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CARBON-13 NUCLEAR MAGNETIC RESONANCE IN ALKALOID CHEMISTRY

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INTRODUCTION

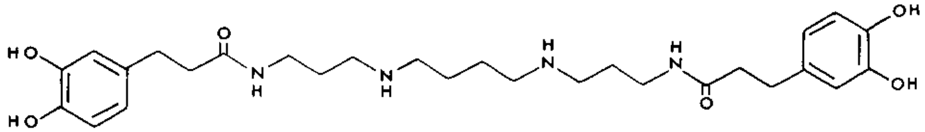
Inasmuch as one is usually dealing with unknown compounds in alkaloid chemistry, the use of ^{13}C nmr is of great value, especially when used in conjunction with ^{1}H nmr. Carbon resonance provides information not available in the more routine methods of spectroscopic analysis, *i.e.*, ir, ^{1}H nmr and ms. For this reason and for the fact that newly discovered alkaloids are increasingly complex, the use of ^{13}C nmr is gaining popularity. It is also gaining popularity in analytical applications other than structural elucidation such as quantitative determination, ^{13}C enriched biosynthetic studies, conformational studies, *etc.*.

This review covers the literature from 1978 to 1980 as other reviews of this subject have been made covering the literature prior to 1978 (1-8). A few earlier references have been included if they were left out of some of the earlier reviews. For the sake of brevity, shift assignments usually are listed for naturally-occurring alkaloids only, and not for synthetic derivatives.

1. Noncyclic Nitrogen Alkaloids

The structure of kukoamine A (1) isolated from *Lycium chinense* was determined (9). The complete ^{13}C nmr assignments were not given. See Figure 1.

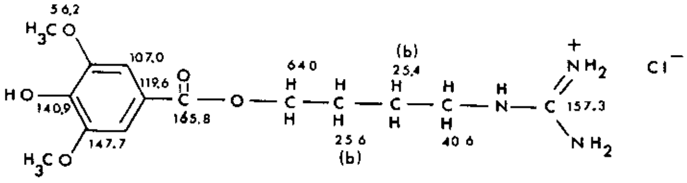
Figure 1



1

The ^{13}C nmr spectra of leonurine hydrochloride (2) from Leonorus gibiricus L. and thirteen of its synthetic analogues were studied (10). See Figure 2. Substituent and conformational effects were noted.

Figure 2(a)



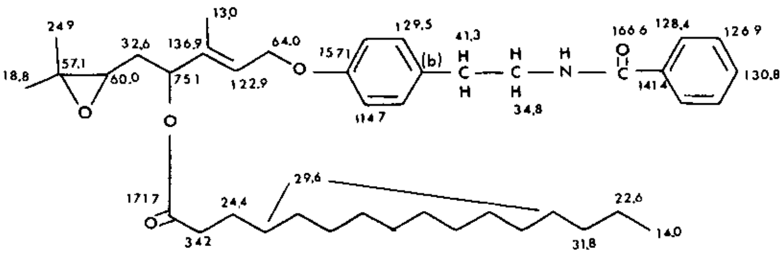
2

(a) In DMSO-d_6

(b) Interchangeable assignments.

Severine palmitate (3), a Rutaceae alkaloid, was isolated from Atalantia monophylla and Hesperethusa crenulata. Nmr and ms spectra prompted a revision of the structure of severine (11). The ^{13}C nmr shift assignments can only be surmised as the authors did not clearly label the structure and the corresponding shifts. See Figure 3.

Figure 3(a)



3

(a) In deuterioacetone. TMS was used as internal standard.

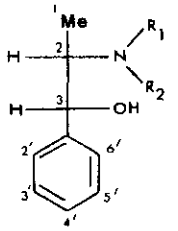
(b) Signal obscured.

Non-cyclic nitrogen alkaloids and a berberine-type alkaloid were isolated from Zanthoxylum species and identified with the use of "fingerprint" identification by ^{13}C nmr (12).

2. Ephedrae Alkaloids

The ^{13}C nmr shift assignments were made for the simple Ephedrae alkaloids (phenethylamines) (13). Peak heights in ^{13}C nmr spectra of crude Ephedrae extracts were measured to determine the amounts and proportions of l-ephedrine (4) and d-pseudoephedrine (5). This method compared well to the authors' glc method of determining the same. See Table 1.

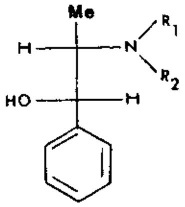
Table 1.(a)



4 R_1 = H, R_2 = Me

6 R_1 = R_2 = Me

7 R_1 = R_2 = H



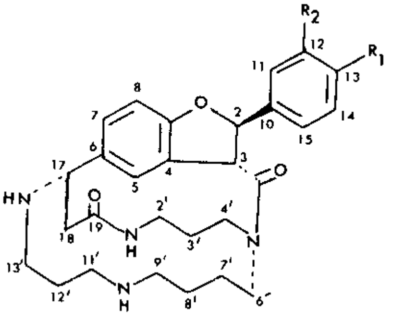
5 R_1 = H, R_2 = Me

Carbon	l-Ephedrine	d-Pseudoephedrine	l-Methylephedrine	l-Norephedrine
C-1	10.6	12.8	8.5	13.3
C-2	60.8	60.5	67.4	53.3
C-3	72.1	75.5	71.5	73.7
N-Me	31.7	30.9	41.1	
Me			42.8	
C-1'	139.4	140.5	140.3	139.4
C-2',6'	126.9	127.8	126.8	127.1
C-3',5'	129.6	129.8	129.8	129.7
C-4'	129.2	129.8	129.3	129.4

(a) The spectra were of the hydrochloride salts in deuterium oxide. Dioxane (δ_c = 67.4) was used as the internal standard.

Hypotensive alkaloids were extracted from the roots of Ephedraceae. The Ephedra phenethylamine alkaloids are extracted from the aerial portion. The ^{13}C nmr assignments were made for ephedradine A (8,14), B (9,15), and C (10,16). All three were analyzed by ir, ^1H nmr, ms and uv. A was analyzed by X-ray cystallography, but crystals of B and C were not obtained. Circular dichroism confirmed the absolute configuration of B and C. See Table 2.

Table 2.(a)



Ephedradine A, B, and C.

R_1 = OH, R_2 = H 8 (A)
R_1 = OH, R_2 = OMe 9 (B)
R_1 = R_2 = OMe 10 (C)

Carbon	A	B	C
C-2	88.7	88.7	88.0
C-3	52.6	52.5	52.0
C-4	125.2	125.3	125.8
C-5	134.8	134.3	133.4
C-6	127.0	126.9	126.1
C-7	121.6	121.5	121.0
C-8	111.3	111.1	111.3
C-9	160.2	159.9	159.1
C-10	130.3	130.8	130.7
C-11	129.2	111.1	110.4
C-12	111.6	147.9	148.4(c)
C-13	156.8	145.9	148.0(c)
C-14	111.6	115.7	109.8
C-15	129.2	120.5	119.7
C-16	171.1 (b)	171.1 (b)	170.7(b)
C-17	59.3	59.2	58.7
C-19	175.5 (b)	175.2 (b)	174.5(b)
C-18	22.0	21.8	21.4
C-2'	23.2	23.1	22.8
C-3'	25.9	25.7	25.2
C-4'	25.9	25.7	25.4
C-6'	38.1	38.0	37.7
C-7'	38.6	38.0	37.9
C-8'	42.1	42.3	41.9
C-9	42.7	42.7	42.6

Carbon	A	B	C
C-11'	45.0	44.8	44.2
C-12'	46.5	46.5	46.0
C-13'	46.7	46.5	46.0
R_1			55.5
R_2^1		56.4	55.5

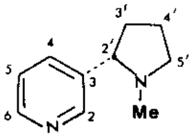
(a) Recorded for the dihydrochloride of A and the dihydrobromides of B and C in deuterium oxide; no internal standard reported.

(b)(c) Ambiguous assignments.

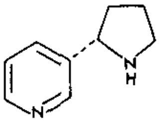
3. Pyridine and Piperidine Alkaloids

The ^{13}C spin-lattice relaxation times were studied to determine the conformation of nicotine (11) in solution (17). The H(2')-C(2')-C(3)-C(2) dihedral angle is approximately zero degrees. The shift assignments for nicotine (11) and nornicotine (12) were reported earlier (18). See Table 3.

Table 3.(a)



11



12

Carbon	Nicotine	Nornicotine
C-2	149.5	148.6
C-3	138.8	140.5
C-4	134.9	134.0
C-5	123.6	123.2
C-6	148.5	148.0
C-2'	68.9	60.0
C-3'	35.2	34.5
C-4'	22.6	25.6
C-5'	57.0	47.0
$N-CH_3$	40.3	

(a) In deuteriochloroform.

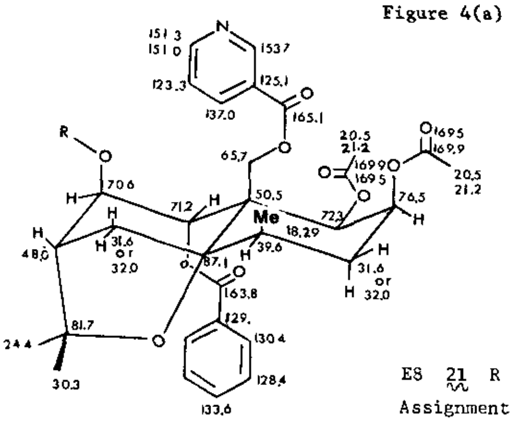
$^{13}CO_2$ (97 atom %) was incorporated into nicotine (11) for biosynthetic studies (19). [2',3',N-CH_3-$^{13}C_3$]Nicotine was synthesized for confirmation of the ^{13}C nmr experiments (20). It was found that the difference in the relative intramolecular ^{13}C labeling of the C(2')/C(3') and C(4')/C(5') two carbon units of 11 was larger than the experimental error. The significance of this finding to nicotine biosynthesis is unsure.

The ^{13}C nmr spectra of nicotine (11) and many of its metabolites and related compounds were studied. The shift assignments were consistent with those previously reported. It was claimed that C2' of nicotine is the best site for ^{13}C labelling in elucidating metabolic pathways of nicotine (21).

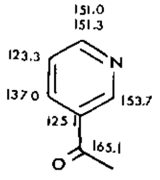
Leete has reviewed the use of ^{13}C nmr in biosynthetic studies. Its use has an advantage over the traditional use of ^{14}C and ^{3}H as tracers, in that troublesome degradation is not required; the location of the labeled carbons can be detected by ^{13}C nmr. In the use of precursors with only one labeled carbon, enrichment of the natural product site by at least 0.5% is required. But, when precursors with two contiguous ^{13}C atoms are used, incorporation with enrichment as little as 0.025% can be detected as this gives tell-tale satellite peaks. Most examples cited are those of pyridine alkaloids (22).

Eleven new alkaloids with sesquiterpene cores from Catha edulis were characterized (23-26). Although (+)-norpseudoephedrine had been isolated from the drug (khat) earlier, (27) it is a minor alkaloid and the newly isolated alkaloids, cathedulins K1 (13,23,25) E2 (14,23,24), K2 (15, 23,25), E3 (16,23,26), E4 (17,23,26), E5 (18,23,26), E6 (19,23,26), K6 (20,23,25), E8 (21,23,24), K12 (22,23,26) and K15 (23,23,25) were also responsible for physiological activity (CNS stimulation and appetite suppression). Geographical differences in alkaloid content were observed (E = Ethiopian, K = Kenyan). See Figure 4.

Figure 4(a)



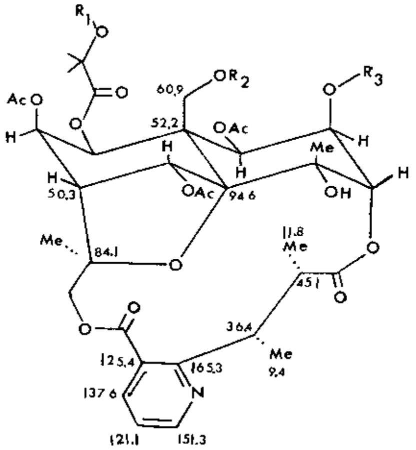
E8 21 R = H (b)
Assignments shown for E2.



E2 14 R = above

Figure 4(a) (Continued)

Shifts Given for Cathadulin K2 15



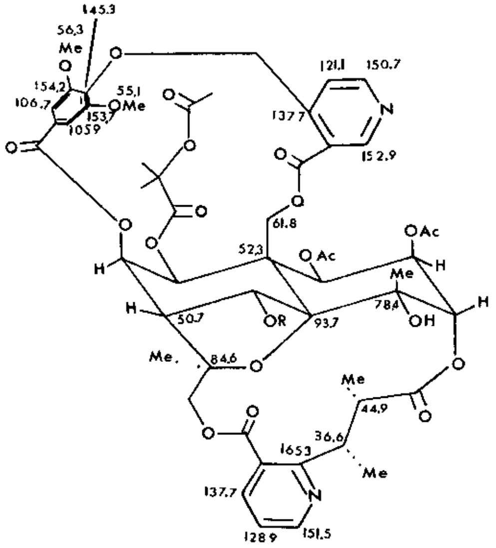
K1 13 $R_1 = R_2 = R_3 = Ac$

K2 15 $R_1 = R_2 = Ac$, $R_3 = H$

K6 20 $R_1 = Ac$, $R_2 = R_3 = H$

K15 23 $R_1 = R_2 = R_3 = H$

Shifts Given for Cathadulin E3 16

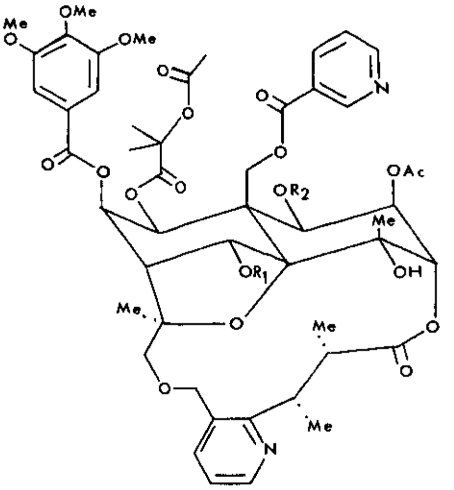


E3 16 R = Ac E4 17 R = H

E5 16 R_1 = H, R_2 = Bz

E6 17 R_1 = Ac, R_2 = Bz

K12 20 R_1 = R_2 = Ac

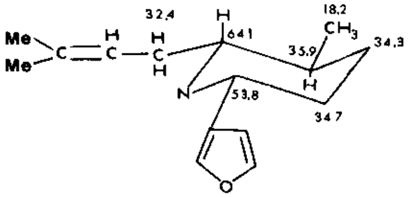


(a) All compounds in deuteriomethanol.

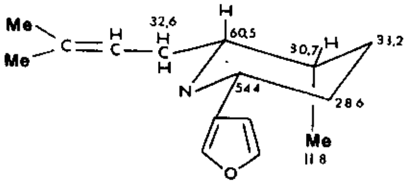
(b) E8 could be an artifact.

The stereo-controlled syntheses of the Nuphar alkaloids (-)-anhydronupharamine (24) and (-)-nuphenine (25) were made in eleven steps (28). The configurations and conformations of the intermediates were monitored by ^1H and ^{13}C nmr. The ^{13}C nmr assignments were reported earlier (29). See Figure 5.

Figure 5(a)



(-)-Anhydronupharamine 24

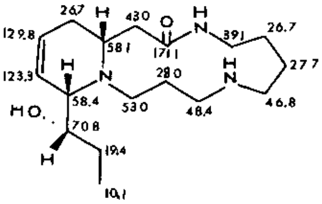


(-)-Nuphenine 25

(a) In deuteriochloroform; TMS was used as internal standard.

The absolute configuration of palustrine (26) derived from Equisetum palustra, was determined by examination of the ^1H and ^{13}C nmr data of the four diastereomeric methyl esters of (±)-dihydropalustramic acid (30). See Figure 6.

