallucinatory" (in reality a complex action) or as provoking cerebral mycetisms, tends to show that the section *Caerulescentes* is a natural one, whatever weight conservative authors may still give the veil characters in other groups of agarics. The fact that *Ps. cubensis* is among the hallucinogenic mushrooms will thus serve as an additional argument in favor of its transfer from *Stropharia* to *Psilocybe* (Singer, **15**) where its real affinities are. Why, in view of the considerable evidence in favor of its transfer, Heim (**3**) retains the species in *Stropharia,* with the cryptic remark "ils [*i.e., Ps. cubensis* and synonyms or related species] restent cependant apparentés avec *Stropharia squamosa* Fr. ex Pers.," [6] is not recorded.

The type of vegetation in which hallucinogenic psilocybes occur is not uniform. The vegetation found in the Huautla region (and apparently in other areas where hallucinogenic mushrooms were observed in Oaxaca) is markedly different from that in Mexico and Puebla, further north and higher up. The Oaxaca localities, or, more properly, th Huautla region, can be characterized as transitional between tropical montane and temperate montane, the tropical montane zone being immediately adjacent in the ravines below 1500 m and the temperate montane zone in the alder forests above 2000 m altitude. The tropical montane region adjoins farther down and farther east the more truly tropical rain forests, as seen in the lower-level forests of Santa Cruz—near Jalapa, for example, where Murrill collected—and the transition zone characteristic of the localities where hallucinogenic psilocybes abound may well be likened to the South American fog- or cloud-forest. It differs, however, in at least one important point: the Mexican forests are rich in trees belonging to the order Fagales, especially in evergreen oaks, which determine the mycoflora and make the presence of abundant ectotrophic mycorrhiza possible. In many places in this transitional

[6] This is a species so different from both typical *Strophariae* like *S. aeruginosa* and typical psilocybes like *Ps. semilanceata* (because of the combination of characters of the cystidia and the hypodermial and hymenophoral trama-structure) that it has been pointed out by Kühner (**7**) as anatomically closer to *Hypholoma.* For that reason it was transferred by Singer (**16**) to the genus *Naematoloma* (= *Hypholoma* sensu Kühner). *Stropharia squamosa,* or better *Naematoloma squamosum,* differs sharply from both typical stropharias and typical psilocybes in habitat requirements also, being, like so many naematolomas, a wood-inhabiting species; this ecological character of course also occurs in other genera, and in itself cannot be considered to be decisive.

zone or modified cloud forest limestone crops out, and a high percentage of calcium may be expected in soil samples, especially from our *Ps. mexicana* habitats. The rainy season extends over the entire summer, and the rains are extraordinarily abundant and almost continuous for weeks in certain times of the year.[7]

The often torrential rainfall, in combination with the quality of the soil and the steepness of the mountain sides, creates a situation quite comparable to that in the upper Yungas in South America. Here as there frequent earth and stone avalanches cover the vegetation and bring the subsoil and deeper layers to the surface. This process is particularly accelerated by the methods of agriculture and will be speeded further by roadbuilding.

The natural forest, interspersed with small pastures, fields (mostly sugar cane, some corn), and now an increasing number of coffee plantations, is partly preserved, and contains, aside from tropical and endemic elements and the species of *Quercus* already mentioned, some elements in common with the subtropical and temperate forests of the southeastern United States from North Carolina to Florida. Such elements among the trees are *Liquidambar styraciflua,* among the fungi *Hygrophoropsis tapinia* Sing., and among the species referable to *teonanácatl, Psilocybe caerulescens* Murr. At the same time one observes numerous species of *Marasmius* which prove the tropical relations of this region. All to-

[7] The climate of this transitional-vegetation area where all our Huautla material came from varies between limits such as those quoted for the two extreme localities Huauchinango (Puebla) and Jalapa (Veracruz), the one being more similar to the upper limit of the Huautla zone, the other being at the lower level of the tropical montane zone. In these two comparable localities temperature records (°F) are:

Locality	Lowest minimum	Highest maximum	Ave. coldest month	Ave. hottest month	Ann. ave.
Huauchinango	25	104	50	66	60
Jalapa	36	99	58	68	64

The observed precipitation (inches) as rain:

