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An Investigation of *Sophora secundiflora* Seeds (Mescalbeans)

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ABSTRACT.—The seeds of *Sophora secundiflora* (mescalbeans) have been purported to have hallucinogenic activity because of their past use in certain Native American ceremonies during which visions were experienced by those consuming the seeds. Chemical analysis of mescalbeans revealed the absence of detectable amounts of tryptamine derivatives; however, two additional quinolizidine alkaloids, *epi*-lupinine and Δ^{5}-dehydrolupanine, were isolated. Thus far, seven quinolizidine alkaloids have been detected in mescalbeans and quantitation of these constituents showed that the major alkaloid present is cytisine (0.25%). The toxicity of mescalbeans in mice (oral LD_{50} 1.4 g/kg) is only partially attributable to the known alkaloid content. In addition, the ethnobotanical reports regarding the Native American use of mescalbeans were reviewed. No unequivocal evidence was found in this study to support the proposal that mescalbeans are hallucinogenic.

Sophora secundiflora (Leguminosae) is a shrub or small tree native to the southwestern United States and to parts of Mexico. The colorful yellow to scarlet seeds of this plant, usually referred to as mescalbeans, have been employed by Native American groups for various purposes over a period of approximately 6000 years (1). While the most widespread use of mescalbeans appears to have been as seed beads (2), some Indian groups utilized the seeds in rites during which visions were experienced by those consuming the seeds (3). This use has led to the inference that mescalbeans may have hallucinogenic activity, but no pharmacologic or chemical data are available to verify this effect (4). This report is a chemical, toxicological, and ethnobotanical evaluation of mescalbeans and their purported hallucinogenic activity.

Very little is known about the pharmacologic effects of mescalbeans. In 1878, Wiegand (5) published the only case report of human intoxication in which an adult subject experienced headache, several bowel movements, great difficulty in walking, and sleep which lasted several hours when one-fourth of a seed (approximately 150 mg) was consumed orally. No mention was made of any hallucinogenic effects. The only information available regarding the proposed hallucinogenic activity of mescalbeans is found in ethnographic reports regarding their use by Native Americans. Thus, in this study these reports were critically reviewed in an effort to clarify the role mescalbeans as a medium for the induction of the visions experienced in certain Native American ceremonies.

The first phytochemical investigation of the mescalbean was published by Wood in 1878 when the isolation of sophorine was reported (6). This compound was later shown to be identical to the quinolizidine alkaloid cytisine (7, 8). Recently, Keller (9) reported the isolation of *N*-methylcytisine and sparteine from the seeds. Izaddoost *et al.* (10) detected two additional quinolizidine alkaloids, anagyrine and thermopsine. The latter investigators also reported the identification of several amino acid derivatives from mescalbeans.

Although a pharmacologic evaluation of cytisine and related alkaloids for hallucinogenic activity has not occurred in the literature, other plants containing high levels of these compounds are not generally considered to be hallucinogenic. In this investigation, an hallucinogen is considered to be an agent which produces, together or alone, changes in perception, thought and mood, without causing stupor, narcosis, excessive stimulation, or major disturbances of the autonomic nervous system (11). The seeds of the common laburnum (*Laburnum anagyroides*) contain up to 1.3% cytisine as well as several other quinolizidine alkaloids to give a total alkaloid content of almost 3% (12, 13). Numerous case reports of human intoxication due to laburnum seed ingestion have been published and the symptoms reported are consistent with the nicotine-like effects of cytisine: nausea, vomiting, pallor, drowsiness, dizziness, incoordination, muscle twitching, with delirium and coma occurring in severe cases (14, 15). Some early reports do mention hallucinations as an occasional effect of laburnum intoxication (14), but since this effect is always associated with the other effects listed above, laburnum should not be considered to be an hallucinogen. Substances such as laburnum, which can induce a delirious state occasionally accompanied by hallucinations, have been defined as deliriants to distinguish them from hallucinogens (16). Some secondary references have cited cytisine as an hallucinogenic constituent of *Cytisus canariensis* (17). However, the original report concerning the effects of this plant indicates it is a tobacco-like intoxicant rather than an hallucinogen, an effect consistent with its cytisine content (18). Thus, it appears that the known alkaloid content of mescalbeans does not support the proposal that these seeds have hallucinogenic activity as defined above. In this investigation the alkaloid fraction of mescalbeans was studied to determine if hallucinogenic tryptamine derivatives, known to occur in other members of the Leguminosae, were present.