Figure 6(a)

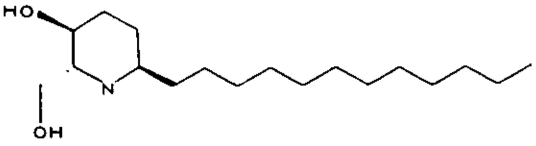


26 Palustrine

(a) In deuteriobenzene.

The piperidine alkaloids, prosopinine (27), isoprosopine A (28), isoprosopine B (29), prosopine (30), and cassinine (31) from <u>Prosopis africana</u> were characterized by ^{13}C nmr, cf. (31) pp. 148-156. See Table 4.

Table 4

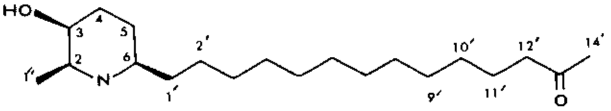


27 10'-oxo

28 7'-oxo

29 8'-oxo

30 11'-hydroxy



31

Table 4 (Continued)

Carbon	27 (a)	28 (a)	29 (a)	30 (b)	31 (a)
2	57.9	57.7	57.7	57.6	55.4
3	67.9	67.9	67.9	67.5 (c)	67.7
4	27.2	27.2	27.2	26.0	32.0
5	28.4	28.4	28.4	27.5	26.1 (c)
6	50.0	50.0	50.0	50.4	57.0
1"	62.2	62.3	62.3	61.4	18.7
1'	33.3	32.5	32.5	31.8	37.0
2'	26.3	26.2	26.2	26.0	25.7 (c)
3'	29.3	29.2	29.2	29.2	29.4
4'	29.3	29.2	29.2	29.2	29.4
5'	29.3	23.7	29.2	29.2	29.4
6'	29.3	42.5	23.7	29.2	29.4
7'	29.3	(d)	42.5	29.2	29.4
8'	23.9	42.5	(d)	29.2	29.4
9'	42.3	23.7	42.5	25.4	29.4
10'	(d)	31.3	26.2	38.8	29.4
11'	35.7	22.2	22.2	67.0 (c)	23.7
12'	7.9	13.7	13.7	27.7	43.8
13'					(d)
14'					29.4

(a) In deuteriochloroform.

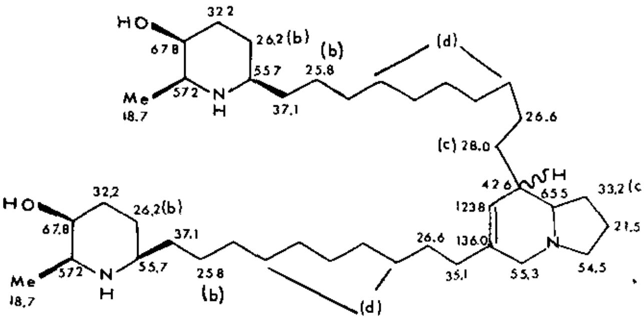
(b) In deuteriochloroform/methanol, 2:1.

(c) Interchangable assignments.

(d) Shift not reported.

A structure for the new alkaloid juliprosopine (32), isolated from Prosopis juliflora, has been proposed on the basis of spectroscopic data including ^{13}C nmr (32). See Figure 7.

Figure 7(a)



32

(a) In deuteriochloroform; TMS used as internal standard.

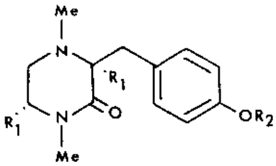
(b)(c) Reversible assignments.

(d) Shifts between 29.4 and 30.0 ppm.

4. Piperazine Alkaloids

The ^{13}C nmr spectra of two piperazine fungal metabolites (33 and 34) were reported (33). The shift assignments were not reported. See Figure 8.

Figure 8



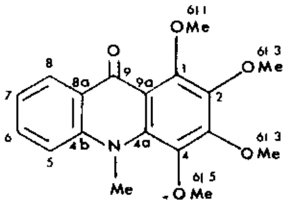
33 R_1 = SMe, R_2 = H

34 R_1 = SMe, R_2 = γγ-dimethylallyl

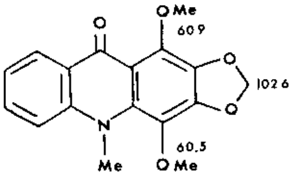
5. Acridone and Carbazole Alkaloids

The ^{13}C nmr shift assignments for melicopicine (35), melicopidine (36), and melicopine (37) derived from Melicope faraena have been given (34). See Table 5.

Table 5 (a)



35



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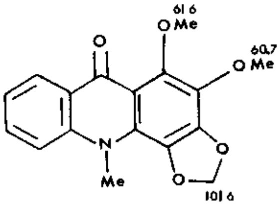

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Table 5(a) (Continued)

	1	2	3	4	4a	4b	5	6
35	149.1	136.8 (b)	152.1	141.4 (b)	138.8 (b)	144.5	116.4	133.2
36	137.2	135.1	145.0	128.9	136.5	144.2	116.4	132.7
37	142.4	130.9	148.6	120.7	133.1	143.4	114.8	133.2

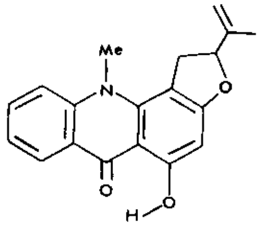
	7	8	8a	9	9a	N-CH_3
35	121.1	125.8	123.3	175.9	115.1	41.5
36	121.1	125.6	123.4	175.8	113.9	41.6
37	120.8	126.3	122.4	175.3	112.7	37.2

(a) In DMSO-d_6.

(b) Ambiguous assignments.

The ^{13}C nmr assignments were made from the acridone alkaloids isolated from <u>Ruta graveolens</u>, arborinine (38), gravacridondiol (39), gravacridontriol (40), isogravacridonchlorin (41), rutacridone (42), and two of their glucosides (35). See Table 6.

Table 6



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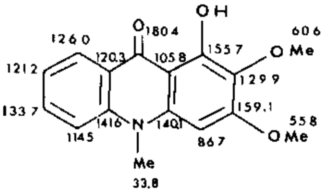

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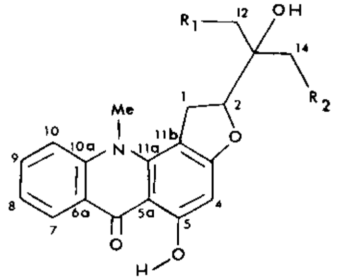


39 R_1 = H, R_2 = OH

40 R_1 = R_2 = OH

41 R_1 = H, R_2 = Cl

	1	2	3a	4	5	5a	6	6a
39	37.7	86.3	167.4	91.5	164.9	105.0	179.9	120.0
40	37.7	84.5	167.2	91.6	164.9	105.1	179.9	120.0
41	37.7	86.0	167.0	91.6	165.0	105.1	180.0	120.0
42	37.6	85.8	166.8	91.6	165.3	105.3	180.0	120.0

Table 6 (Continued)

	7	8	9	10	10a	11a	11b	12
39	125.2	121.4	134.1	115.7	142.1	143.1	101.4	20.6
40	125.2	121.3	134.1	115.7	142.1	143.1	101.6	62.2 (b)
41	125.2	121.4	134.2	115.8	142.1	143.1	101.1	20.9
42	125.3	121.6	134.3	115.8	142.2	143.1	100.7	112.4

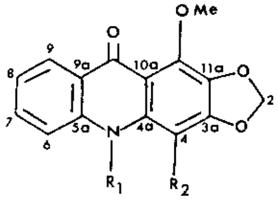
	13	14	$N-CH_3$
39	72.7	65.9	31.4
40	74.7	61.8 (b)	31.2
41	72.3	49.9	31.5
42	143.4	16.9	35.9

(a) Deuteriochloroform was solvent and reference.

(b) Ambiguous assignments.

The ^{13}C nmr assignments were made for the acridone alkaloids, xanthevodine (43) (from *Evodia xanthoxyloides*), melicopidine (36), and evoxanthine (44) (from *Evodia xanthoxyloides*). See Table 7. The assignments were also made for the pyrido[4,3-*b*]carbazole alkaloids, ellipticine (45) (from *Ochrosia elliptica*) and olivicine (46) (from *Aspidosperma olivaceum*) (36). See Table 8.

Table 7(a)



34 R_1 = H, R_2 = OMe
27 R_1 = Me, R_2 = OMe
35 R_1 = Me, R_2 = H

	2	3a	4	4a	5a	6	7
43	102.9	141.8	126.2	134.7	140.1	117.5	133.2
36	102.2	145.1	128.9	137.1	144.5	115.6	132.6
44	102.0	154.6	90.1	143.2	142.8	115.0	133.4

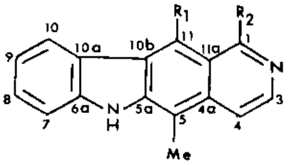
Table 7(a) (Continued)

	8	9	9a	10	10a	11	11-OMe
43	122.2	126.5	122.2	178.3	110.8	137.3	60.5
36	121.3	126.7	124.3	177.4	114.4	138.3	60.8
44	121.8	127.3	123.7	177.8	111.6	141.8	60.8

	R_1	R_2
43		61.4
36	41.9	61.4
44	35.4	

(a) The spectra were recorded in solvents indicated: 36, deuteriochloroform; 43 and 44, deuteriochloroform:methanol-d_4 (1:1).

Table 8(a)



36 R_1 = Me, R_2 = H

37 R_1 = H, R_2 = Me

	1	3	4	4a	5	5a	6a	7	8
45	152.9	140.9	115.8	132.3	107.9	140.4	142.6	110.5	127.0
46	114.7	140.7	115.3	132.3	110.8	140.4	142.5	110.8	127.4

	9	10	10a	10b	11	11a	5-Me	R_1	R_2
45	119.1	123.6	123.3 (b)	121.9	123.0 (b)	123.3 (b)	11.8	14.2	
46	119.0	121.3	122.7	121.8	158.6	124.7	12.3		22.9

(a) In DMSO-d_6.

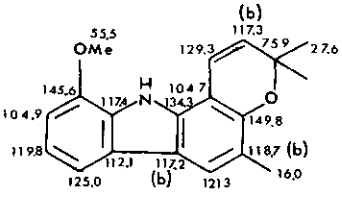
(b) Ambiguous assignments.

The ^{13}C nmr spectral assignments of the carbazole alkaloid mupamine (47) and several related compounds have been made (37). See Figure 9.

Figure 9 (a)

(a) In deuteriochloroform.

(b) Ambiguous assignments.



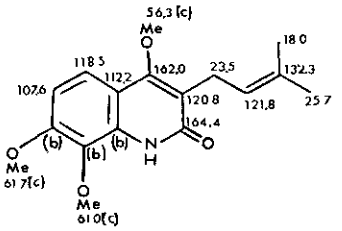
47

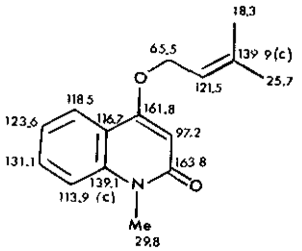
6. Quinoline Alkaloids

The ^{13}C nmr shift assignments of the sixteen quinoline alkaloids, preskimmianine (48), ravenine (49), ravenoline (50), orixine (51), balfourolone (52), lunacridine (53), isoplatydesmine (54), balfourodine (55), ribalinine (56), araliopsine (57), pseudoribalinine (58), lemobiline (59), skimmianine (60), dictamnine (61), evoxine (62), and choisyine (63), were made by comparison with those of ten related compounds. All spectra were determined on synthetic samples. The syntheses were published previously (38). See Figure 10.

Figure 10(a)

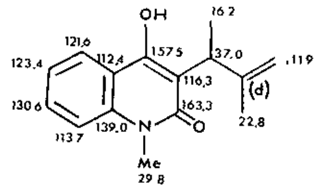
48

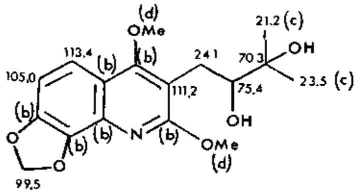




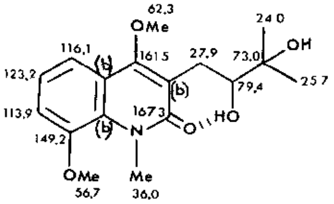
49

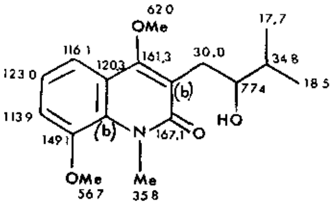
50





51



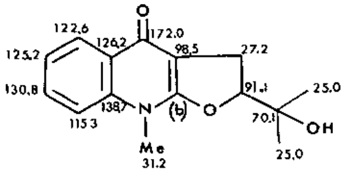


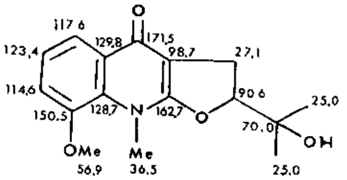
52

53

Figure 10 (a) (Continued)

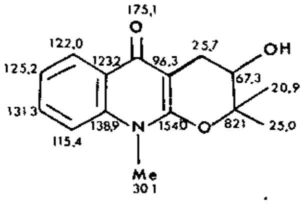
54 (e)

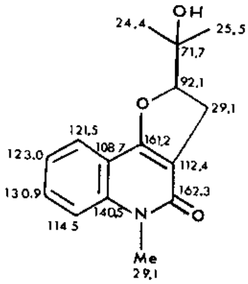




55 (e)

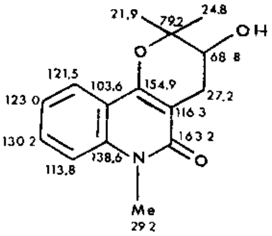
56

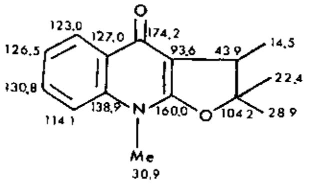




57

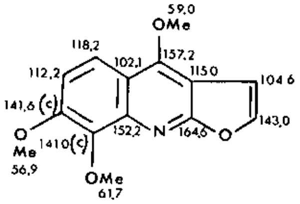
58

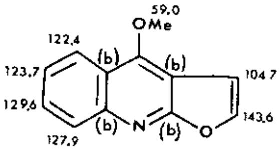




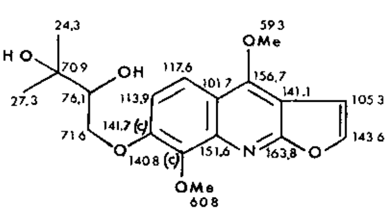
59

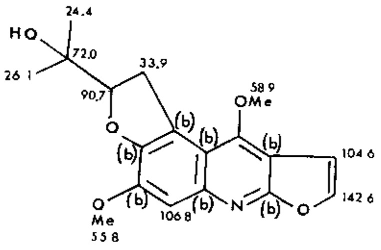
60





61





62 (e)

63

(a) All spectra were from deuteriochloroform solutions except those otherwise noted.

(b) Signal not detected.

(c) Interchangable assignments.

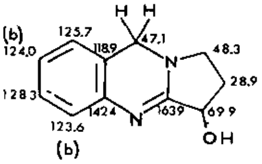
(d) Shift not reported.

(e) In DMSO-d_6.

7. Quinazoline Alkaloids

Vasicine or peganine (64) (isolated from *Adhatoda vasica*) and some synthesized derivatives were characterized by ^{13}C nmr (39). See Figure 11.

Figure 11(a)



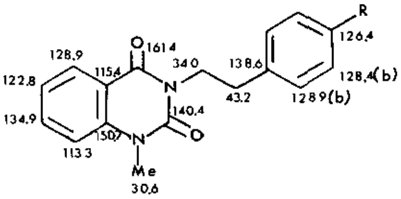
64

(a) In deuteriochloroform.

(b) Ambiguous assignments.

Two new quinazolone alkaloids, (65) and (66), were isolated from *Zanthoxylum arborescens*. The structures were confirmed by synthesis (40). See Figure 12.

Figure 12 (a)



65 R = H

66 R = OCH_3

Assignments given for 65.