Locality	Ave. ann. precip.	Ave. driest month	Ave. wettest month
Hauchinango	87.4	1.9 (Febr.)	15.6 (Sept.)
Jalapa	62	1.8 (Dec.)	11.6 (June)

The data are based on Vivó and Gomez, Climatología de México, Inst. Panamer. Geol. e Historia publ. 19, México, 1946, quoted from Miranda & Sharp (**8**).

gether, the mycoflora of this transition region is just as heterogeneous as the tree flora. As one ascends, entering the *Alnus* stands at about 2000 m, just above the transition zone, one might expect to encounter a fungous flora with even more distinctly northern links. This is not the case. The mycorrhizal partner of the alder is the same as that found at the south tip of the alder area in South America, a bolete, *Gyrodon monticola* Sing., absent from the United States and Canada.

The hallucinogenic psilocybes fruit during early (spring) rains and until fall. *Ps. cubensis* seems to be one of the earliest-fruiting species; I have observed fruiting in spring in Florida. But it continues producing fruiting bodies during the entire season. The habitats of all the species in the Huautla region are characteristic. *Ps. cubensis* is dung-inhabiting. It occurs on pastures where cattle have grazed, or among sugar cane residues, but usually where the substratum has at least been mixed with cow dung. Sugar cane mulch, but without dung, is also a habitat of *Ps. caerulescens,* but it grows just as often on other plant material or around living culms of *Saccharum* on the earth of the fields. The same situation can sometimes be observed of *Ps. mexicana.* However, *Ps. caerulescens* grows mainly in shaded places in plantations or shaded fields, while *Ps. mexicana* prefers sunny open fields and pastures. *Ps. caerulescens,* according to the statements of the Mazatec Indians whom we consulted, regularly inhabits the surface of old landslides, two or more years after the landslide has occurred. We found this observation correct as far as the Huautla stations are concerned, and the description of the type locality in Alabama coincides in type of soil with that seen by us. On the other hand, the open pasture land on which *Ps. mexicana* is found is probably mostly man-made, or at least is maintained in its present condition by the grazing of animals. *Ps. candidipes* grows characteristically on the cleared surface of the earth among tree leaves fallen to the ground under *Coffea* and its shade trees (especially *Inga*). According to our Indian informants, especially Isauro Nava and his neighbors and relatives, and our own observations in this region, *Ps. candidipes* always occurs near the habitats of *Ps. caerulescens* and when found serves as an indication that *Ps. caerulescens* is not far.

The Mazateco name for *Ps. mexicana* is according to Isauro Nava a word he wrote for us and that sounded like the Spanish pronunciation of *di-nizé,* and which means a bird (diminutive), supposedly, always according to Isauro, because it makes you sing happily like a bird.[8]

[8] Mr. George M. Cowan, a student of the Mazateco language, was kind enough to offer the following comments: "We use what we choose to call a practical orthography in all published materials used by Mazatecs now. This is simply a

For *Ps. caerulescens* the indigenous name noted is *di-ki-sho* (or what sounded like this); it was explained that *di* stands again for the diminutive and *ki-sho* means landslide, this name being related to the habitat of the fungus.[9] For *Ps. cubensis* we were given two native names, one being San Isidro, which is self-pronouncing, and the other what sounds like and was transcribed as *di-shi-tjo-le-ra-ja,* which means steer mushroom in a diminutive form.[10] It is quite obvious that San Isidro stands for an earlier heathen god who was supposed to speak through the mushroom. It is also obvious that the relation of the fungus with the steer is again that of habitat, since in the Huautla region the species grows mostly on cattle dung. *Ps. candidipes* is referred to as *'nchè-jè 'nchè-jè* (Isauro's spelling).[11]

The two montane-temperate to subalpine-frigid habitats in the *pinares* (pine woods region) of the mountains nearer Mexico City mentioned above as harboring two hallucinogenic psilocybes (*Ps. aztecorum* and *Ps. muliercula*) differ from the transition forest of the Mazatec region not only climatically but likewise in the type of vegetation. The mushrooms do not, apparently, depend in any way on the

phonetic alphabet adapted as far as possible to the Standard Spanish alphabet. Tone is significant in Mazateco; the numbers $^{1\ 2\ 3\ 4}$ represent relative pitch of the syllables; ^{1} represents the highest, ^{4} the lowest level. [The symbol] (') cannot be transcribed in English orthography and is not heard by the untrained ear; it is sort of a glottal catch preceding the following sound." The correct phonetic spelling of *di-nizé* is, according to Mr. Cowan, 'nti^{1}-ni^{4}-se^{3}; it is pronounced ndee^{1} nee^{4} say^{3}; nti = ndee means an affectionately regarded object (referring to the mushroom) and ni-se, bird.