Mescalbeans have a reputation of being very toxic. This appears to have been derived primarily from ethnographic reports which state the profound effects were produced by the consumption of one-half to three seeds (19–22). The only published study dealing with the oral toxicity of mescalbeans in animals was conducted by Boughton and Hardy (23) who investigated the effects of mescalbeans in sheep. Oral administration of finely ground seeds produced no effect at a dose of 2.4 g/kg, while twice that amount produced trembling, difficulty in walking, and a semiconscious state. An oral dose of 10 g/kg produced death in about 18 hours. Because of the paucity of information regarding the toxicity of mescalbeans, the oral LD_{50} of the seed material and the major alkaloid constituent, cytisine, were determined in this study using mice.

With the exception of the purported hallucinogenic activity, most of the effects attributed to mescalbeans are consistent with quinolizidine alkaloid intoxication. However, Izaddoost *et al.* (10) reported that the alkaloid fraction of an ethanol extract of mescalbeans did not appear to be responsible for all of the effects produced by the total extract when tested in rats. In the current study, mescalbeans were quantitatively assayed for the major quinolizidine alkaloids present in order to determine more precisely the contribution of these compounds to total toxicity of the seeds.

EXPERIMENTAL

PLANT MATERIAL.—Fresh, ripe seed pods of *Sophora secundiflora* (Ort.) Lag. *ex* DC. were collected in the Amistad Recreation Area, near Del Rio, Texas, during the fall of 1974 and 1975. A sample of the seeds has been deposited in the University of Michigan Herbarium.

CHROMATOGRAPHIC SYSTEMS.—In this study the following thin-layer chromatography (tlc) and gas chromatography (gc) systems were utilized. Tlc system A: silica gel G, chloroform-methanol-58% ammonium hydroxide, 100:10:1. Tlc system B: silica gel G, chloroform-methanol, 5:1. Gc system A: 3% OV-17 on Gas Chrom Q, ¼ inch x 6 ft glass, 125° initial, 6°/min to 265°. Gc system B: 3.8% UC-W982 on Chromosorb WHP, 6 mm x 4 ft glass, 220° for 2 min, 10°/min to 265°.

CHROMATOGRAPHIC ANALYSIS FOR TRYPTAMINE DERIVATIVES.—The seeds were ground in a Waring blender and defatted with petroleum ether using a Soxhlet apparatus. The defatted material (5 g) was extracted with methanol (100 ml) by stirring for 8 hours. The methanol extract was reduced to 15 ml and chromatographically evaluated for the presence of tryptamine derivatives using several tlc systems (24) and PDAB reagent (2% *p*-dimethylaminobenzaldehyde in conc. HCl-ethanol, 1:1). A compound was detected which gave an indole-like purple chromophore with PDAB and heat (R_F 0.65, tlc system A). Isolation of this constituent, as described below, revealed it to be Δ^5-dehydrolupanine. No other compounds were detected in significant levels (>0.0005%) which gave an indole-like reaction with PDAB reagent. The petroleum ether extract was also devoid of such compounds.