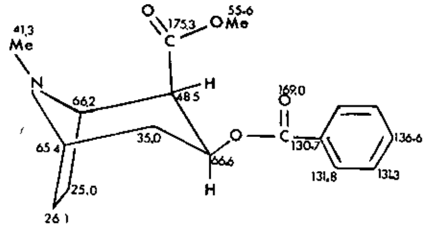
(a) Solvent not reported.

(b) Ambiguous assignments.

8. Tropane Alkaloids

The ^{13}C nmr assignments of cocaine (67), its metabolites and their derivatives have been reported (41). The assignments for cocaine reported earlier were not in agreement (42). See Figure 13.

Figure 13(a)

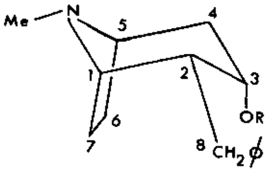


67

(a) Hydrochloride salt in deuterium oxide.

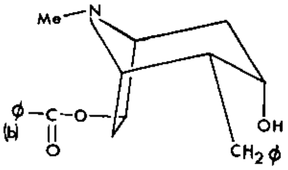
The stereostructures of five tropane alkaloids, (68), (69), (70), (71), and (72), from Knightia deplanchei were elucidated by ^{13}C nmr, cf. (31) pp. 139-147. See Table 9. The gross structures of some of them had been previously elucidated (43). A review of a few alkaloid ^{13}C nmr studies was also reported by the same source.

Table 9(a)



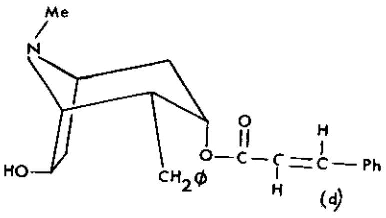
68 R = -COϕ (b)

69 R = $-COCH_3$ (c)

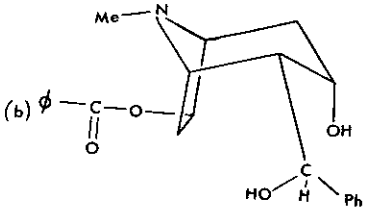


70

Table 9 (Continued)



71



72

Carbon	**68**	**69**	**70**	**71**	**72**
1	63.2	63.3	64.2	70.7	62.5
2	45.8	45.4	44.9	38.6	49.4
3	69.7	69.3	65.4	69.3	64.6
4	37.0	37.0	36.9	31.0	36.0
5	59.6	59.8	66.5	58.3	66.3
6	25.3	25.3	80.5	40.9	80.3
7	21.9	21.6	32.2	72.8	33.1
8 (e)	35.2	35.1	35.2	35.0	74.2
i-C	139.0	139.2	140.0	138.9	142.7
o-C	127.9	128.1	128.1	127.9	126.4
m-C	128.7	128.7	128.8	128.7	128.4
p-C	125.7	125.8	125.7	126.0	127.8
N-Me	40.3	40.4	40.6	36.7	40.3

(a) In deuteriochloroform.

(b) All benzoyl shifts are reported as being: carbonyl 165.8 ± .4 ppm, ipso-C 130.3 ± .2 ppm, ortho-C 129.2 ± .1 ppm, meta-C 128.1 ± .1 ppm, and para-C 132.7 ± .2 ppm.

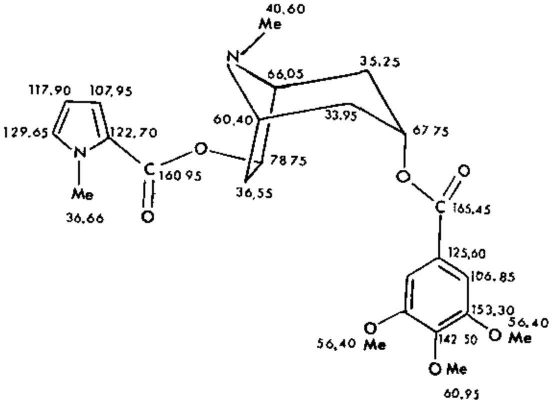
(c) The acetyl shifts were not reported.

(d) The cinnamate shifts are as follows: carbonyl 165.6, α 118.0, β 144.8, ipso 134.0, ortho 128.7, meta 128.3, and para 130.2 ppm.

(e) 8, i-C, o-C, m-C, and p-C refer to the benzyl groups present in all five of the these alkaloids.

Three new tropane alkaloids, catuabine A, B, and C were isolated from Erythroxylum vaccinifolium. A complete interpretation of the ^{13}C nmr spectrum of catuabine A (**73**), including determination of configuration, was given (44). See Figure 14.

Figure 14(a)



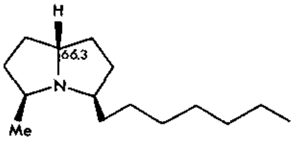
73

(a) In deuteriochloroform.

9. Pyrrolizidine Alkaloids

(5Z,8E)-3-Heptyl-5-methylpyrrolizidine (74), a presumed venomous constituent from the cryptic thief ant Solenopis sp. near tennesseensis, was isolated and characterized by ^{1}H and ^{13}C nmr (45). See Figure 15. The configuration and structure were confirmed by synthesis.

Figure 15(a)

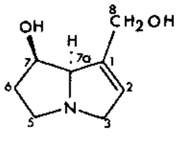


74

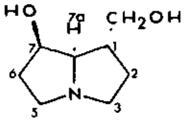
(a) Solvent not reported.

The ^{13}C nmr assignments have been made for the pyrrolizidine alkaloids, retronecine (75), platynecine (76), heliotrine (77), supinine (78), europine N-oxide (79), lasiocarpine (80), crispatine (81), monocrotaline (82), maduresine (83), and retrorsine (84), belonging to the families Boraginaceae, Compositae, Crotolaria, Leguminosae, and Apocynaceae (46-48). Mody et al. (46) disputed the previously made assignments for 79 (48) and for 84 (47). A new pyrrolizidine alkaloid, senecionine (85) has been isolated from Senecio nemorensis and characterized by ^1H and ^{13}C nmr (49). See Table 10.

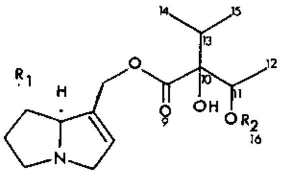
Table 10(a)



75

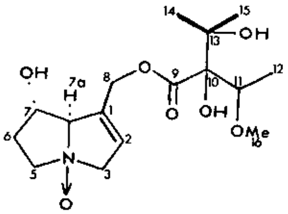


76

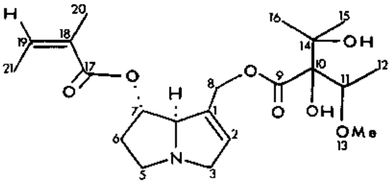


77 R_1 = OH, R_2 = Me

78 R_1 = R_2 = H

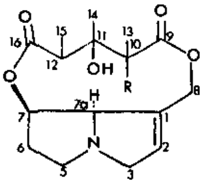


79



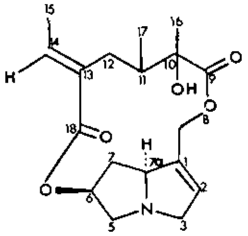
80

Table 10 (Continued)

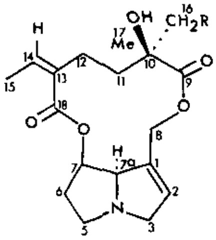


81 R = H

82 R = OH



83



84 R = OH

85 R = H

	1	2	3	5	6	7	7a	8
75	137.9	127.1	58.7	54.2	35.3	71.1	79.5	61.9 (46)
76	45.8	30.4	57.2	55.6	38.3	75.0	73.1	63.4 (46)
77	136.4	127.4	62.0 (c)	54.2	34.3	75.6	78.6	62.8 (c) (46)
78	137.9	125.6	61.9 (c)	56.9	25.9	30.2	69.3	62.4 (c) (46)
79	132.2	124.4	68.6	61.9	33.6	97.1 (e)	72.3	77.9 (e) (48)
80	135.0	128.6	62.3	54.3	30.5	76.9	78.9	62.3 (46)
81	132.9	135.5	60.9	53.2	33.6	76.3	75.3	61.3 (46)

Table 10 (Continued)

82	132.8	134.3	60.4	53.7	33.5	76.7	75.0	61.3 (46)
83	129.9	136.1	59.3	66.4	74.7	73.7 (c)	75.2	61.5 (46)
84	132.4	134.7	34.7 (e)	52.9	37.9	77.4	75.0	66.9 (e) (47)
84	132.4	134.7	61.0 (e)	52.9	37.9	77.4	75.0	62.7 (e) (46)
85	131.7	135.9	59.9	52.9	34.6	77.5	74.7	62.7 (49)

	9	10	11	12	13	14	15	16
77	175.1	82.6	80.1	12.5	31.8	17.1 (d)	16.4 (d)	57.0 (46)
78	175.2	83.1	71.5	17.3 (d)	33.1	17.1 (d)	17.0 (d)	(46)
79	174.4	86.1	79.7	13.5	74.3	26.4	25.7	57.1 (48)
80	173.9	83.8	78.9	13.0	56.5	73.0	24.6 (c)	26.5 (c) (46)
81	175.6 (c)	37.6	76.3	48.1	27.1	18.4	11.3	174.4 (c) (46)
82	173.5 (c)	78.7	76.8	44.2	22.0	17.7	13.6	174.1 (c) (46)
83	176.9	76.3	40.5	27.6	135.6	142.5	15.0	24.6 (46)
84	175.7	81.3	35.7	61.0 (e)	131.2	136.6	14.9	62.2 (e) (47)
84	175.7	81.3	35.7	34.7 (e)	131.2	136.6	14.9	66.9 (e) (46)
85	177.3	76.6	37.3	38.3	133.2	133.7	14.9	24.9 (49)

	17	18	19	20	21
80	167.8	127.7	138.5	20:5	15.9 (46)
83	10.8	167.0 (46)			
84	11.6	167.3 (47)			
84	11.6	167.3 (46)			
85	10.9	167.4 (49)			

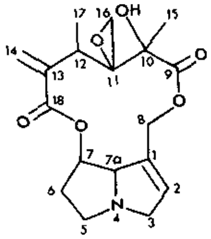
(a) The spectra for 76 and 79 (ref. 46 and 48) were taken in deuterium oxide, all others were taken in deteriochloroform. TMS was the internal standard.

(c)(d) Interchangeable assignments.

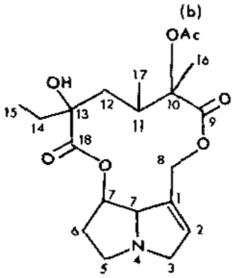
(e) Disputed assignments.

Drewes et al. (50) reported the ^{13}C nmr shifts of the Senecio alkaloids retrorsine (84), retronecine (75), swazine (86), isoline (87), and hygrophylline (88). They also disputed the assignments of retrorscine (84) made by Casal et al. (47) differing at nine positions, i.e. C-1, C-2, C-3, C-6, C-8, C-12, C-13, C-14, and C-16. See Table 11.

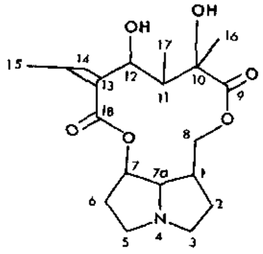
Table 11(a)



86



87



88

Carbon	**84** (c)	**75** (c)	**86**	**87**	**88**
1	131.1	138.0	131.8	131.6	41.9
2	136.5	127.1	136.6	135.7	29.8
3	60.8	58.7	61.2	60.6	54.4
5	52.8	54.1	53.1	53.2	52.2
6	34.5	35.1	34.1	34.6	35.3
7	75.3	71.1	75.9	76.9	73.5
7a	77.3	79.5	77.6	77.5	75.4
8	62.7	61.9	62.6	63.3	65.2
9	175.4	---	176.6	176.1	178.2
10	81.3	---	77.4	83.6	78.1
11	35.5	---	79.4	37.3	40.7
12	37.8	---	35.6	39.6	70.0
13	132.3	---	143.1	78.8	133.5
14	134.4	---	122.0	33.3	135.1
15	14.8	---	21.9	7.4	15.6
16	66.8	---	41.7	14.9	25.7
17	11.4	---	16.9	15.9	5.9
18	167.2	---	168.1	172.1	167.6

(a) All spectra in deuteriochloroform.

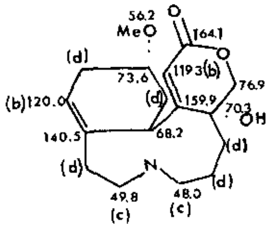
(b) Acetyl carbonyl shift not reported; acetyl methyl 21.4 ppm.

(c) Refer to Table 10 for structure.

10. Pyrrolo[1,2-a]azepine Alkaloids

Phellibilidine (**89**), an alkaloid isolated from Phelline billiardieri has been given ^{13}C nmr shift assignments (51). See Figure 16.

Figure 16(a)



89

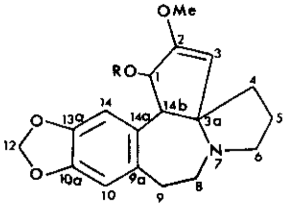
(a) In deuteriochloroform.

(b)(c) Ambiguous assignments.

(d) Ambiguous assignments: 35.5, 32.4, 28.2 and 21.0 ppm. Four signals were listed for five carbons.

The ^{13}C nmr shift assignments have been made for the naturally occurring <u>Cephalotaxus</u> alkaloids, cephalotaxine (90), acetylcephalotaxine (91), harringtonine (92), isoharringtonine (93), drupacine (94), and cephalotaxinone (95a) (52). See Table 12.

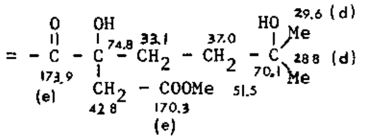
Table 12(a)



90 R = - H

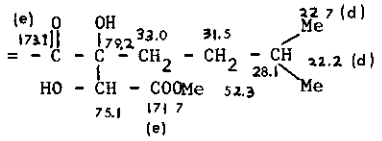
91 R = - COMe (b)

92 R =

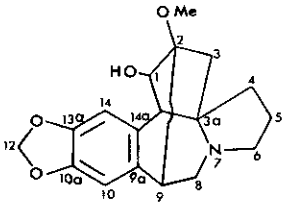


$$R = -\overset{\overset{O}{\|}}{C}-\overset{\overset{OH}{|}}{\underset{\underset{CH_2-COOMe}{|}}{C}}-CH_2-CH_2-\overset{\overset{HO}{|}}{C}(Me)_2$$

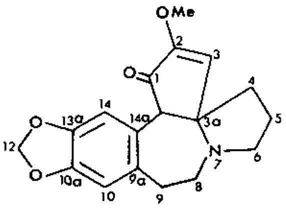
93 R =



$$R = -\overset{\overset{O}{\|}}{C}-\overset{\overset{OH}{|}}{\underset{\underset{HO-CH-COOMe}{|}}{C}}-CH_2-CH_2-CH(Me)_2$$



94



95a

Table 12 (a) (Continued)

Carbon	90	91	92	93	94	95
1	73.2	74.8	74.8	74.8	73.6	200.8
2	160.5	157.6	157.6	157.6	108.6	158.3
3	97.6	100.5	100.9	100.7	35.7	123.9
3a	70.5	70.6	70.7	70.6	65.2	65.4
4	43.6	43.5	43.5	43.5	43.4	39.0
5	20.3	20.4	20.5	20.4	22.4	20.1
6	53.8	53.9	53.9	53.9	52.1	52.9
8	48.5	48.5	48.6	48.5	56.6	47.6
9	31.7	31.7	31.5	31.5	78.3	31.4
9a	128.2	128.7	128.5	128.5	130.2	128.6
10	110.2	109.5	109.8	110.0	107.7	110.3
10a	146.0 (c)	146.0 (c)	146.0 (c)	145.8 (c)	146.5 (c)	146.3 (c)
12	100.8	100.8	100.9	100.9	101.3	101.1
13a	146.8 (c)	146.7 (c)	146.8 (c)	146.7 (c)	147.8 (c)	147.3 (c)
14	112.6	109.5	112.8	112.7	111.9	112.5
14a	134.3	133.9	133.4	133.6	131.2	130.7
14b	57.1	57.3	57.3	57.1	59.7	60.8
$-OCH_3$	58.1	56.9	56.2	56.1	53.9	57.3

(a) All in deuteriochloroform

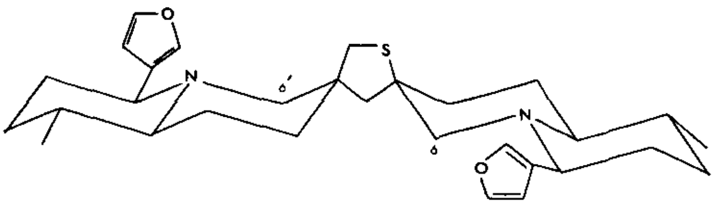
(b) Shifts not reported.