[9] Mr. Cowan's comments indicate that here as in the case of *Ps. mexicana* Isauro's names are current abbreviated words, omitting between the *'nti* and the *ki-sho,* the general term for mushrooms, *xi*^{3}*-tjo*^{3} ("which comes out," presumably of the earth), so that the full name of *Ps. mexicana* would be *'nti*^{1}*-xi*^{3}*-tjo*^{3}*-ni*^{4}*-se*^{3}, and for *Ps. caerulescens: 'nti*^{1}*-xi*^{3}*-tjo*^{3}*-qui*^{3}*-xo*^{1}, pronounced *ndee*^{1}*-shree*^{3}*-t(h)oe*^{3}*-kee*^{3}*-shro*^{1}, meaning dear little thing that comes out of the earth of a landslide. The *x* is a sound as if English sh and r were pronounced at the same time; j and qu are pronounced as in Spanish, *i.e.* as a more aspirated *h* and a *k* respectively. "Tsami kishu" given by J. B. Johnson (quoted from Schultes, **13**) evidently refers to this same species.

[10] G. M. Cowan spells this *'nti*^{1}*-xi*^{3}*-tjo*^{3}*-le*^{4}*-nčha*^{4}*-ja*^{4}, pronounced *ndee*^{1}*-shree*^{3}*-t(h)oe*^{3}*-lay*^{4}*-njra*^{4}*-ha*^{4} (meaning as above: the dear little thing that comes out pertaining to the steer or ox). The pronunciation of čh is described as a sound similar to English *j* (in judge) and *r* (in run) if pronounced simultaneously.

[11] Mr. Cowan, who had a special interview about this new species with Isauro and friends, explains that this means, as Isauro had already told us, "a signal of," in reference to the other hallucinogenic mushrooms, particularly *Ps. caerulescens,* which will appear here or nearby later. The correct spelling is *nchc*^{4} *je*^{4}, pronounced in English like njre^{4}-he^{4}.

detritus or the presence of living roots of the characteristic pines (*Pinus hartwegii* with *Psilocybe aztecorum, Pinus pseudostrobus* with *Ps. muliercula*). Neither do they live on agricultural land or dung, but directly on the earth, naked earth on the banks of mountain streams with occasional salt outcroppings, following the ravines around 3000 m elevation, or else (*Ps. aztecorum*) among grasses and (rosaceous) herbs in openings, often on the slopes of steep ravines even higher up (between 3300 and 3700 m altitude). The subalpine pine woods are here beginning to thin out and approach the absolute timber line (at about 4000 m). The psilocybes are accompanied by those mycorrhizal Basidiomycetes which make the survival of these pines possible at such an altitude, especially *Amanita inaurata* Secr., various species of *Lactarius,* and *Suillus* aff. *brevipes* (Peck) Sing. Non-mycorrhizal Basidiomycetes of this vegetation are *Phlogiotis helvelloides* (Fr.) Martin, *Tubaria* sp. (on *Pentstemon barbatus*), and *Laccaria* aff. *laccata* (Scop. ex Fr.) Berk. & Br. Among the Ascomycetes are *Cordyceps capitata* (Fr.) Link (on *Elaphomyces*) and *Hypomyces lactifluorum* (on *Russula delica*), the former often collected as a remedy for various diseases but doubtfully hallucinogenic,[12] the latter sold in the food markets. In the Piedras Blancas region on Cerro Toluca the presence of *Amanita calyptratoides* Atk., a western North American species, is remarkable; the southeastern race of *A. muscaria,* also a hallucinogenic mushroom of a sort, and almost constantly accompanying pine mycorrhiza, is common in the neighborhood of the psilocybes, but has never been mentioned as a locally accepted drug.