ISOLATION OF Δ^5-DEHYDROLUPANINE.—The constituent of mescalbeans giving an indole-like chromophore with PDAB reagent, as described above, was extracted from 350 g of ground defatted seeds by basifying with a mixture of ammonium hydroxide-ethanol-ether (1:1:8) and extracting with chloroform for 18 hours using a Soxhlet apparatus. Extraction of a portion of the marc with methanol showed complete removal of the desired constituent with chloroform. The chloroform extract was concentrated *in vacuo* and chromatographically fractionated using preparative tlc (silica gel GF 254, 1 mm). After developing a plate in solvent system A, the desired band of adsorbent was removed from the plate and extracted twice by stirring with methanol. The methanol extracts were combined and reduced to dryness, and the residue was extracted with 10 ml of chloroform. The chloroform solution of the alkaloid was rechromatographed using preparative tlc with solvent system B (R_F 0.3). The PDAB positive constituent was removed from the adsorbent, and the resulting chloroform solution was extracted with 0.05N HCl. The aqueous extract was quickly basified (pH 10) with 0.1N NaOH and extracted with ether. The ether extract was reduced to dryness to yield 1.9 mg of residue. Tlc (systems A and B) and gc (system B, retention time 4.8 min) analysis indicated the isolated material was homogeneous.

The proton nmr spectrum (100 MHz) of the isolated material was complex, but distinctive peaks were present at δ 4.9 (t, 1*H*, $J=4$ Hz) and 4.0 (d, 1*H*, $J=12$ Hz). No peaks were observed in the aromatic region. The electron impact mass spectrum showed only two major ions, *m/e* 98 (100%) and 246 (35). A chemical ionization mass spectrum using methane as the reactant gas exhibited no fragmentation and a MH^+ ion at *m/e* 247. Analysis of the spectral data indicated the compound was Δ^5-dehydrolupanine. To confirm this identification the isolated material was subjected to catalytic hydrogenation using the method described by Cho and Martin (25). The reduction product was found to be identical to standard lupanine using tlc systems A and B and gc system B. In addition, the electron impact mass spectrum of the reduction product was identical to standard lupanine.

ISOLATION OF EPI-LUPININE.—Powdered seed material (1.4 kg) was homogenized with ethanol in a Waring blender. After filtration, the ethanolic extract was concentrated *in vacuo*, acidified with 10% acetic acid, and extracted with two successive portions of ether, ethyl acetate, and chloroform. The acidic aqueous solution was rendered basic with 58% ammonium hydroxide and extracted with four portions of chloroform. The combined chloroform extracts were filtered through anhydrous sodium sulfate and reduced to a syrupy liquid *in vacuo*.

The crude alkaloid fraction (5.3 g) was dissolved in chloroform and chromatographed over a silica gel column (3 x 53 cm) using chloroform-methanol (16:1) as the initial eluting solvent. Twenty ml fractions were collected. After collecting 20 fractions, the methanol concentration of the eluting solvent was doubled. The final eluting solvent (fractions 61–80) consisted of chloroform-methanol, 2:1. Fractions were evaluated using tlc system A with Dragendorff's spray as a visualizing reagent. Fractions 56–70 contained a single unknown alkaloid, R_F 0.22. Gc-ms analysis of these fractions using gc system A (retention time 5.4 min) also showed a single compound which exhibited an electron impact fragmentation pattern containing the following major ions: *m/e* 55 (59%), 83 (100), 96 (56), 97 (69), 110 (52), 111 (43), 138 (74), 152 (78), 168 (43), and 169 (74). The ir spectrum of the isolated material contained peaks at ν ($CHCl_3$) 3350 (broad), 2930 (s), 2860 (s), 2810 (m), 2760 (m), 1470 (m), 1445 (m) cm^{-1}. The proton nmr spectrum (60 MHz) was complex and closely resembled that of lupinine. Tlc, ir, and nmr data indicated the isolated material was *epi*-lupinine. This was confirmed by the preparation of a methiodide derivative. Treatment of the isolated base (20 mg) with methyl iodide yielded 33 mg of short white needles mp 249–251° [α-*epi*-lupinine methiodide, lit. mp 250–251° (26)].

QUANTITATION OF ALKALOIDS.—The alkaloids were extracted using the method previously described for the isolation of *epi-lupinine*. An internal standard (200 mg of *N,N*-dimethyl-3,4-dimethoxyphenethylamine) was added to the powdered seed material (100 g) prior to extraction. The alkaloid fraction was analyzed using gc system A, and the peak area-weight ratio obtained from analysis of standard solutions of the internal standard was used to determine the efficiency of the extraction, which was found to be 64%. The identity of the peaks in the chromatogram were determined using standard compounds and/or mass spectral data for each peak. The analytical results are given in the discussion below.