(c)(d)(e)Interchangeable assignments.

11. Quinolizidine Alkaloids

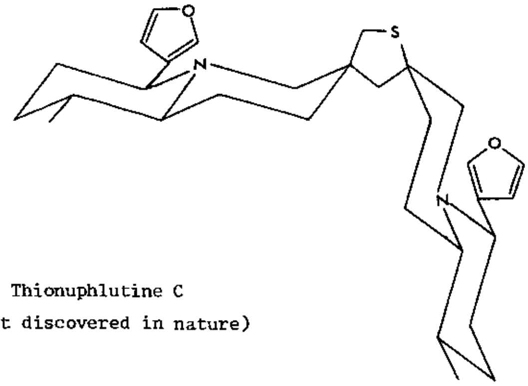
In continuing their studies of the sulfoxides of the *Nuphar* thiaspirane alkaloids, LaLonde and Wong used the ^{13}C nmr assignments of C-6 to determine the configuration of the sulfoxide oxygen. This included making transformations of configuration and selective deuteration at C-6 and at both C-6 and C-6' (53). See Figure 17.

Figure 17

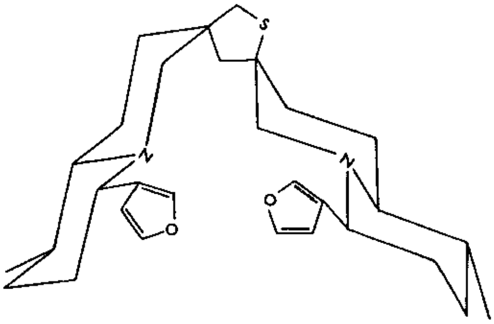


95b Neothiobinupharidine

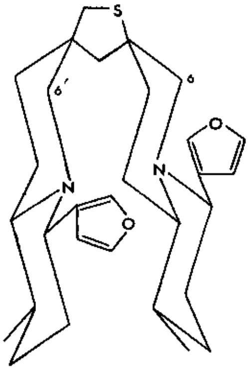
Figure 17 (Continued)



96 Thionuphlutine C
(not discovered in nature)



98 Thionuphlutine B



97 Thiobinupharidine

A review of ^{13}C nmr spectroscopy of quinolizidine derivatives, including alkaloids, has been made covering the literature prior to 1978 (54).

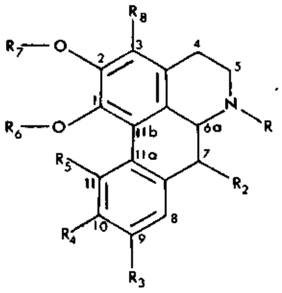
12. Isoquinoline Alkaloids

A. Aporphine and Benzylisoquinoline Alkaloids

^{13}C nmr shift assignments of aporphine and benzylisoquinoline alkaloids (from Papaveraceae, Anonaceae, Lauraceae, and the Monimaceae) have been made for the following compounds: apoglaziovine (99), asimilobine (100), boldine (101), caaverine (102), corydine methiodide (103), dicentrine (104), domesticine (105), dugetine (106), glaucine (107), isoboldine (109), isocorydine (110), isochondodendrine (111), laudanosine (112), laurifoline chloride (113), leucoxine (114), lirionidine (115), magnoflorine iodide (116), O-methylmoscatoline (117)(a), nantenine (118), norglaucine (119), nuciferine (120), nuciferoline (121), ocoteine (122), oliveridine (123), oliverine (124), oliveroline (125), oxoglaucine (126)(a), pachypodanthine (127), papaveraldine (128), papaverine (129), predicentrine (130), thaliporphine (131), and xantoplanine iodide (132), (55-60). Assignments have been reported previously for glaucine (107), isocorydine (110), laudanosine (112), nantenine (118), and nuciferine (120)(61), as well as for domesticine (105)(62). See Table 13 for the aporphine alkaloids and Table 14 for the bisbenzylisoquinolines, 112, 128 and 129. See Figure 18 for 111.

The oxidation products of tetrahydropapaveroline, an alkaloid isolated from the urine of Parkinson's disease patients fed l-dopa, have been characterized by ^{13}C nmr (63).

Table 13(a)



58-87, 89-91

Compd. No.	Reference	Solvent	R_1	R_2	R_3
99	56	DMSO	Me (43.5)	H_2	H
100	56	DMSO	H	H_2	H
101	55	deuteriochloroform	Me (44.0)	H_2	-OH
101	58	deuteriochloroform	Me (b)	H_2	-OH
102	56	DMSO	H	H_2	H

Table 13 (Continued)

103	55	DMSO-d_6	Me (53.0) (43.0)	H_2	H
104	55	deuteriochloroform	Me (44.0)	H_2	OMe (b)
104	56	DMSO	Me (43.5)	H_2	-OMe (55.4)(c)
105	55	DMSO-d_6	Me (43.9)	H_2	9-O-CH_2O-10 (b)
106	56	DMSO	Me (39.9), HCl	H,OH	-OMe (c)
107	55	deuteriochloroform	Me (43.4)	H_2	-OMe (55.6) (c)
108	55	deuteriochloroform	Me (39.0)	H_2	H
109	55	DMSO-d_6	Me (43.8)	H_2	OH
109	56	DMSO	Me (43.6)	H_2	OH
110	55	deuteriochloroform	Me (43.6)	H_2	H
113	58	deuteriochloroform	(42.6)		
		+ methanol	Me (53.4)	H	OH
114 (d)	56	DMSO	Me (43.5)	H_2	O-Me (60.2)
115	56	DMSO	Me (43.6)	H_2	H
116	58	deuteriochloroform	Me (43.4)		
		+ TFA	(54.2)	H_2	H
117	59	deuteriochloroform			
		+ methanol	---	=0	H
118	55	deuteriochloroform	Me (43.6)	H_2	9-OCH_2-0-10 (b)
119	56	DMSO	H, HBr	H_2	O-Me (55.5) (c)
120	55	deuteriochloroform	Me (43.5)	H_2	H
121	56	DMSO	Me (43.5)	H_2	H
122	58	deuteriochloroform	Me (b)	H_2	-OMe (56.0)
123 (e)	55	deuteriochloroform	Me (39.5)	H_2	-OMe (b)
124 (e)	55	deuteriochloroform	Me (40.7)	H_2	-OMe (b)
125 (e)	55	deuteriochloroform	Me (40.6)	H_2	H
126	59	deuteriochloroform			
		+ methanol	---	=0	-OMe (55.8)
127	55	deuteriochloroform	H	H_2	H
130	55	deuteriochloroform	Me (43.8)	H_2	-OMe (b)
131	55	DMSO-d_6	Me (44.0)	H_2	-OMe (b)
132	58	deuteriochloroform			
		+ methanol	Me (43.4)	H_2	-OH

	R_4	R_5	R_6	R_7	R_8
99	H	H	H	-CH_3 (55.7)	H
100	H	H	Me (59.3)	H	H
101	-OCH_3 (b)	H	Me (b)	H	H
101	-OCH_3 (56.1)	H	Me (60.2)	H	H
102	H	H	H	Me (55.8)	H
103	-OCH_3 (b)	-OCH_3 (b)	H	Me (b)	H
104	-OCH_3 (b)	H	1-OCH_2O-2 (b)	1-OCH_2O-2 (b)	H
104	-OCH_3(55.6) (c)	H	1-OCH_2O-2 (100.4)	1-OCH_2O-2 (100.4)	H
105	9-OCH_2O-10 (b)	H	H	-CH_3 (b)	H
106	-OCH_3 (55.6) (c)	H	1-OCH_2O-2 (100.5)	1-OCH_2O-2 (100.5)	H

Table 13 (Continued)

107	-OMe (b)	H	Me (b)	Me (b)	H
108	H	H	1-OCH_2O-2 (b)	1-OCH_2O-2 (b)	-OMe (b)
109	-OMe (b)	H	H	Me (b)	H
109	-Me (55.8)	H	H	Me (55.8)	H
110	H	OH	Me (b)	Me (b)	H
	R_4	R_5	R_6	R_7	R_8
113	-OMe (55.7)	H	H	Me (55.7)	H
114	-OMe (55.6)	H	CH_2 (100.4)	CH_2 (100.4)	H
115	H	H	H	Me (55.8)	H
116	-OMe (55.8)	OH	H	Me (55.8)	H
117	H	H	Me (61.7) (c)	Me (60.9) (c)	-OMe (61.3)(c)
118	9-OCH_2O-10	H	Me (b)	Me (b)	H
119	-OMe (55.8)	H	Me (59.6)	Me (55.5)(c)	H
120	H	H	Me (b)	Me (b)	H
121	OH	H	Me (59.6)	Me (55.5)	H
	R_4	R_5	R_6	R_7	R_8
122	-OMe (55.8)	H	1-OCH_2O-2 (100.4)	1-OCH_2O-2 (100.4)	-OMe (59.3)
123	H	H	1-OCH_2O-2 (b)	1-OCH_2O-2 (b)	H
124	H	H	1-OCH_2O-2 (b)	1-OCH_2O-2 (b)	H
125	H	H	1-OCH_2O-2 (b)	1-OCH_2O-2 (b)	H
126	-OMe (55.8)	H	Me (60.2)	Me (55.8)	H
127	H	H	1-OCH_2O-2 (b)	1-OCH_2O-2 (b)	H
130	-OMe (b)	H	Me (b)	H	H
131	-OMe (b)	H	H	Me (b)	H
132	-OMe (55.8)	H	Me (60.1)	Me (55.8)	H

Compd. No.	1	2	3	3a	4	5	6a	7
99	141.6	146.5	110.2	127.5	28.4	52.8	62.5	33.6
100	143.2	148.9	115.7	126.8	28.5	42.6	53.2	36.9
101	142.0	148.1	113.3	129.9	28.9	53.5	62.5	34.2
101	141.9	147.9	113.2	129.7 (c)	28.8	53.3	62.5	34.1
102	141.6	146.5	110.9	127.3	28.4	42.7	53.2	36.8
103	143.0	149.0	112.1	119.1	23.0	59.9	67.9	29.6
104	141.7	146.6	106.1	126.6	29.2	53.6	62.4	34.3
104	141.2	147.2	106.4	126.2 (c)	28.7	52.9	61.9	33.4
105	141.2	146.6	110.0	123.2	28.6	53.3	62.5	34.0
106	141.1	147.2	106.7	127.7	24.6	50.8	64.6	69.8

Table 13. Continued.

Compd. No.	1	2	3	3a	4	5	6a	7
107	144.2	151.8	110.4	128.8	29.2	53.3	62.5	34.5
108	143.9	134.9	139.5	119.3	17.2	49.3	64.2	69.7
109	140.8	146.5	109.3	123.1	28.6	53.1	62.6	33.9
109	140.6	146.5	109.2	126.7	28.4	52.9	62.4	33.7
110	141.7	150.8	110.8	128.8	29.1	52.4	62.6	35.6
113	142.2	1480	108.0	119.8	23.5	61.5	69.7	28.6
114	141.6	146.0	106.8	126.7 (c)	28.7	52.9	61.7	25.8
115	141.6	146.5	110.3	127.4	28.4	52.9	62.7	34.4
116	140.2	148.8	109.6	120.3 (c)	23.4	61.5	69.7	30.3
117	148.2	147.0	156.2	130.8	118.9	144.3	145.0	182.3
118	144.0	151.4	110.3	128.2	29.0	52.9	62.1	34.9
119	144.3	152.8	111.2	126.4 (c)	24.8	40.8 (c)	51.9	32.3
120	144.6	151.4	110.9	128.1	28.9	52.8	61.9	34.8
121	144.3	151.3	111.6	127.7	28.7	52.5	62.3	33.5
122	143.2	134.8	139.1	119.1	23.6	53.2	62.3	34.1
123	141.6	146.5	106.3	126.9	23.2	49.8	64.3	70.0
124	141.4	146.4	106.5	127.4	25.3	52.0	63.4	81.5
125	142.4	146.8	107.4	127.6	22.8	48.9	64.6	69.8
126	148.9	156.1	105.7	134.8	122.9	144.3	144.9	180.7
127	141.8	146.7	107.9	127.2	29.1	42.7	60.4	83.2
130	142.3	148.2	113.5	129.6	28.7	53.3	62.5	34.2
131	140.7	145.8	108.7	123.9	29.0	53.5	62.7	34.5
132	145.9	153.6	109.8	124.4	24.0	61.5	69.9	28.8

	7a	8	9	10	11	11a	11b	11c
99	126.0	127.9	115.4	155.3	113.2	133.0	119.4	122.9
100	136.3	127.7 (c)	127.5 (c)	127.2 (c)	126.5 (c)	132.1	125.1	129.3
101	130.2	144.2	145.1	145.6	110.1	123.6	126.8	125.9
101	130.1 (c)	114.1	144.9	145.4	110.1	123.5	126.6	125.8
102	135.7	128.1 (c)	128.1 (c)	126.2 (c)	125.9 (c)	132.4	119.7	123.5
103	125.8	123.3	110.6	152.0	144.8	124.2	124.6	120.8
104	128.3	110.5	148.2	147.6	111.2	123.4	116.6	126.4

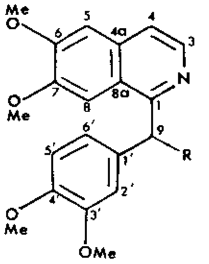
Table 13 (Continued)

Cmpd	7a	8	9	10	11	11a	11b	11c
104	128.3	110.7	148.2	146.0	111.9	122.6	115.8	126.5 (c)
105	130.1	108.2	145.4	145.3	108.8	126.0	119.7	127.2
106	133.4	108.1	148.3	141.6	110.5	123.6	115.8	121.0
107	129.3	110.9	148.0	147.4	111.6	124.4	126.8	127.2
108	138.7	123.6	126.9	126.9	125.7	128.7	110.7	124.1
109	129.2	115.1	148.4 (c)	145.2	113.7	123.6	119.6	126.7
109	129.1	114.9	145.4	145.3	113.6	123.0	119.7	123.5
110	129.6 (c)	118.6	110.7	149.0	143.6	119.8	125.4	129.8 (c)
113	123.7	114.3	145.4	146.2	112.1	122.5	118.2 (c)	118.3 (c)
114	115.6	146.8	135.9	150.8	102.4	125.8	116.0	126.4 (c)
115	135.7	128.1 (c)	127.5 (c)	126.2 (c)	126.0 (c)	132.4	119.2	123.5
116	123.8	120.8	110.9	147.6	140.2	119.2 (c)	118.9	117.7
117	131.4	127.9	128.7	134.1	127.4	134.3	115.4	122.5
118	130.4	107.8	146.0 (c)	145.9 (c)	108.4	125.1	126.4	127.0
119	126.2 (c)	111.6	148.3	147.3	111.6	123.1	125.7	120.8
120	135.9	127.7 (c)	126.7 (c)	126.4 (c)	127.3 (c)	131.6	126.3	127.0
121	126.6	128.4	114.5	155.7	114.0	132.1	125.9	128.6
122	127.4	111.1	147.5	147.5	110.0	123.5	110.4	127.4
123	141.3	109.0	159.1	112.5	127.8	121.4	116.3	122.5
124	139.4	109.3	159.0	112.2	128.0	122.2	116.0	123.5
125	138.8	123.8	127.6	127.8	127.0	128.6	116.5	123.4
126	126.3	109.2	150.2	153.2	109.7	128.7	119.1	121.1
127	136.4	123.1	127.4	127.4	126.7	129.6	114.8	124.7
130	129.2	110.7	148.1	147.6	110.0	124.1	126.3	125.9
131	128.9	110.9	147.6	147.1	112.0	124.8	119.5	127.2
132	123.9	114.5	145.9	146.5	111.4	122.0	127.6	118.4

(a) Compounds 117 and 126 are unsaturated at positions 4, 5, 6 and 6a.