While the substratum of both *Ps. aztecorum* and *Ps. muliercula* is apparently comparable to that of *Ps. caerulescens* (more or less unstable or shifting bare soil), the climatic conditions and the surrounding vegetation are very different in this region from the *Psilocybe* habitats in Oaxaca. There is frequent freezing in the altitudes indicated, and the precipitation is not so abundant here as in the Mazatec country. During the summer-fall rainy season, precipitation is heavy enough to maintain a relatively rich flora of large fleshy Basidiomycetes reminiscent of that further north in Mexico and in the United States. This, obviously, is possible only because of the relatively lower temperatures, even in summer, whereby evaporation is kept at a minimum.

[12] It is remarkable that another species of the same family, *Cordyceps sinensis,* growing on insects, is widely used as a medicine in China, while still another species of the Hypocreaceae, *Claviceps purpurea,* ergot, is the source of several alkaloids which have only recently been studied thoroughly. In view of this, it is very probable that the Mexican medicinal hypocreaceous species would be well worth a special investigation, particularly from the biochemical point of view.

Psilocybe aztecorum is known as *niños del agua* (Spanish: children of the water; this is apparently an allusion to their habitat along the ravines). *Ps. muliercula* from Piedras Blancas is also known as "niños," but as such it is only one of the elements referred to by the more general term niños which includes "mujercitas" and "hombrecitos" (little women and little men). Only the "mujercitas" are agarics (*Ps. muliercula*); the "hombrecitos" are *Cordyceps capitata* (Fr.) Link (det. Mains). There is an obvious misinterpretation of these names in the literature. Although "mujercitas" are correctly interpreted as *Psilocybe,* the term has been thought to refer to a variety of *Ps. mexicana.* Dr. Herrera and the author, however, found the difference in external appearance and habitat constant enough to separate the "mujercitas" from *Ps. mexicana,* inasmuch as in all natural habitats of the two species the spore size is consistently different. On the other hand, "hombrecitos" have been interpreted as merely smaller individuals of *Ps. mexicana* var., or, since hallucinatory mushrooms in Mexico are always given in pairs, the complementary individuals—in other words, part of the same drug. Our own interpretation has been reconfirmed several times, and it is also obviously the logical interpretation, since the allusion to the shape of the respective fruiting bodies is self-explanatory, and the terms lose all descriptive significance if Heim's and Wasson's explanations are accepted.

It is interesting to note that not only are the conditions under which the respective fungi develop widely different, but the use made of the mushrooms is likewise different, in the main hallucinogen-producing states of Mexico visited by me. The Nahua Indians, according to the data obtained by us in discussions with inhabitants of San Pedro de Nexapa and Tenango del Valle as well as the mountains near these villages, do not talk about the hallucinogenic effect of the mushrooms, but volunteer information merely on their healing qualities. In these villages, the use is strictly a matter of religious healing, the business of the curandero or curandera. Permission has to be granted by God in the curandero's dream before the drug can be employed safely. On the other hand, the Mazatecs talk freely about the hallucinogenic and euphoric effects of these mushrooms, and eat them for precisely that effect. The religious healing ceremonies of the Mazatecs are also directed by curanderos, but more emphasis is given to the revelations obtained by the intoxicated persons, so that the use made of the mushroom in Huautla is at least partly divinatory rather than directly medical. Whether this corresponds to any difference in the chemicals present in the respective species, or merely to ethnological factors, cannot

be stated at present. At any rate, the Mazatecs seem to have preserved more of the original Aztec lore about *teonanácatl* than the people living now in Aztec country, who are at least in part the direct descendants of the Aztecs. It is of course possible that the secretive and exclusive use the Nahuas make of their "niños" is a result of more complete repression and conversion in the early times of the Spanish rule, when the Oaxaca Indians of the Sierras were practically left to their own devices.

From all the species mentioned above, including also *Panaeolus sphinctrinus,* both tissue cultures and spore germinations were obtained.