DETERMINATION OF TOXICITY.—A 60-mesh powder of the whole seed was suspended in water and orally administered to male mice (Swiss Webster), weighing approximately 35 g. The following dose-levels were tested using 10 mice for each dosage: 1.10, 1.40 and 1.70 g/kg. Initial studies indicated this dosage range included the LD_{50}. The mice were observed for one hour after dosing, and from the number which died during this period, the LD_{50} was calculated using the method of Litchfield and Wilcoxon (27). The oral LD_{50} was found to be 1.4 g/kg. Death usually occurred in approximately 12 minutes and was due to respiratory arrest. Clonic convulsions were noted in some animals. Ataxia was noted at a dosage about 0.8 g/kg. Below this dosage no effects were observed. The oral LD_{50} for cytisine was determined using the same procedure and was found to be 50 mg/kg. At this dosage death occurred in approximately 4 minutes. The symptoms of intoxication were similar to those observed with the whole seed material.

RESULTS AND DISCUSSION

Unfortunately, the decision as to whether a drug is or is not hallucinogenic ultimately depends on human testing. Since such studies would be very difficult to conduct today for ethical and medico-legal reasons, numerous attempts have been made to develop alternative methods, based on the use of laboratory animals, for detecting hallucinogenic activity (28-30). However, a truly reliable bioassay of this sort is not yet available. The toxic effects of mescalbeans also complicate pharmacologic testing for hallucinogenic activity since most bioassays for this type of activity are based on subtle changes in animal behavior that previously have been shown to be produced by known hallucinogens. Because of the potential difficulties involved in the pharmacologic evaluation of mescalbeans for hallucinogenic activity, a chemical approach to the problem was taken in which the alkaloid fraction of the seeds was examined for the presence of hallucinogenic constituents. Previous studies (6-10) have shown that mescalbeans contain several quinolizidine alkaloids; however, none of these compounds have been shown to be hallucinogenic. All of the known hallucinogenic compounds from the Leguminosae are indole derivatives and, of these, tryptamine derivatives such as *N,N*-dimethyltryptamine are the most prevalent (11, 32, 32). Thus, a methanolic extract of mescalbeans was screened for the presence of tryptamines using tlc and PDAB reagent. A constituent of the extract was detected which gave an indole-like purple chromophore and this compound was subsequently isolated using preparative tlc.

The proton nmr spectrum of this constituent lacked peaks in the aromatic region characteristic of an indole derivative, but the spectrum generally resembled that of lupanine, a quinolizidine alkaloid. The mass spectrum of the isolated material using both chemical and electron impact ionization showed the compound had a molecular weight of 246, which indicated a dehydro derivative of lupanine (mw 248). A survey of the literature revealed the isolated alkaloid was Δ^5-dehydrolupanine. As further proof of the identification, the isolated material was reduced to lupanine. The reduction product was identical to lupanine in gc, tlc, and mass spectral characteristics.

Δ^5-Dehydrolupanine has been isolated and characterized from only one other source, *Thermopsis rhombifolia* (25). However, this alkaloid may be much more prevalent since it is a probable precursor of the unsaturated tetracyclic and tricyclic quinolizidine alkaloids such as anagyrine and cytisine (33, 34). The apparent limited distribution of Δ^5-dehydrolupanine may be due to the fact that this alkaloid is easily hydrolyzed and would normally be lost in many alkaloid isolation schemes (25). The discovery that this alkaloid can be easily detected using tlc and PDAB reagent should make the detection of this compound more common in the future.

Thus, in this study no tryptamine derivatives were detected in mescalbeans. The sensitivity of the chromatographic assay was such that these compounds could be detected if present in the seeds above the level of 0.0005%. Below this level, the presence of such compounds would be unlikely to be pharmacologically significant.