(b) Signal not reported. (c) Ambiguous assignments. (d) OH substituted on C-8. (e) The C-7 substituent and H-6a are *cis*.

Table 14



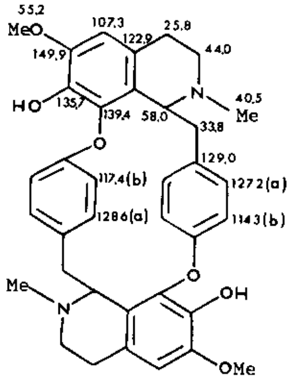
128 R = =O (reference 58)
129 R = H_2 (reference 56)
112 R = H_2 (reference 59)

1, 2, 3, and 4 are saturated and N is methylated in 112

	Papaveraldine (59)	Papaverine (57)	Laudanosine (60)
Carbon	128	129	112
1	153.5	157.4	64.9
3	139.7	140.6	47.1
4	120.9	118.3	25.7
4a	133.6	133.0	126.0 (a)
5	104.6	104.9	113.1 (b)
6	152.9	152.0	148.5 (c)
7	150.7	149.7	147.2 (c)
8	103.8	103.8	111.1 (d)
8a	122.5	122.5	129.5 (a)
9	186.4	42.0	40.7
10	129.6	131.9	132.5
11	111.7	120.1	111.1 (d)
12	148.7	148.6	147.2 (c)
13	153.5	147.0	146.3
14	109.7	110.5	111.1 (c)
15	126.6	111.5	121.8
OMe (12)	55.9	(b)	55.7
OMe (13)	55.9	55.5	55.7
OMe (7)	55.9	(b)	55.7
OMe (6)	55.9	(b)	55.7
N-Me	55.9		42.7

(a) Ambiguous assignments. (b) Signal not reported.

Figure 18

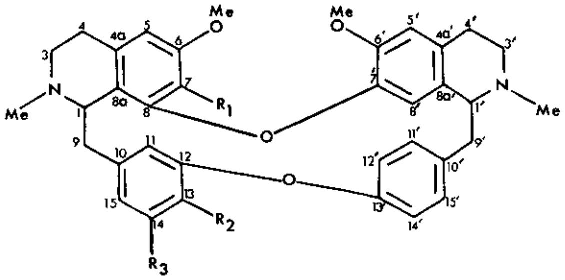


Isochondodendrine (111),(56)

(a)(b) Interchangeable assignments

Four bisbenzylisoquinoline alkaloids of the berbamine type, phaeanthine (133), tenuipine (134), nortenuipine (135), and berbamine (136), were analyzed by ^{13}C nmr to determine conformation (64). The conformation is similar but not the same as that determined by x-ray diffraction. See Table 15.

Table 15



133 $R_1 = R_2 =$ OMe, R_3 = H
134 R_1 = OMe, $R_2 = R_3 = -OCH_2O-$
135 R_1 = OH, $R_2 = R_3 = -OCH_2O-$
136 R_1 = OMe, R_2 = OH, R_3 = H

Table 15 (Continued)

Carbon	**133** (a)	**134** (b)	**135** (a)	**136** (a)
C-1	61.4	61.4	61.5	62.0
C-3	44.1	44.0	44.0	44.7
C-4	22.1	22.0	21.7	23.9
C-4a	128.0 (c)	127.5 (c)	123.0 (d)	129.0
C-5	105.8	105.6	104.7 (c)	105.4
C-6	151.2	151.2	145.6	151.7
C-7	137.9	136.6	134.3	136.8
C-8	148.2	148.3	141.6	147.7
C-8a	123.0	122.4	123.0 (d)	120.1
C-9	41.9	42.2	42.2	37.5
C-10	134.9	136.4	136.5	134.0
C-11	116.2	110.3	110.3	115.3
C-12	146.9	143.1	143.1	143.8
C-13	149.3	133.4	133.3	147.3
C-14	111.6	148.1	148.2	114.6
C-15	122.6	104.5	104.5 (c)	123.5
C-1'	63.9	63.7	63.5	63.4
C-3'	45.3	45.0	45.0	45.2
C-4'	25.3	24.8	25.2	24.8
C-4'a	128.1 (c)	127.9 (c)	128.2 (e)	127.9
C-5'	112.7	112.5	112.8	111.1
C-6'	148.5	148.5	148.6	149.9
C-7'	143.7	143.6	143.3	143.4
C-8'	120.0	120.0	120.4	119.7
C-8'a	127.8 (c)	127.2 (c)	127.7 (e)	126.3
C-9'	38.3	38.2	37.5	38.2
C-10'	134.9	134.9	135.1	134.6
C-11'	129.9 (d)	129.9 (d)	129.9 (f)	130.0 (c)
C-12'	121.7	121.5	121.4	121.2
C-13'	153.6	153.3	153.1	153.9
C-14'	121.7	121.5	121.4	121.4
C-15'	132.4 (d)	132.4 (d)	132.3 (f)	132.0 (c)

Table 15. Continued.

Carbon	133 (a)	134 (b)	135 (a)	136 (a)
R_1	60.1	60.0		60.3
R_2	(g)	101.2	101.2	
R_3		101.2	101.2	
N-Me	42.3 (e)	42.0	42.2	42.6 (d)
N-Me	42.6 (e)	42.0	42.2	42.0 (d)
(C-6)-OMe	55.8	55.5	56.0	55.7
(C-6')-OMe	56.1	55.5	56.0	55.7

(a) In deuteriochloroform

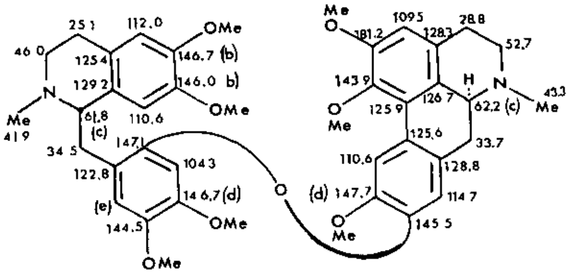
(b) In deuteriochloroform and methanol.

(c-f) Interchangeable assignments.

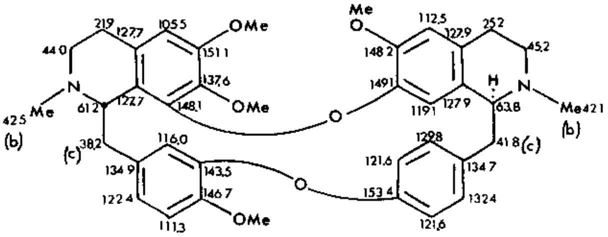
(g) Signal not reported.

^{13}C nmr assignments have been made for the bisbenzylisoquinoline alkaloids, thalicarpine, (137), tetrandine (138), limacine (139), hernandezine (140), thalbrunine (141), thalbrunimine (142), epistephanine (143), hypoepistephanine (144), and panurensine (145). Assignments were also made for sciadenine which is identical to isochondodendrine (111)(65). See Figure 19.

Figure 19(a)

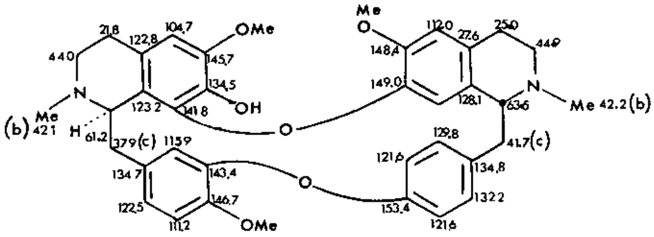


137

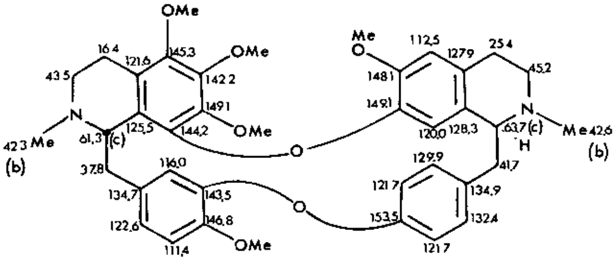


138

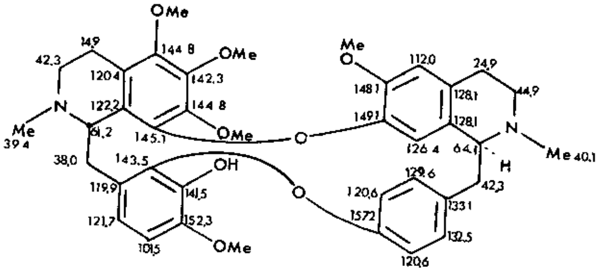
Figure 19 (a) (Continued)



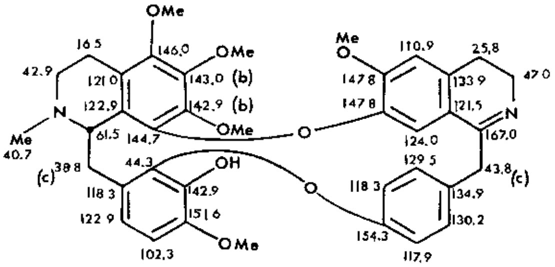
139



140

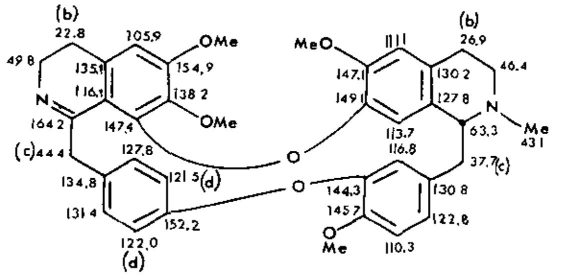


141

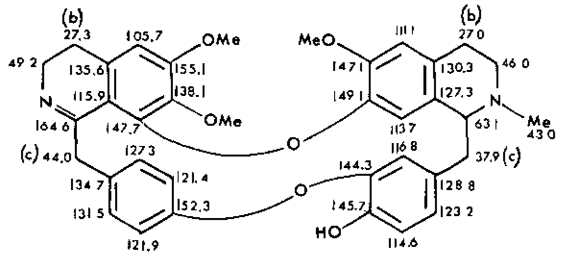


142

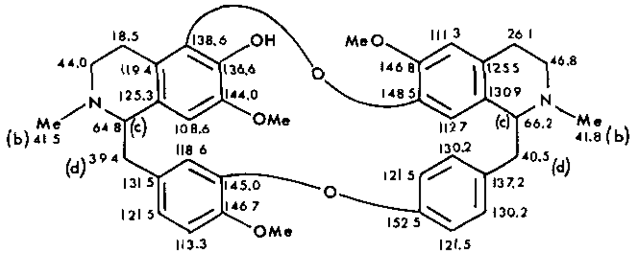
Figure 19 (a) (Continued)



143



144



145

(a) In deuteriochloroform; methoxy carbon signals were not reported.

(b-d) Interchangeable assignments.

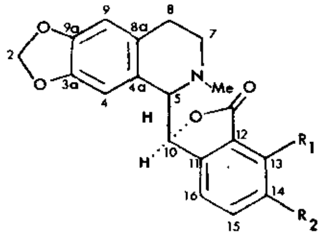
(e) Signal not reported.

B. Protoberberine, Pseudoberberine and Phthalideisoquinoline Alkaloids

The stereochemistry of benzo[a]quinolizidine derivatives was examined by ^{13}C nmr. The shifts of C-6 and C-7 are reliable indicators of conformation. This information can be extrapolated to the analyses of tetrahydroprotoberberines (66).

^{13}C nmr assignments of the alkaloids, β-hydrastine (146), hydrastidine (147), isohydrastidine (148), and (-)-(S)-isocorypalmine (149), isolated from Hydrastis canadensis have been made (67). β-Hydrastine (146) has previously been characterized by ^{13}C nmr (68). (-)-(S)-Isocorypalmine (149) has previously been isolated from species of the Papaveraceae. Hydrastidine (147) and isohydrastidine (148) are new alkaloids. See Table 16.

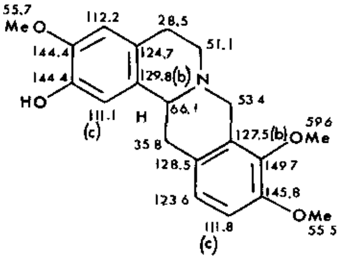
Table 16(a)



146 $R_1=R_2=OMe$
147 $R_1=OH$ $R_2=OMe$
148 $R_1=OMe$ $R_2=OH$

	2	3a	4	4a	5	7	8	8a	9	9a
146	100.5	145.4 (b)	107.4	129.8 (c)	65.7	48.7	26.3	124.1 (c)	108.1	146.4 (b)
147	100.8	145.2 (b)	107.7	130.4 (c)	65.7	49.3	26.9	124.4 (c)	108.4	146.8 (b)
148	100.7	145.5 (b)	107.5	130.1 (c)	66.1	48.7	26.4	124.1 (c)	108.4	146.5 (b)

	10	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*N-Me*	*R_1*	*R_2*
146	82.5	140.4	119.2	147.5	152.1	118.5	117.5	167.3	43.4	61.9	56.5
147	85.0	138.7	(d)	145.8(b)	(d)	118.2	114.0	(d)	45.1	---	56.8
148	*83.3*	*134.0*	*118.0*	*148.8*	*144.5*	*121.3*	*117.8*	*167.6*	*44.6*	*62.9*	---



149

(a) In deuteriochloroform; deuteriochloroform used as shift reference.

(b)(c) Interchangeable assignments.

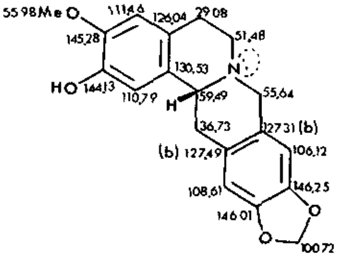
(d) Signal not observed.

Berbanone-like compounds have been synthesized from 6,7-dimethoxy-3,4-dihydroisoquinoline (69). Configurations were examined by ^{13}C nmr.

Protoberberine alkaloids and derivatives were converted into phthalideisoquinoline alkaloids and derivatives. Notably, berberine chloride was converted to (+)-β-hydrastine (70). The synthetic intermediates were analyzed by ^{13}C nmr. The shift assignments of berberine (7) and hydrastine (68) were reported previously.

Four pseudoprotoberberines extracted from Isopyrum thalictroides were reduced with sodium borohydride to tetrahydropseudoprotoberberines. ^{13}C nmr showed that the products have a trans configuration (71). See Figure 20 for one of the products.

Figure 20 (a)



150

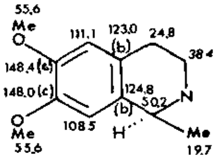
(a) In deuteriochloroform.

(b) Ambiguous assignments.

C. Other Isoquinoline Alkaloids

The ^{13}C nmr assignments of salsolidine (151) (an alkaloid of Salsola arbuscula) have been reported (60). See Figure 21.

Figure 21 (a)



151

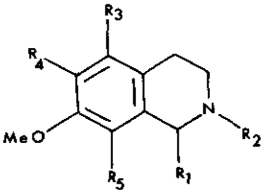
(a) In deuteriochloroform with TMS as reference.

(b) Interchangeable assignments.

(c) Interchangeable assignments.

The tetrahydroisoquinoline alkaloids, nortehuanine (152), tehuanine (153), weberidine (154), heliamine (155), lemairecocerine (156), and oxymethylcorypaline (157) were isolated from Lemaireocerus weberi and given ^{13}C nmr shift assignments (72). Nortehuanine (152), weberidine (154), and lemaireocerine (156) were previously undiscovered. Assignments were also made for carnegine (158). See Table 17. The structures of these alkaloids were confirmed by synthesis. The author (72) disputed the assignments of salsolidine (151) (see Figure 21) made by Singh et al. (60) claiming that they had the assignments of C-1 and C-3 reversed.