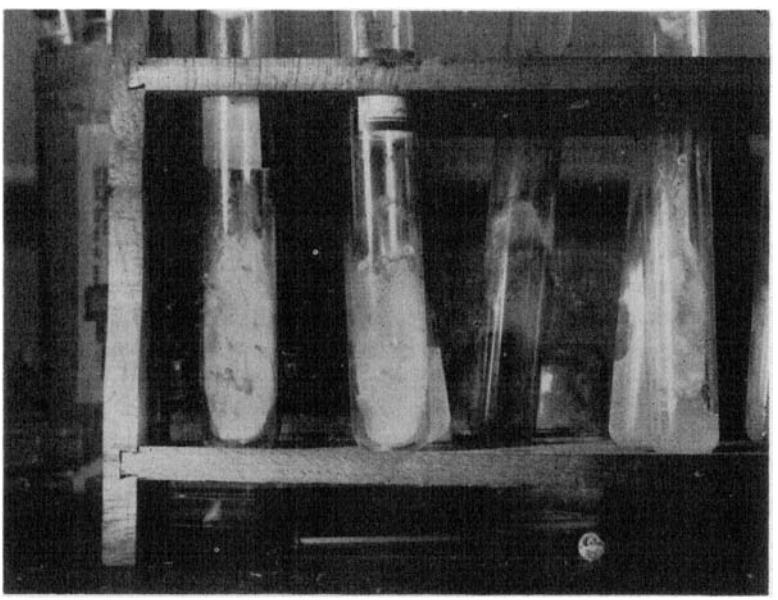

FIG. 2. *Psilocybe cubensis.* Stringy mycelium (upper portion of slant in tube at extreme left) and primordia. Phot. R. Singer.

The tissue fragments grew well at the room temperatures of Mexico City in July, some even better at 27–29° C, and better on malt-extract agar and Kauffman's (modified) medium than on potato-dextrose agar. These were the first pure cultures obtained directly from fruiting bodies at their classical habitats. Subcultures have been deposited at the Instituto Politécnico and the Instituto de Biología of the University of Mexico, at the Department of Botany of the University of Michigan, The New York Botanical Garden, and the Phytopathology Laboratory of the Ministerio de Agricultura y Ganadería in Buenos Aires, all in

personal care of responsible scientists for specified further research on these organisms. For the sake of comparison, isolations were also made from North American spore prints of *Psilocybe caerulipes* (Peck) Sacc. (northern Michigan), also belonging to the section *Caerulescentes*, and from *Copelandia caerulescens* (Berk & Br.) Sing.

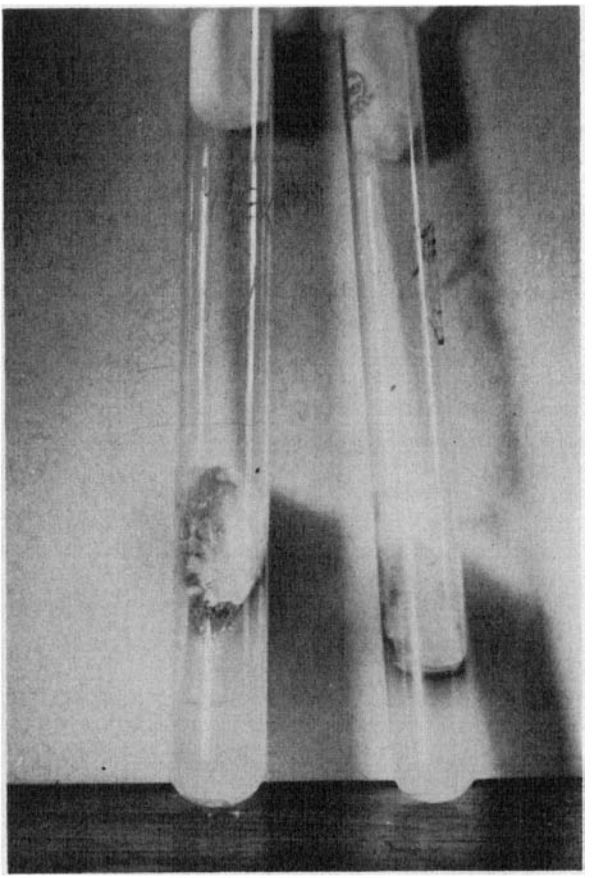

FIG. 3. *Psilocybe mexicana*, showing the dark discoloration of the medium beneath the whitish mycelium in both test tubes. Phot. R. Singer.

Panaeolus sphinctrinus, Psilocybe cubensis, Ps. caerulescens, Ps. candidipes, and *Ps. mexicana* were checked by Dr. W. J. Robbins for antibiotic activity. None was evidenced against *Staphylococcus aureus* or *Escherichia coli,* and the action against *Mycobacterium smegma* was slight.