Qualitative evaluation of the alkaloid fraction of mescalbeans using gc-ms revealed the presence of an additional previously unidentified alkaloid. This constituent was isolated using column chromatography. Mass spectral analysis showed that the isolated alkaloid had a fragmentation pattern identical to lupinine (35). However, tlc, nmr, and ir data were distinctly different from that obtained from standard lupinine. A notable difference between the two compounds was observed in the ir spectra, which were taken in dilute chloroform to minimize intermolecular hydrogen bonding. The isolated material exhibited less intramolecular hydrogen bonding (OH stretch, 3360 cm^{-1}) than lupinine (3200 cm^{-1}), which indicated the isolated alkaloid was the equatorial isomer of lupinine, *epi*-lupinine. To confirm this identification, a methiodide derivative was prepared and the melting point of the derivative was found to be identical to that reported form α-*epi*-lupinine methiodide. *Epi*-lupinine has been isolated from several members of the Leguminosae, but this represents the first report of the alkaloid from the genus *Sophora* (32).

With this study, seven quinolizidine alkaloids have now been reported to occur in *S. secundiflora* seeds. The toxicity of mescalbeans has generally been assumed to be due to these constituents, but no quantitative data have been published to support this assumption. Thus, in this study the alkaloid fraction was quantitatively assayed using a gc-ms technique. The following levels of alkaloids were found to be present: cytisine (0.25%), *N*-methylcytisine (0.026%), sparteine (0.018%), *epi*-lupinine (0.003%), anagyrine (0.001%), and Δ^5-dehydrolupanine (0.001%). Contrary to a previous report (10) thermopsine was not detected.

Of the known alkaloidal constituents of mescalbeans, cytisine appears to contribute most to their toxicity. The oral LD_{50} of cytisine in mice was found to be 50 mg/kg in this study and 101 mg/kg by Barlow and McLeod (36). The difference in these values may be due to the strain, sex, and other differences that exist in the animals utilized in these studies. The other major alkaloids present are much less toxic. Barlow and McLeod (36) found the oral LD_{50} (mice) for *N*-methylcytisine to be in excess of 500 mg/kg, and sparteine has been shown to be even less toxic (37). Little is known about the pharmacologic effects of the other alkaloids present, but their toxicological significance is probably minimal due to the low concentration of these compounds in the seeds.

It is interesting to note that the known alkaloid content of mescalbeans does not account for all of their oral toxicity in mice. The oral LD_{50} of the seed material was found to be 1.4 g/kg. This amount would contain about 4 mg of cytisine and related alkaloids, which is far below the oral lethal dose of these compounds. This observation is consistent with the report of Izaddoost *et al.* (10) who found that both alkaloid and nonalkaloid fractions of the seeds contribute to their toxicity. These investigators proposed that amino acid constituents were toxic, but no data were provided to support this claim.

Unfortunately, it is difficult to predict the dose of mescalbeans required to produce toxic effects in man. Barlow and McLeod (36) found that cytisine is very similar to nicotine in its pharmacologic effects, but is about twice as toxic when administered orally to mice. The effects of nicotine in man have been studied extensively (38), and the minimum lethal dose is usually estimated to be about 60 mg (39). However, oral doses of 1–2 mg have been reported to produce toxic effects in nonsmokers (40). Thus, if the relative toxicity of cytisine and nicotine is similar in man, a single seed containing about 2 mg of cytisine might well produce toxic effects. As mentioned above, other as yet unidentified constituents of mescalbeans appear to contribute to their toxicity in mice and the same is probably true with humans.

Since these and other chemical studies of mescalbeans have not provided support for the belief that these seeds are hallucinogenic, a review of the ethnographic literature describing the use of mescalbeans by Native American groups was undertaken to clarify their role as a medium for inducing visions. By visions is meant the contact and communication that occurs between a human individual and a being of the non-human realm. From the perspective of American Indian groups, such contacts usually took place on a spiritual as opposed to a material level of reality and often occurred while an individual was in a trance-like state. Such states cannot be equated with sleep. In fact, most North American Indian groups who employed mescalbeans carefully distinguished between the relatively powerless dream that occurred during sleep and the potentially power-laden visions experienced during trance. In this sense, the phenomena interpreted as visions by American Indians would fall into the Western category of hallucinations.