Table 17(a)



152-158

	R_1	R2	R_3	R_4	R_5
152	H	H	OCH_3	OCH_3	H
153	H	CH_3	OCH_3	OCH_3	H
154	H	H	H	H	H
155	H	H	H	OCH_3	H
156	H	H	H	H	OCH_3
157	H	CH_3	H	OCH_3	OCH_3
158	CH_3	CH_3	H	OCH_3	H

Table 17 (a) (Continued)

Carbon	152	153	154	155	156	157	158
1	48.0	57.6	48.0	47.3	43.2	52.7	58.4
3	43.4	52.4	43.6	43.3	43.2	57.5	48.7
4	23.0	23.4	27.9	28.0	28.1	29.3	27.4
4a	120.7	119.8	126.4	125.2	129.2	129.7	125.7
5	151.2	150.9	129.7	111.5	123.9	107.0	111.0
6	140.0	140.0	112.0	146.7	110.3	149.7	147.0
7	151.3	151.3	157.2	146.5	144.9	139.7	147.0
8	104.7	104.9	110.4	108.5	149.8	151.6	109.7
8a	131.2	130.2	136.4	127.2	127.5	120.8	131.4
R_1	---	---	---	---	---	---	19.5
R_2	---	45.7	---	---	---	46.1	42.7
R_3	60.1	60.0	---	---	---	---	---
R_4	55.7	55.7	---	55.2	---	60.7	55.7
7-OCH_3	60.1	60.0	54.8	55.2	55.3	(b)	55.7
R_5	---	---	---	---	59.7	60.7	---

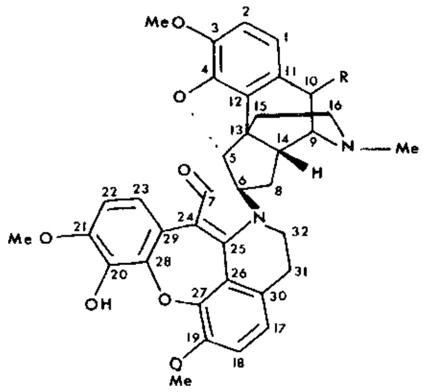
(a) All spectra in deuteriochloroform, TMS was internal standard.

(b) Shift not reported.

Oxychelerythrines and their regioisomeric dimers were synthesized via photocycloaddition (73). They were characterized by ^{13}C nmr.

Cancentrine (159) and 10-oxocancentrine (160), a new alkaloid, (from Dicentra canadensis) were characterized by ^{13}C nmr by comparison to the spectra of codeine alkaloids (74). See Table 18.

Table 18(a)



159 R = H_2

160 R= =O

	1	2	3	4	5	6	7	8	9
159	119.7	115.3	142.7	145.1	97.5	79.1	194.0	40.2	58.8
160	120.2	115.3	146.6	143.3	96.7	78.3	193.2	40.0	68.0

	10	11	12	13	14	15	16	17	18
159	20.4	127.4	127.7	51.4	46.2	33.2	46.6	124.3	116.3
160	196.3	124.4	135.6	52.5	48.9	32.1	47.3	124.2	115.9

	19	20	21	22	23	24	25	26	27
159	149.8	138.0	146.8	109.2	116.6	104.3	160.1	121.4	147.7
160	149.5	137.8	146.6	108.9	115.9	104.3	160.4	121.0	146.8

	28	29	30	31	32	3-OCH_3	19-OCH_3	21-OCH_3	NCH_3
159	140.7	119.7	127.8	29.0	57.8	56.5	56.5	56.5	43.2
160	140.5	119.2	127.5	28.8	57.3	56.3	56.3	56.3	43.3

(a) In deuteriochloroform, TMS was internal standard.

The accepted structure for the reaction product of the alkaloid, cotarnine, with 6-nitropiperonal has been revised on the basis of ^{13}C nmr (75).

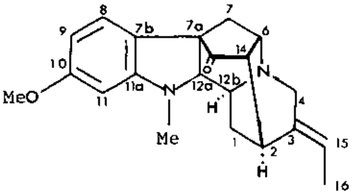
13. Indole Alkaloids

A. Yohimbinoid Alkaloids

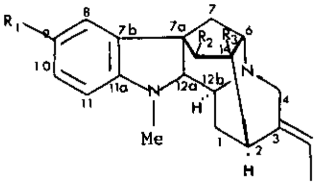
1. Rauwolfia Alkaloids

The ^{13}C nmr assignments of vincamajoreine (161), majoridine (162), vincamajine (163), rauflexine (164), and ajmaline (165) were made. An alkaloid originally called purpeline was originally assigned an incorrect structure. It is now called rauflexine (104) and yields a new alkaloid, reflexine, (also from Rauwolfia reflexa) upon treatment by sodium borohydride, one double bond being hydrogenated (76). See Table 19.

Table 19(a)



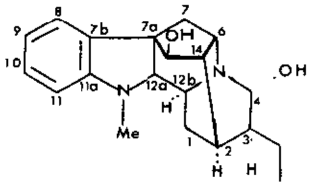
164



161 R_1 = OMe$_3$, R_2 = OH, R_3 = H in 5:1 deuteriochloroform/methanol-d_4

162 R_1 = OMe, R_2 = OAc, R_3 = H in deuteriochloroform

163 R_1 = H, R_2 = OH, R_3 = COOMe in 5:1 deuteriochloroform/methanol-d_4



165 Ajmaline in DMSO-d_6

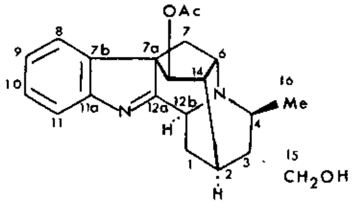
Carbon	161	162	163	164	165
1	29.2	29.4	21.4	31.5	31.6
2	27.9	27.8	29.6	28.5	28.4
3	138.6	139.3	135.6	137.3	42.2
4	54.6	55.2	54.7	55.7	87.6
6	55.8 (b)	55.9 (b)	61.1	53.1 (b)	52.5 (b)
7	34.9	36.1	35.0	35.3	35.3
7a	54.9	53.6	56.5	57.8	55.5
7b	134.4	133.3	129.7	121.6	134.5
8	110.2	110.0	124.2	122.5	123.1
9	153.0	153.0	118.5	103.8	118.5
10	111.4	111.1	127.6	160.1	126.7
11	109.2	109.6	108.4	97.5	109.1
11a	147.7	147.8	153.8	155.1	154.0
12a	79.6	79.6	74.4	78.4	79.4
12b	49.0 (b)	49.3 (b)	52.7	50.1 (b)	44.6 (b)
13	76.0	79.1	73.9	214.0	76.3
14	51.9	50.1	59.6	50.3 (b)	48.7 (b)
15	114.2	114.3	116.1	115.7	25.5
16	12.5	12.8	12.3	12.9	12.3
NMe	34.8	35.1	33.8	34.2	34.3
ArOMe	55.6	55.5		55.3	
C=O, ester		169.9	172.8		
Me		21.1	51.1		

(a) In deuteriochloroform.

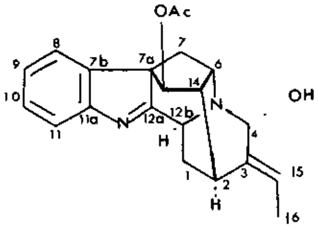
(b) Ambiguous assignments.

New Rauwolfia alkaloids of New Caledonia, raucaffrinoline (166) and vomilenine (167) have been structurally identified and characterized by ^{13}C nmr (77). See Table 20.

Table 20(a)



166



167

	1	2	3	4	6	7	7a	7b	8	9	10	11	11a	12a	12b	13	14	15	16	C=O(Ac)	CH_3(Ac)
166	21.7	26.6	45.7	53.2 (b)	51.2 (b)	37.5	65.0	136.5	123.8	125.4	128.6	120.9	156.5	183.6	57.2	78.2	49.7 (b)	61.7	18.3	169.9	(c)
167	26.3	28.2	131.0	119.4	50.9 (b)	36.4	65.1	136.1	123.9	125.8	128.9	121.1	156.3	183.6	54.3 (b)	77.5	49.0 (b)	131.0	82.5	169.7	21.1

(a) In deuteriochloroform.

(b) Ambiguous assignments.

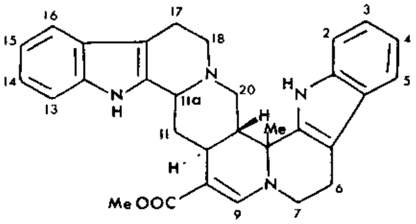
(c) Signal not reported.

2. Other Yohimbinoid Alkaloids

Lounasmaa and Hameila have investigated the stereochemical relationships in several indolo[2,3-a]quinolizine derivatives by ^{13}C nmr spectral analysis and selective deuteration (78).

The ^{13}C nmr shifts of roxburghine C (168), D (169), and E (170) have been reported and the configuration confirmed (79). See Table 21.

Table 21



C	168	H-11a α	Me α
D	169	H-11a β	Me α
E	170	H-11a β	Me β

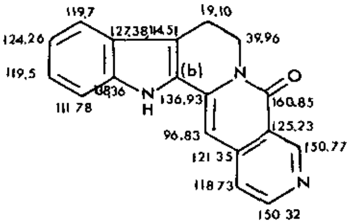
Carbon	C 168	D 169	E 170
1a	137.3 (b)	135.3	137.4 (b)
2	111.9	110.4	112.4
3	122.2	120.4	122.4
4	119.7	118.0	120.0
5	118.8	117.0	118.8
5a	128.1	126.8	128.7
5b	107.7	106.0	107.6
6	22.7 (c)	23.0	23.0
7	50.7	49.9	47.4
9	146.9	144.8	149.1
10	96.2	95.1	105.7
10a	36.1	30.6	29.5
11	35.3	32.9	32.8
11a	60.6	54.0	55.1
11b	136.5 (b)	132.9	132.3
12a	137.4 (b)	135.3	137.7 (b)
13	111.7	110.2	112.2
14	121.1	119.5	122.1
15	119.2	117.5	119.8
16	118.1	116.4	118.7
16a	127.3	125.5	127.7
16b	109.9	108.1	109.7
17	23.3 (c)	17.6	17.5
18	54.0	51.4	52.1
20	57.9	48.1	48.6
20a	50.0	49.4	49.3
20b	58.5	57.7	58.1
20c	137.2 (b)	135.3	137.2 (b)
Me	18.7	18.1	26.9
C=O	167.7	165.4	167.8
-OMe	50.1	49.4	50.8

(a) In deuterioacetone. TMS was used as internal standard. Spectra were also taken in deuteriochloroform for D and E. (b)(c) Interchangeable assignments.

Strictosamide, a yohimbinoid, was shown to be the penultimate biosynthetic percursor of camptothecin, a quinoline alkaloid from Camptotheca acuminata, by incorporation of ^{13}C enriched tryptamine with ^{13}C nmr analysis (80). The shift assignments were not reported.

Nauclefine (171) has been synthesized via a photocyclization synthesis. The ^{13}C nmr shift assignments of 171 and some of its derivatives were reported (81). See Figure 22.

Figure 22(a)



171

(a) In DMSO-d_6.

(b) Signal not reported.

B. Strychnos Alkaloids

Twelve reports dealing with the ^{13}C nmr spectra of strychnine (172) or brucine (173) have been published since 1973 when Wehrli first published his preliminary results (82-93).

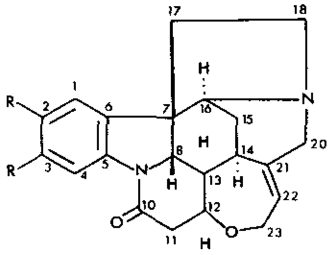
Leung and Jones (86) reported the shift assignments of strychnine (172) and ten derivatives. Their assignment procedure was based upon selective proton decoupling and comparison of the spectra of strychnine and ten of its derivatives.

Verpoorte et al. (87) reported the shift assignments of strychnine, brucine, and thirteen analogous compounds. The analogues were both synthetic derivatives and other strychnos alkaloids. Their assignments were based upon the comparison of the spectra of the fifteen compounds and the assignments of brucine previously made by Wehrli (83). Verpoorte et al. (87) disputed several assignments made by Srinivasan and Lichter (85) and reversed a pair of assignments that Verpoorte had previously made (84).

Wenkert et al. (88) presented a ^{13}C and ^{1}H nmr analysis of strychnine, brucine, Wieland-Gumlich aldehyde, diaboline, hemitoxiferin-I, 10-methoxy-O-demethylsilanine, toxiferine-I, strychnospermine and their derivatives. The data were used to deduce a variety of configurations and conformations.

Apparantly ignorant of the reports which preceded theirs, Singh et al. reported shift assignments of strychnine and brucine (89). Subsequently Verpoorte (91) pointed out the inaccuracy of the assignments of Singh et al. indicating the discrepancy of Singh's assignments with those of the other authors who had published reports on the subject. Later, Martin (93) said that the source of the error, incorrect determination of spin multiplicities from sford spectra, can be avoided in even the most complex spectra by use of the spin-lattice relaxation time (T$_1$) measurements and selective excitation with gated decoupling or single frequency off-resonance decoupling (sesford). Martin illustrated these techniques using the assignment of ^{13}C nmr signals of brucine as an example. See Table 22.

Table 22



172 R = H

173 R = OMe

Cmpd.	172(a)	172(b)	172(b)	172(b)	172(c)	173(b)	173(b)	173(b)	173(b)
ref.	(86)	(87)	(88)	(89)	(92)	(87)	(88)	(89)	(93)
1	124.99	122.3	121.9	124.2	134.5	105.7	105.1	105.6	105.1
2	122.67	124.3	123.8	122.3	141.4	146.2	145.6	146.2	145.4
3	128.61	128.6	128.1	128.6	141.7	149.3	148.5	149.2	148.4
4	116.52	116.2	115.8	116.3	130.2	101.1	100.5	101.1	100.3
5	142.21	142.2	141.8	142.3	147.8	136.0	135.3	136.0	135.3
6	132.91	132.6	132.4	132.7	143.1	123.6	122.9	123.6	122.9
7	52.33	51.9	51.7	52.0	62.4	51.9	51.4	51.8	51.0

Table 22. (Continued)

Cmpd.	172(a)	172(b)	172(b)	172(b)	172(c)	173(b)	173(b)	173(b)	173(b)
ref.	(86)	(87)	(88)	(89)	(92)	(87)	(88)	(89)	(93)
8	60.42	60.1	59.9(d)	60.2	74.5	60.3	59.8(d)	59.9(d)	59.9
10	170.31	169.4	168.8	169.3	182.5	168.9	168.2	168.9	168.0
11	42.46	42.3(d)	42.2	48.2	52.2	42.3	41.8	48.2	41.6
12	77.73	77.5	77.3	77.2	86.2	77.8	77.1	77.3	76.9
13	48.44	48.2	48.0	42.9(d)	56.8	48.3	47.7	42.4	47.4
14	31.83	31.5	31.4	42.5(d)	40.2	31.5	31.1	42.4	30.8
15	26.92	26.8	26.7	31.7	35.3	26.8	26.3	31.6	26.0
16	60.42	60.1	59.8(d)	60.2	71.2	59.9	59.3(d)	60.3(d)	59.1
17	43.05	42.8(d)	42.6	26.9	48.2	42.3	41.9	26.8	41.5
18	50.49	50.2	50.1	52.8	64.4	50.1	49.6	52.6	49.3
20	52.76	52.7	52.4	50.4	63.1	52.7	52.1	50.2	51.8
21	140.04	140.3	140.2	140.5	142.2	140.6	139.8	140.6	139.7
22	128.99	127.7	126.8	127.5	147.0	127.2	126.7	127.1	126.3
23	64.84	64.6	64.3	64.6	75.3	64.6	64.0	64.6	63.7
2-OMe						56.4(d)	56.0(e)	56.1(e)	55.3(d)
3-OMe						56.2(d)	55.7(e)	56.4(e)	55.7(d)

(a) In deuteriochloroform and deuteriomethanol 2:1.