Psilocybe cubensis has been observed to form a stringy mycelium in malt-agar test tubes. Mycelium of this species, more than that of other species studied in pure culture, has a tendency, greater at lower temperatures than at higher ones, to turn blue in culture. *Ps. cubensis* also tends to produce most easily what might be termed white rhizo-

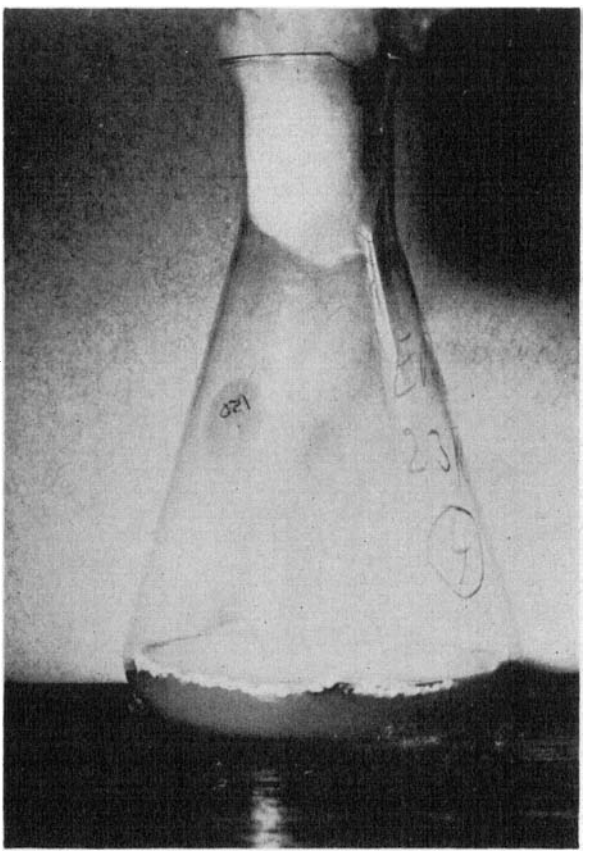

FIG. 4. *Psilocybe caerulescens.* Typical mycelium culture in Erlenmeyer flask. Phot. R. Singer.

morphs in the stringy portions of the mycelium, and a large number of small fruiting bodies on the agar (FIG. 2). These carpophores or primordia do not always attain full size during later development, and often fail to mature; they tend to turn blue without being handled. The agar cultures of *Ps. mexicana* have a tendency to turn deep brown in contact with the mycelium (FIG. 3). On partially drying out they also

FIG. 5. *Panaeolus sphinctrinus.* Abundant carpophore production in artificial mushroom house culture, natural size. Photog. Serv. Penn. State Univ., courtesy Dr. L. R. Kneebone.

frequently produce normal fruiting bodies. On the other hand, *Ps. caerulescens* under the conditions in which it was kept in the laboratory did not form white rhizomorphs or fruiting bodies in pure culture, and the mycelium merely colors the medium light brown (FIG. 4). In Czapek with 1% sucrose and vitamins, *Ps. caerulescens* produced aerial mycelium which broke down into "oidia" (mycelial fragments often referred to as arthrospores), observed for the first time by Dr. R. Ames. The mycelium of the *Panaeolus* remains pure white and fluffy without distinct discolorations, rhizomorphs, or fructifications. The same is true for other psilocybes except *Ps. muliercula,* which tends to form a slightly brownish aerial mycelium.

Panaeolus sphinctrinus (FIG. 5) and other species of *Panaeolus* grow in mushroom-house conditions as well as or better than *Agaricus bisporus* (Lange) Sing., the cultivated mushroom. The psilocybes were also grown not only under laboratory conditions in large glass containers (FIG. 6), where some produce large fleshy fructifications, but also in greenhouse conditions (FIG. 6) on compost trays, where the method used by commercial mushroom growers had to be considerably modified.