Because no Native American group presently employs mescalbeans for the induction of visions, the only sources of information concerning this use of mescalbeans by Native Americans are ethnographic descriptions collected in the past. A survey of this ethnographic literature revealed that a very limited number of American Indian groups employed mescalbeans in contexts that they associated with the receipt of visions. Over thirty ethnographically documented North American Indian groups located in Texas and the Prairies, Plains, Basin-Plateau, and southwestern portions of the United States are known to have employed mescalbeans. Most, if not all of these groups used mescalbeans as seed beads, which they attached to their clothing and other articles (2). Yet, less than half these groups consumed mescalbeans or a decoction prepared from these seeds, and the majority of the groups who did ingest mescalbeans did so primarily for their emetic and purgative effects, apparently failing altogether to consider them to be hallucinogenic (1). In fact, only six Native American groups are suspected to have associated the consumption of mescalbeans with visionary experiences. These six groups are the Coahuilteco, Tonkawa, Hasinai Caddo, and Wichita of Texas, the Pawnee of Nebraska, and the Ponca of Nebraska and South Dakota.

The information regarding the use of mescalbeans by these six groups is rather fragmentary. In fact, there is no entirely unequivocal evidence that any of them employed mescalbeans to induce visions, though the evidence is more suggestive for some groups than for others. The Coahuilteco generally are assumed to have ingested mescalbeans, perhaps in conjunction with peyote (*Lophophora williamsii*), but no information exists concerning the pharmacologic effects that resulted therefrom (4, 41). Similarly, the Tonkawa are known to have consumed mescalbeans, but the only effect reportedly resulting from this consumption was "intoxication" (42, 43). Early eighteenth century missionary reports indicate that Hasinai Caddo men and women ingested mescalbeans and peyote in communal contexts and seem to have experienced visions as a result (44). However, the statement containing this information is ambiguously worded and can be interpreted to indicate that the Hasinai consumed mescalbeans and peyote either at separate times or in conjunction. If the latter was the case, it would be impossible to determine to what extent, if any, mescalbeans contributed to the inducement of any visions that might have occurred. The Hasinai also administered rather potent decoctions to certain selected individuals who, as a result, reportedly experienced unconsciousness lasting twenty-four hours, apparently accompaned by visions (44). It is not known if mescalbeans were included in these decoctions since their ingredients are not revealed.

The manner in which the Ponca, Pawnee, and Wichita employed mescalbeans is more substantially documented. Among the Ponca, all members of the medicine society referred to by Howard (45) as the "mescal bean cult" consumed a decoction of mescalbeans during the performance of their ceremonies. These individuals are reported to have occasionally experienced visions after drinking the decoction. Although the amount of mescalbean in the decoction is not specified, one sip of it was said to have been sufficient. However, there is reason to doubt the accuracy of this report. None of the individuals who described the ceremony for Howard had actually viewed it themselves, relying instead on hearsay for their information regarding it. In fact, Howard's principal informant for this ceremony was a prominent Ponca peyotist who may have unconsciously extended the hallucinogenic properties of peyote to mescalbeans.

The members of the Pawnee Deer Society prepared a decoction of half a mescalbean in a "kettle" of water, which they administered to individuals seeking admittance to their society. Despite the fact that this decoction contained a low concentration of mescalbean constituents, the initiate reportedly fell into a state of unconsciousness after consuming it (22, 46). There is no explicit statement that the initiate experienced any visions subsequent to the ingestion of the mescalbean preparation. On the other hand, a Pawnee vision story describes the receipt of visions by an individual after he consumed an unspecified amount of whole mescalbeans and apparently fell unconscious (47). In addition, the Pawnee claimed that "all animal powers were learned through the power of the mescal bean" (22). Since "animal powers" usually were secured in visions, it seems possible that the Pawnee associated the receipt of visions with the ceremonial consumption of mescalbeans. However, as will be discussed below, the visions perhaps experienced by the Pawnee Deer Society initiates may have been due to intervening cultural factors rather than to any hallucinogenic constituent of mescalbeans.