(b) In deuteriochloroform.

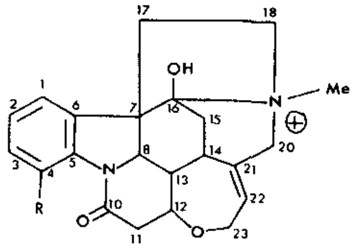
(c) In 70% aqueous perchloric acid.

(d)(e) Assignments reported to be reversible.

The sulfonation of strychnine and some related compounds by sulfur dioxide and manganese dioxide (the Leuchs reaction) was investigated with ^{13}C nmr and pK measurments (92).

Vomicine (174) has been synthesized from strychnine (172) by two methods, each comprising seven steps, each involving icajine (175) as an intermediate (94). See Table 23 for the ^{13}C nmr assignments of 174 and 175.

Table 23(a)



174 R = OH (b)

175 R = H (b)

	1	2	3	4	5	6	7	8	10
174	117.9(c)	127.8	117.8(c)	145.2	126.6	136.6	55.0	60.1	169.2
175	126.3(c)	124.6	128.4(c)	115.8	140.3	133.5	55.1	59.0	167.9

	11	12	13	14	15	16	17	18	20
174	40.7	77.1	47.0	35.3	45.9	192.6	42.8	48.4	62.5
175	41.5	78.0	46.6	35.5	45.8	193.7	43.0	47.7	62.6

	21	22	23	19-Me
174	141.2	130.8	65.4	39.6
175	141.4	130.5	65.5	39.5

(a) In deuteriochloroform and deuteriomethanol 4:1. Spectra also reported for 174 and 175 in deuteriotrifluoracetic acid.

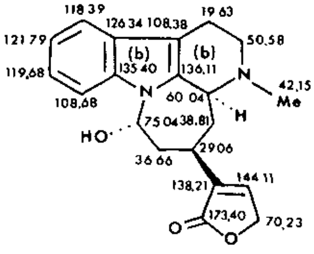
(b) These salts are presumably the iodides since they are prepared with methyl iodide. This publication never mentions which type of salt these compounds are, even the analyses do not report halide in the formulae.

(c) Reversible assignments.

A new corynantheine-type alkaloid, strychnorubigine, was identified in the root bark extract of Strychos rubiginosa D.C.. 11-Methoxydiaboline and normacusine B were also isolated and the ^{13}C nmr spectral data of their O-acetyl derivatives were reported (95).

Two new alkaloids, 10-hydroxyakagerine and akagerinelactone (176), have been isolated from the stem bark of Strychnos decussata (96). See Figure 23 for the reported ^{13}C nmr spectral assignments of 176.

Figure 23(a)



176

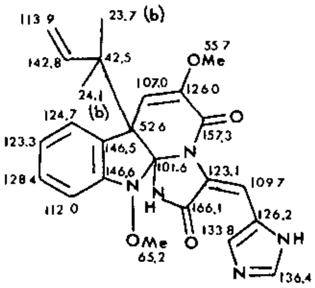
(a) In deuteriochloroform and deuteriomethanol.

(b) Reversible assignments.

C. Penicillium Alkaloids

A new alkaloid, oxaline (177), is the main alkaloid of several strains of Penicillium oxalicum. The ^{13}C nmr spectral assignments and CH coupling constants of 177 and four derivatives have been reported (97). See Figure 24.

Figure 24(a)



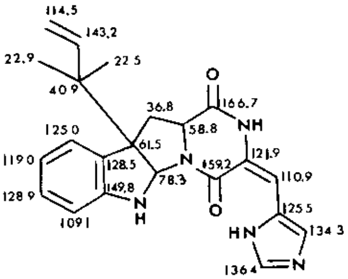
177

(a) In deuteriochloroform.

(b) Ambiguous assignments.

A comparison of nmr data has elucidated the structures of roquefortine (178), an alkaloid isolated from Penicillium roqueforti, and isoroquefortine, a photo-rearrangement product of 178. Feeding experiments with tritium labeled histidine have indicated the biosynthetic removal of the pro-S hydrogen atom from C-3 of histidine in the biosynthesis of 177 and 178 (98). See Figure 25 for the ^{13}C nmr assignments of 178.

Figure 25(a)

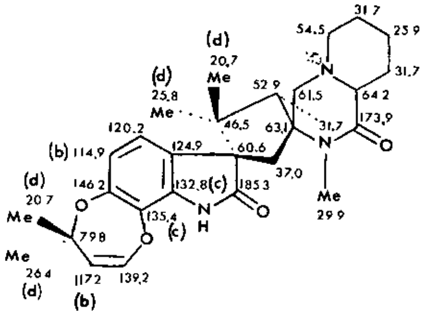


178

(a) Solvent not reported.

The alkaloids, marcfortine A (179), B, and C have been isolated from the B26 strain of Penicillium roqueforti. The structure of 179 was established by ^{13}C nmr and x-ray diffraction (99). See Figure 26 for the ^{13}C nmr assignments of 179.

Figure 26(a)



179

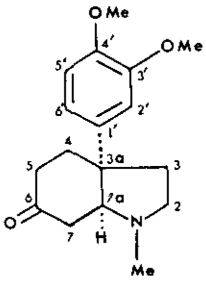
(a) In deuteriochloroform

(b)(c)(d) Reversible assignments

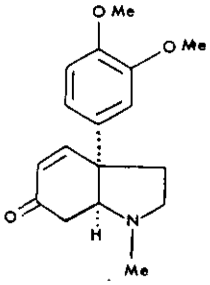
D. Other Indole Alkaloids

The mesembrine alkaloids, mesembrine (180), mesembrenone (181), mesembranol (182), epimesembranol (183), mesembrenol (184), epimesembrenol (185), 4-O-demethylmesembrenone (186), and sceletenone (187), all isolated from Sceletium strictum, were characterized by ^{13}C nmr (100). See Table 24. Mesembrenone appears to be identical to mesembrinine (101).

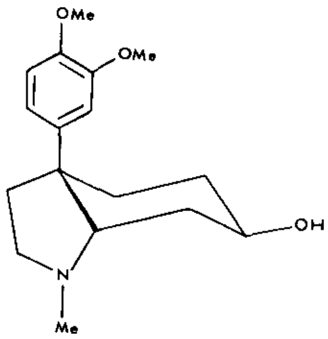
Table 24(a)



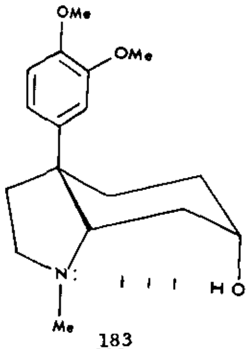
180



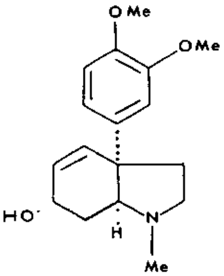
181



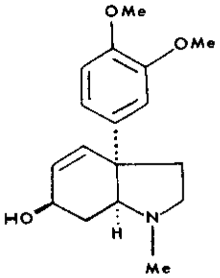
182



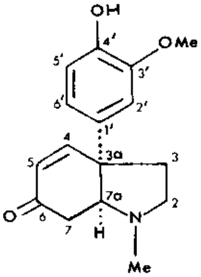
183



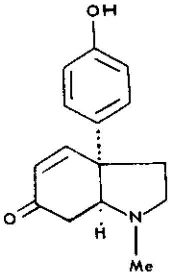
184



185



186



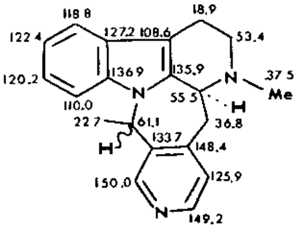
187

	180	181	182	183	184	185	186	187
2	55.0	56.2	54.6	53.6	56.4	54.1	56.2	55.8
3	38.8	38.3	34.9	41.4	39.3	38.0	38.5	38.4
3a	47.6	50.9	46.9	47.7	49.5	46.8	51.2	50.6
4	35.2	153.3	33.1	28.3	134.4	134.5	154.3	155.1
5	36.3	126.2	33.9	29.9	128.4	127.0	126.3	125.9
6	210.3	196.9	66.8	67.3	63.7	62.8	197.8	197.8
7	40.2	36.4	40.5	41.0	30.1	29.5	36.2	35.9
7a	70.4	73.5	70.4	69.1	73.8	73.2	73.9	73.4
N-Me	39.9	40.1	40.3	41.1	40.7	40.9	39.9	40.0
1´	139.9	135.2	139.6	138.3	139.3	138.2	134.8	133.6
2´	109.9	110.0	113.3	110.6	111.3	110.3	109.6	126.8
3´	138.7	148.6	149.0	148.9	148.3	148.2	145.0	115.5
4´	147.2	147.7	147.3	147.2	147.1	147.2	146.9	154.3
5´	111.0	110.9	111.4	111.6	111.3	110.7	115.0	115.5
6´	117.7	118.8	118.9	118.7	118.9	118.4	119.5	126.8
3´-OMe	56.0	55.8	56.5	56.5	56.1	55.8	56.2	---
4´-OMe	56.1	55.9	56.6	56.6	56.3	55.9	---	---

(a) Solvent not reported.

The ^{13}C nmr spectral assignments have been made for mostueine (188), a new alkaloid from the leaves and stems of Mostuea brunonis (102). See Figure 27.

Figure 27 (a)

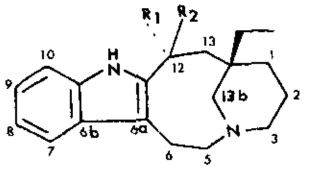


188

(a) Solvent not reported.

The ^{13}C nmr shifts of the pyrido[3',2',1':8,9,1]azonino[4,5-b]indole alkaloids quebrachamine (189), epivincadine (190), vincadine (191), cleavamine (192), velbanamine (193) and sixteen similar compounds were determined and correlated with conformations and configurations (103). See Table 25.

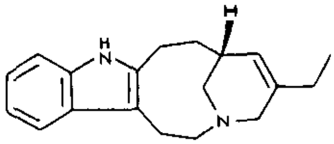
Table 25(a)



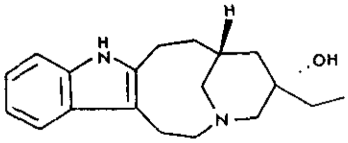
189 $R_1 = R_2 = H$

190 $R_1 = H$ $R_2 = COOMe$

191 $R_1 = COOMe$ $R_2 = H$



192



193

Carbon	189	190	191	192	193
1	33.4	37.3	33.9	122.3	40.4
2	22.6	23.6	22.3	140.4	71.6
3	54.9	53.8(b)	55.0	55.1	65.8

Table 25 (a) (Continued)

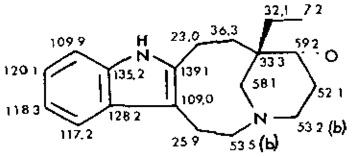
Carbon	189	190	191	192	193
5	53.2	54.0(b)	52.7	53.8(b)	52.3
6	21.7	26.2	21.8	26.1	22.7
6a	108.3	111.5	109.4	109.5	108.0
6b	128.6	127.6	127.7	128.5	127.4
7	117.1	117.9	117.4	117.6	116.8
8	118.4	118.7	118.5	118.5	118.4
9	119.9	121.4	120.6	120.3	120.4
10	109.9	110.6	110.5	109.8	110.8
10a	134.5	135.7	134.9(b)	135.2	135.2
11a	139.7	133.7	135.2(b)	139.2	138.5
12	22.4	40.9	37.8	22.4	22.7
13	34.7	42.8	38.6	34.1	31.5
13a	36.9	35.6	37.9	35.3	30.1
13b	56.6	60.8	56.7	53.5(b)	50.6
CH_2	32.0	35.6	30.6	27.6	32.3
Me	7.8	7.3	7.4	12.6	6.9
C=O	---	175.6	176.2	---	---
-OMe	---	51.9	52.0	---	---

(a) Deuteriochloroform was solvent and reference.

(b) *Interchangeable assignments.*

Wenkert et al. continued their studies of cleavamines and quebrachamines (104). They reported ^{13}C nmr data of eight additional compounds of this type including voaphylline (194). See Figure 28.

Figure 28(a)



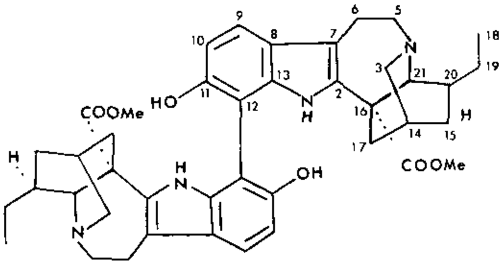
194

(a) Deuteriochloroform was solvent and reference.

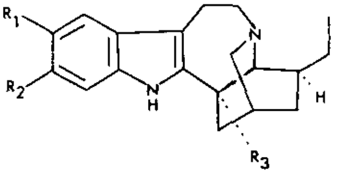
(b) Interchangeable assignments.

A new alkaloid bis-12-(11-hydroxycoronaridine) (195) was isolated from Bonafousia tetrastachya. The structure was identified by the usual analytical methods and by ^{13}C nmr spectral correlation with the Iboga type alkaloids, coronaridine (196), voacangine (197), isovoacangine (198), ibogamine (199); ibogaine (200), tabernanthine (201), heyneanine (202), catharanthine (203) and other compounds (105). See Table 26.

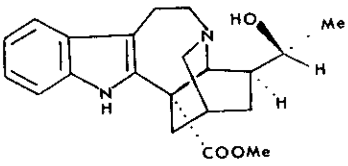
Table 26(a)



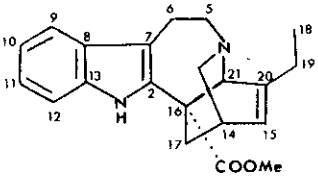
195



196 $R_1 = R_2 = H$ $R_3 = COOMe$
197 $R_1 = OMe$ $R_2 = H$ $R_3 = COOMe$
198 $R_1 = H$ $R_2 = OMe$ $R_3 = COOMe$
199 $R_1 = R_2 = R_3 = H$
200 $R_1 = OMe$ $R_2 = R_3 = H$
201 $R_1 = R_3 = H$ $R_2 = OMe$



202



203

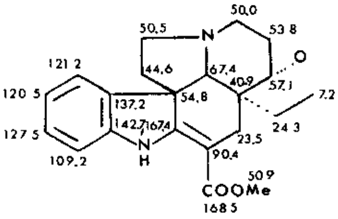
C	195	196	197	198	199	200	201	202	203
2	136.2	136.0	137.3	136.3	141.9	142.9	140.7	135.8	136.0
3	51.1	51.5	51.7	51.4	49.9	50.0	49.8	51.3	49.4
5	53.1	53.0	53.1	53.1	54.2	54.2	54.1	52.2	52.9
6	22.2	22.0	22.2	22.2	20.7	20.7	20.8	21.4	21.4
7	111.0	110.0	110.0	110.0	109.2	109.1	108.9	109.7	110.4
8	123.4	128.0	129.1	123.2	129.8	129.7	124.3	128.4	128.6
9	120.2	117.9	100.7	119.0	118.0	100.3	118.5	118.4	117.7
10	110.0	118.7	154.0	108.9	119.1	153.9	108.4	119.3	119.0
11	149.8	121.4	111.9	156.5	120.9	110.8	155.8	122.0	121.3
12	100.0	109.7	111.1	94.3	110.2	110.6	94.4	110.4	110.1
13	133.8	135.0	130.6	135.3	134.7	130.0	135.4	135.6	134.6
14	27.2	27.3	27.3	27.4	26.6	26.5	26.6	26.7	30.7
15	31.9	31.9	32.0	32.1	32.2	32.0	32.2	23.0	123.2
16	55.0	54.9	55.0	55.1	42.1	42.0	42.0	54.2	55.3
17	36.1	36.4	36.5	36.4	34.2	34.2	34.2	36.9	38.4

C	195	196	197	198	199	200	201	202	203
18	11.6	11.9	11.7	11.7	11.9	11.9	11.9	20.4	10.7
19	26.7	26.7	26.7	26.7	27.9	27.8	27.8	71.3	26.2
20	39.0	39.0	39.1	39.2	41.5	41.5	41.4	39.5	148.8
21	58.2	57.2	57.6	57.6	57.6	57.5	57.8	59.7	61.7
C=O	175.1	175.0	175.6	175.9	---	---	---	174.5	173.5
O-Me	52.6	52.3	52.7	52.5	---	---	---	52.9	52.0
Ar-OMe	---	---	55.7	55.7	---	56.0	55.8	---	---

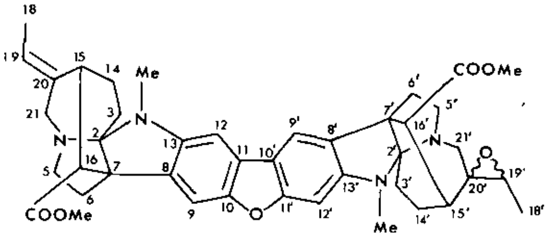
(a) In deuteriochloroform with TMS as internal reference.