ACKNOWLEDGMENTS

It is a pleasant duty to thank the University of Tucumán and the Instituto Miguel Lillo for having granted the necessary leave to carry out the present investigations; the authorities of the Instituto de Biología (University of Mexico), and especially Dr. R. Llamas, for having authorized the collaboration of the staff and the use of its facilities; and Miss Martha Zentena Zevalla and Dr. Teófilo Herrera for help in the preparation of media and the organization of field trips. Both went beyond purely scientific collaboration by trying successfully to make my stay in Mexico as pleasant as possible. Mrs. Ana Mas Gomez of the American Embassy was kind and patient in obtaining all the permits for the collection, export, and import into the United States of America of the cultures, spore prints, and dried material, and offered many other courtesies. Miss Dorothy Parker of the Rockefeller Foundation in Mexico was very helpful in establishing valuable contacts during the Mexican phase of the work. Mr. G. M. Cowan, Summer Institute of Linguistics, offered generous help in the interpretation of my notes on Mazateco fungus names.

This cooperation continued in the United States. Dr. K. L. Jones, Head of the Department of Botany, University of Michigan, and Dr. E. B. Mains, Director of the University Herbarium, made it possible

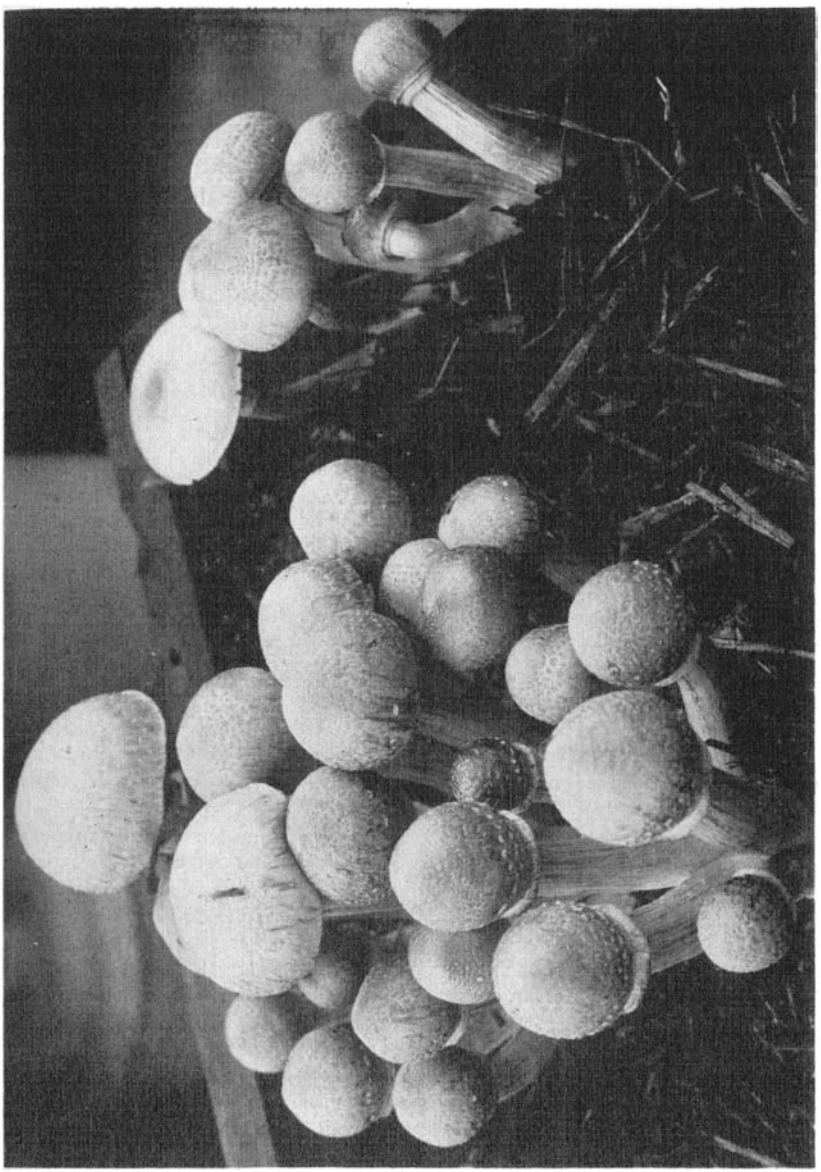

FIG. 6. *Psilocybe cubensis*. Greenhouse culture on uncased tray with compost, slightly reduced. Photog. Serv. Penn. State Univ., courtesy Dr. L. R. Kneebone.

for me to carry out part of the research in Ann Arbor. Dr. A. S. Sussman was particularly kind in supplying the necessary equipment and in providing valuable advice to me and my collaborators in the Department of Botany. He as well as Dr. A. H. Smith offered interest and encouragement.