The most detailed information available regarding the association between the ingestion of mescalbeans and the elicitation of visions is found in a description of the initiation ceremony of the Wichita Deer Society, preserved in a Wichita origin myth (20). According to this myth, the ceremony was staged in a typical Wichita grass lodge specially prepared for the occasion. In the early evening, the members of the Deer Society arranged themselves around the interior circumference of the lodge with a group of four singers at each of the cardinal directions. The initiate was a youth about fifteen years of age who had been accepted for initiation by the society members at the request of his mother. The ceremony commenced when a large fire was kindled in the center of the lodge and one of the four groups of singers began to sing their songs. Some of the participants began to dance and the youth joined in. Then the leader of the ceremony announced that the initiate should be administered mescalbeans "in order that he might possess the same power that they had." A man seated on the east side of the lodge produced two mescalbeans by sleight-of-hand, which he chewed up into a dough and gave to the boy to swallow. The leader of the ceremony then produced another mescalbean, again by sleight-of-hand, which he masticated and administered to the youth, bringing the total number of mescalbeans consumed by the initiate to three.

The boy began dancing again and by late evening experienced cramps in his arms and legs and had to be supported by his mother, being unable to dance alone. By noon of the following day, the youth could not move at all and evidently was unconscious. The members of the society laid him out flat on the ground and scratched his body with a sharpened stone. If the youth had flinched in the least, he would have been required to resume dancing, but the scratching evoked no reaction. Some of the people participating in the ceremony expressed anxiety that the boy had been killed, but the leader of the ceremony calmed them by claiming that he would "live again at the end of four days." He then appointed four men to carry the youth to an elevation located to the east of the lodge, where he was to remain in isolation for the next four days.

The general drift of the account suggests that the initiate regained consciousness by the evening of the day following his placement on the mound. At this time, the youth experienced a vision in which he was awakened by the spirit of the Bear, who appeared to him in human form. When daylight approached, the spirit disappeared and the boy slept until nightfall. The Bear visited the initiate on each of the remaining two nights to instruct him in his knowledge and bestow his powers upon him. On the morning of the fourth day after being placed on the elevation (the sixth day after the commencement of the ceremony), the boy arose and returned to his mother's home, the ceremony being completed.

Even though it is couched in a myth and partially structured according to mythical conventions, this account is the most detailed description of mescalbean use by Native Americans in a ceremony during which visions were experienced. Because so little is known about the effects of mescalbeans on humans, especially at sublethal doses, it is difficult to determine what effects, if any, the ingested seeds had on the initiate. The muscle cramping and unconsciousness experienced by the initiate are similar to the effects observed in animals intoxicated by mescalbeans (23). However, the three seeds ingested by the initiate appear to constitute a rather low dose for such profound effects, especially when one considers that the seeds were premasticated by others prior to their ingestion by the initiate. Another difficulty encountered in attributing the unconscious state to the effects of the ingested mescalbeans is the period of time that elapsed between the ingestion of the seeds and the onset of unconsciousness. The exact period is not stated in the myth, but it appears that 8 to 12 hours had transpired. This delayed onset is not consistent with the rapid onset of the effects produced by mescalbeans as observed in animal studies.

It is interesting to note that the visions experienced by the initiate occurred approximately forty-eight hours after consumption of the mescalbeans. Although hallucinogenic agents are known which have a delayed onset of activity (11, 16), it seems unlikely that a mescalbean constituent could produce this effect after two days had transpired. If it is assumed that the ingested mescalbeans were not directly responsible for the visions noted in the myth, how can their occurrence be accounted for?