It should also be stated that had it not been for the consistent initiative and the financial backing of the Bertram and Roberta Stein Neuropsychiatric Research Program, Inc., of Chicago, the present work would not have been possible, and the investigations now in progress elsewhere would have had no chance of realization. I am particularly indebted to Dr. Sam I. Stein, Executive Medical Director of the organization.

DEPARTAMENTO DE BOTÁNICA
INSTITUTO MIGUEL LILLO
UNIVERSIDAD NACIONAL DE TUCUMÁN, ARGENTINA

LITERATURE CITED

1. **Douglas, B.** 1917. Mushroom poisoning. Torreya **17**: 171–175.
2. **Ford, W. W.** 1923. A new classification of mycetisms (mushroom poisonings). Trans. Assoc. Amer. Physic. **38**: 225–229.
3. **Heim, R.** 1956. Les champignons divinatoires utilisés dans les rites des Indiens Mazatèques recueillis au cours de leur premier voyage au Mexique, en 1953, par Mme Valentina Pavlovna Wasson and M. R. Gordon Wasson. Comptes Rendus Acad. Sci. Paris **242**: 965–968.
4. ——. 1956. Les champignons divinatoires recueillis par Mme Valentina Pavlovna Wasson et M. R. Gordon Wasson au cours de leurs missions de 1954 et 1955 dans les pays mije, mazatèque, zapotèque et nahua du Mexique méridional et central. Ibid. **242**: 1389–1395.
5. ——. 1957. Les agarics hallucinogènes du genre *Psilocybe* recueillis au cours de notre récente mission dans le Mexique méridional et central en compagnie de M. R. Gordon Wasson. Ibid. **244**: 659–700. (This, and items 3 and 4, were reprinted in Rev. de Mycol. **22**: 58–79, 183–198. 1957.)
6. **Krieger, L. C. C.** 1935. A popular guide to the higher fungi (mushrooms) of New York State. N. Y. State Mus. Handb. 11. pp. 1–538. Albany.
7. **Kühner, R.** 1936. Observations sur le genre *Hypholoma*. Bull. Soc. Mycol. Fr. **52**: 9–30.
8. **Miranda, F. and A. J. Sharp.** 1950. Characteristics of the vegetation in certain temperate regions of eastern Mexico. Ecology **31**: 313–333.
9. **Murrill, W. A.** 1916. A very dangerous mushroom. Mycologia **8**: 186–187.
10. **Reko, V.** 1936. Magische Gifte, Rausch- und Betäubungsmittel der Neuen Welt. Stuttgart. 1936.
11. **Sahagun, Bernardino de.** 1932. A History of Ancient Mexico 1. (English translation.) Nashville.
12. **Santesson, C. G.** 1939. Einige mexikanische Rauschdrogen. Ark. Bot. **29a** (12): 1–9.

13. **Schultes, R. E.** 1939. Plantae Mexicanae II. Botan. Leaflets Harv. Univ. **7**(III): (37)–(54).
14. **Sharp, A. J.** 1948. Some fungi common to the highlands of Mexico and Guatemala and the eastern United States. Mycologia **40**: 499–502.
15. **Singer, R.** 1946. Diagnoses Fungorum novorum Agaricalium. Sydowia **2**: 26–42.
16. ——. (1949) 1951. The Agaricales (mushrooms) in modern taxonomy. Lilloa **22**: 1–832.
17. —— **and A. H. Smith.** 1958. New species of *Psilocybe*. Mycologia **50**: 141–142.
18. **Verrill, A. E.** 1914. A recent case of mushroom intoxication. Science II **40**: 408–410.
19. **Wasson, R. G.** 1957. Seeking the magic mushroom. Life **49**(19): 100–120.
20. **Wasson, V. P. and R. G. Wasson.** 1957. Mushrooms Russia and History, 2 vols., **1**: I–XXI, 1–214; **2**: 215–433. Pantheon Books. New York.