An exclusively materialistic model that envisions a direct causal relationship between the consumption of mescalbeans and the generation of visions appears incapable of accounting for the origin of these visions. A more suitable model is one that incorporates the relationships among a number of variables, including not only the possible toxic effects of the mescalbeans but also the impact on the initiate of the physical and intellectual contexts associated with the ceremony in general and his visionary experiences in particular. In relation to the initiate, it is possible to distinguish two relevant contexts, one external, the other internal. The external context consists of the immediate setting and events of the initiation ceremony itself together with the set of beliefs maintained by the ceremony's participants in terms of which they organized and interpreted the ceremony. The internal context refers to the physiological and psychological states of the initiate as well as to the beliefs and expectations which he brought with him to the ceremony. The nature and interaction of these contexts must be considered in accounting for the visions he experienced.

To begin with, the ceremony itself was structured and performed in such a fashion as to have a powerful impact on the initiate. The initiation was staged at a time and in a place culturally defined as special, extraordinary, and highly significant. The ceremonial lodge, lined with aromatic sage and illuminated by the blaze of the central fire, became the stage for the unfolding of a series of ritual dramas, enacted in song and dance to the accompaniment of gourd rattles and twanging musical bows. The initiate, led into the lodge by his mother, was soon engulfed by a myriad of sensory impressions, the impact of which no doubt was enhanced by the fact that the initiate himself was the central figure in the ceremony rather than just another performer or simply a spectator.

It is generally accepted that such impressive, sensorially stimulating settings alone are capable of generating numinous and sometimes ecstatic states in the individuals who created and participated in them (48). But perhaps the most important factor in the generation of these states—a factor generally intrinsic to these milieux and internalized by the individuals who operate within them—is the expectation that such states, which often are associated with visionary experiences, are likely to occur (49). The Wichita, like most American Indian groups, subscribed to the belief that visions were both possible and desirable and inculcated this belief in their children from birth. That the Deer Society initiation ceremony was one context within which they would have expected visions to occur is suggested by the fact that the participants in the ceremony attempted to create the external and internal contexts they considered most conducive to visionary experiences.

Among the Wichita an individual who desired a vision usually isolated himself from other human beings and attempted to induce in himself a trance-like state. They, together with most other American Indian groups, employed a number of techniques in their attempts to generate such states, including meditation, self-hypnosis, self-deprivation, and among some groups, self-multilation (50, 51). In the case of the Wichita initiate, this trance-like state apparently was produced by the combined effects of a lack of sleep and sustenance, forced exertion lasting from twelve to sixteen hours, and possibly the nonhallucinogenic toxic effects of the mescalbeans ingested. After collapsing from the rigors of his ordeal, the youth was separated from his peers and placed in seclusion to await the arrival of the vision he believed would occur.

By rendering the initiate unconscious and by separating him from other human beings, his initiators made him conform to their model of the proper condition of a vision seeker. But it is likely that they interpreted his unconsciousness and isolation in more symbolic terms as well. The participants in this ceremony evidently viewed the unconscious condition of the initiate as resembling a state of death and his isolation as indicating his separation from the world of the living. While such death and rebirth symbolism is almost definitive of initiation rituals the world over, it was particularly appropriate in a Wichita context within which visions were being sought. In Wichita belief, the dead generally were in closer contact with supernatural beings than were the living (21). An appropriate means for signifying and, from the Wichita perspective, accomplishing contact with these supernatural beings would have been the inducement of a death-like state such as that produced in the initiate.

Thus, the members of the Wichita Deer Society created for the initiate the external setting that was recognized by themselves, and presumably the initiate as well, as appropriate to the receipt of visions. In addition, they manipulated the initiate in such a fashion as to generate in him the psychological and physiological states that were considered to enhance his chances of experiencing a vision. The actual occurrence of the youth's visions therefore can be attributed to the interplay of a number of factors: the nature of the external setting within which the ceremony and the visions took place, the physical and psychological condition induced in the youth during the enactment of the ceremony, the belief maintained by the initiate and other participants that this setting and the boy's condition were conducive to the generation of visions, and the initiate's expectation that he would undergo a visionary experience before his initiation was completed. Mescalbeans played a part in creating the context within which these visions took place, but apparently cannot be attributed with a direct or preeminent role in their generation.

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