Lochnericine (204) and three new dimeric indole alkaloids, pecyline (205), peceylanine (206), and pelankine (207) have been isolated from *Petchia ceyanica* and characterized by ^{13}C nmr (106). See Table 27.

Table 27(a)

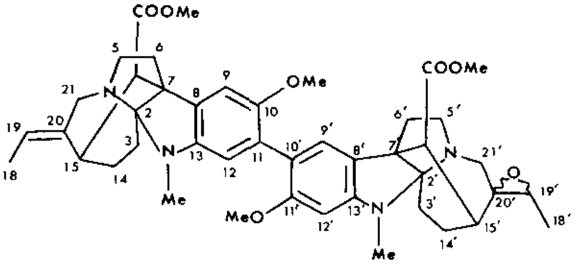


204

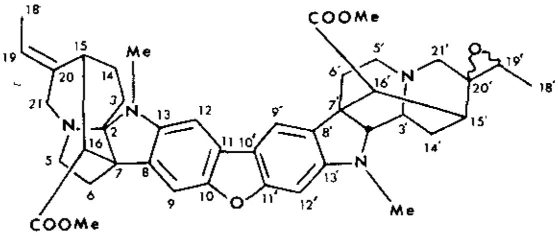


205

Table 27 (a) (Continued)



206



207

cmpd	2	3	5	6	7	8	9	10	11
205	97.5	41.4	54.8	20.5	57.0	134.7	107.1	148.9	123.8
206(b)	97.2	41.4	54.8	20.4	57.2	135.6	108.5	149.2	127.3
207	97.5	41.3	54.9	20.6	57.1	135.1	107.4	149.3	123.5
	12	13	14	15	16	18	19	20	21
205	93.8	145.3	26.3	34.6	50.9(c)	13.5	121.9	138.9	58.2
206(b)	110.4	143.2	26.1	34.5	50.7(c)	13.4	121.7	138.0	58.2
207	94.1	145.4	26.3	34.7	51.1	13.5	122.0	139.0	58.3
	C=O	OMe	NMe	2′	3′	5′	6′	7′	8′
205	173.6	51.5	27.9	96.3	41.4	54.8	21.4	56.1	131.8
206(b)	173.5	51.3	27.7	96.3	40.7	54.8	21.2	56.0	127.6
207	173.5	51.5	27.8	79.3	53.8	49.9(c)	33.1	42.5	135.8

	9'	10'	11'	12'	13'	14'	15'	16'	18'
205	114.6	114.1	157.7	88.5	148.7	25.0	39.0	51.1(c)	14.6
206(b)	126.2	115.7	156.8	89.9	149.2	24.9	38.9	50.5(c)	14.4
207	112.5	116.3	156.7	93.1	152.9	33.4	39.3	47.0	15.8

	19'	20'	21'	C=O'	OMe'	NMe'
205	63.1	63.7	56.8	173.5	51.4	27.1
206(b)	63.1	63.8	56.8	173.3	51.3	27.1
207	65.5	65.8	55.7(c)	173.1	51.4	33.8

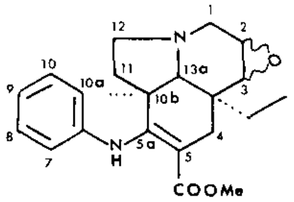
(a) Deuteriochloroform was used as solvent and reference.

(b) Aromatic methoxy shifts are 55.5 and 57.3 ppm.

(c) Reversible assignments.

Lochnericine (204) has been isolated from the roots of Vinca pusilla, and vindorosine (208), and venoterpine (209) were isolated from the leaves of the same plant. Their structures were elucidated with the use of ^{13}C nmr (107). See Table 28. The ^{13}C nmr assignments of pachysiphine (210) and vindoline (211) were also reported.

Table 28(a)

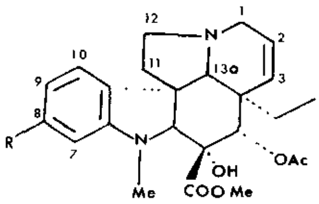


204 2α, 3α epoxide

210 2β, 3β epoxide

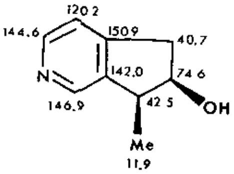
	1	2	3	3a	4	5	5a	6a	7	8
204	49.6	50.6	56.7	40.6	22.9	90.1	167.0	142.4	109.0	127.2
210	49.4	52.0	56.2	37.0	23.5	90.4	164.9	142.9	109.2	127.6

	9	10	10a	10b	11	12	13a	C=O	OMe	CH_2	CH_3
204	120.2	120.8	136.9	54.5	44.3	50.2	67.1	168.1	53.5	24.0	6.9
210	120.3	121.3	137.5	54.7	43.9	51.0	70.9	(b)	(b)	26.5	7.1



208 R = H
211 R = OMe

Carbon	1	2	3	3a	4	5	5a	6a	7
208	50.6	123.5	129.8	42.5	75.8	78.9	82.3	151.8	108.8
211	50.9	123.9	130.2	42.8	76.2	79.5	83.2	153.6	95.6
	8	9	10	10a	10b	11	12	13a	C=O
208	127.6	118.7	121.8	132.4	52.8	43.7	51.6	66.9	171.2(c)
211	161.1	104.5	122.4	124.9	52.6	43.9	51.9	67.0	170.4
	OCH_3	CH_2	CH_3	Ac C=O	Ac Me	N-Me	R		
208	51.7	30.4	7.2	169.9(c)	20.5	37.9	---		
211	51.9	30.6	7.5	171.7	20.8	38.0	55.1		



209

(a) Solvent not reported.

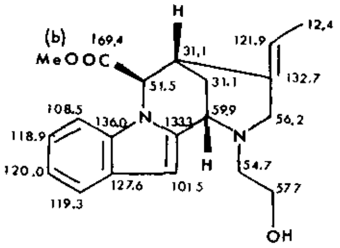
(b) Signal not reported.

(c) Reversible assignments.

Leete has demonstrated the intact incorporation of tryptophan into vindoline (211) by feeding experiments with ^{13}C and ^{14}C labeled tryptophan in Catharanthus roseus (108). See page 869 for a similar study done with nicotine.

The structure and configuration of vinoxine (210) isolated from Vinca minor L. was deduced with the use of ^{13}C nmr (109). See Figure 29. ^{13}C nmr shift assignments for 210 were also reported earlier (110).

Figure 29 (a)



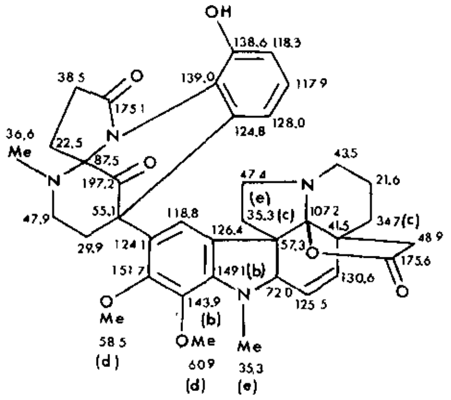
210

(a) In deuteriochloroform with TMS as internal reference.

(b) Signal not reported.

The alkaline potassium permanganate oxidation product of haplophytine (211) was analyzed with the use of ^{13}C nmr. It differs from the alkaline hydrogen peroxide oxidation product (111). See Figure 30 for the assignments on 211.

Figure 30 (a)



211

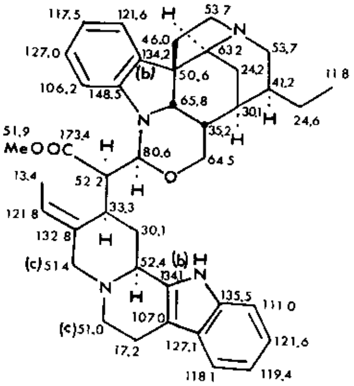
(a) In deuteriochloroform.

(b-d) Reversible assignments.

(e) Superimposed signals.

The ^{13}C nmr spectral assignments have been made for geissospermine (212) (112). See Figure 31.

Figure 31(a)



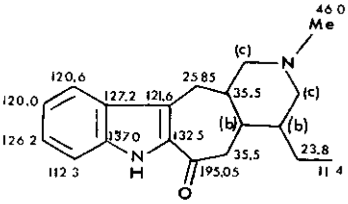
212

(a) In deuteriochloroform.

(b)(c) Reversible assignments.

Nine alkaloids have been isolated from Hazouta modesta of which one, 213, has been given complete ^{13}C nmr spectral assignments (113). See Figure 32.

Figure 32(a)



213

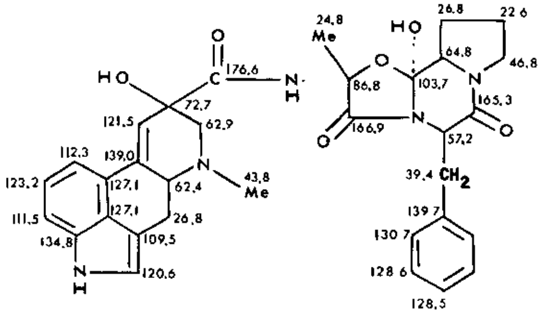
(a) In deuteriochloroform.

(b) 35.5 ppm or 41.2 ppm.

(c) 57.4 ppm or 58.7 ppm.

^{13}C nmr was used in the identification of 8-hydroxyergotamine (214), a minor alkaloid of ergot (114). The ^{13}C nmr spectrum was very similar to that of ergotamine reported earlier (115). See Figure 33.

Figure 33 (a)



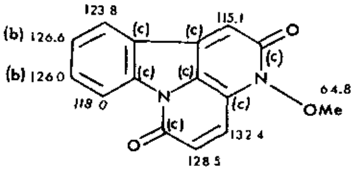
214

(a) DMSO-d_6 was solvent and reference.

An ergoline derivative which is an active antiserotonin agent has been analysed by ^{13}C nmr (116).

Two new alkaloids 8-methoxycanthin-6-one and 3-methoxycanthin-2,6-dione (215) were isolated from the bark of <u>Simba</u> <u>cuspidata</u>. The elucidation of the structure of 215 included ^{13}C nmr spectral correlation (117). See Figure 34.

Figure 34(a)



215

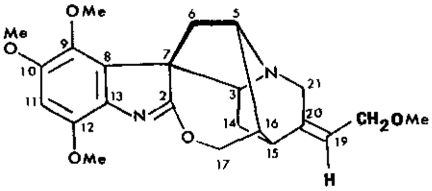
(a) In deuteriochloroform, TMS was internal standard.

(b) Interchangeable assignments.

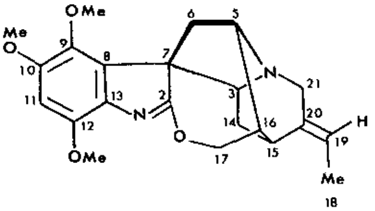
(c) Signal not reported.

The ^{13}C nmr spectra of the Gardneria alkaloids gardneramine (216), 217, chitosenine (218), 219, gardnerine (220), hydroxygardnerine (221), hydroxygardnutine (222), and their derivatives were studied. Configurations were determined (118). See Table 29.

Table 29

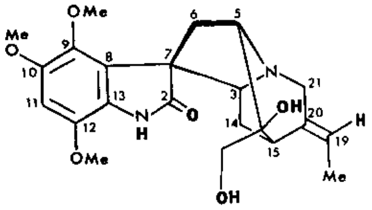


216

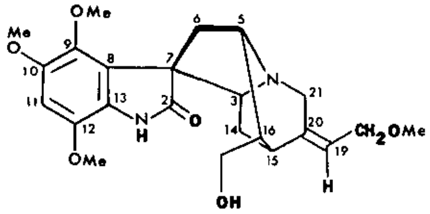


217

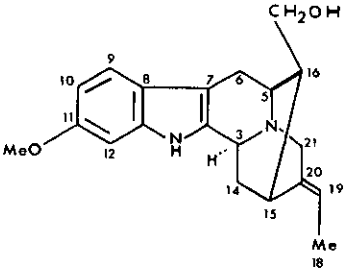
Table 29 (Continued)



218

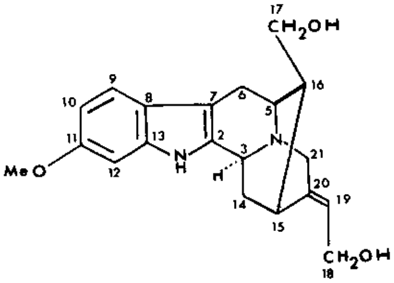


219

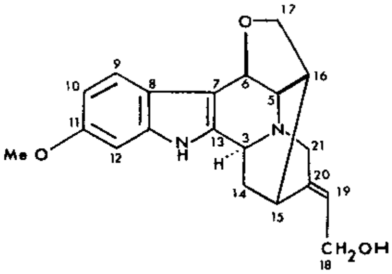


220

Table 29 (Continued)



221



222

Carbon	216(a)	217(a)	218(b)	219(a)	220(b)	221(b)	222(c)
2	178.7	178.8	180.5	180.1	138.3(f)	138.2(f)	141.7(f)
3	62.4	63.0	66.0	66.4	50.5(e)	50.3(e)	59.1
5	60.4	59.9	69.0	58.3	53.0(e)	53.0(e)	59.1
6	31.2	30.3	33.5	32.1	23.4	23.2	70.6
7	63.0	63.0	59.2	58.3	106.0	105.8	102.7
8	133.1	133.2	131.0	122.5	(d)	(d)	120.5
9	134.1	134.1	139.6	130.3	118.8	118.8	118.3
10	139.4	139.6	141.0	139.0	108.7	108.7	108.4
11	100.2	100.2	99.6	98.4	156.3	156.4	155.3
12	145.7	145.5	(d)	141.6	95.8	96.0	95.4

Table 29 (Continued)

Carbon	216(a)	217(a)	218(b)	219(a)	220(b)	221(b)	222(c)
13	150.5	150.5	(d)	150.1	137.9(f)	137.6(f)	136.6(f)
14	32.2	32.2	24.1	23.7	27.9	27.9	27.8
15	36.9	29.8	34.0	34.0	27.3	27.9	27.4
16	42.0	41.8	75.8	43.5	43.6	43.6	47.9
17	72.0	72.3	65.2	61.6	60.5	60.5	63.9
18	68.0	12.7	12.6	68.1	13.0	58.0	56.7
19	115.0	112.1	113.0	113.4	112.6	120.0	119.5
20	147.6	142.0	142.6	148.9	142.3	144.0	141.9
21	46.4	49.4	50.3	46.8	56.9	56.6	55.1
18-OMe	58.2	-----	-----	57.8	-----	-----	-----
Arom-OMe	56.7	56.7	56.6	56.4	55.6	55.6	55.5
	57.6	57.6	57.0	57.0	-----	-----	-----
	61.3	61.3	61.8	61.9	-----	-----	-----

(a) In deuteriochloroform with TMS as internal reference.

(b) In deuteriopyridine

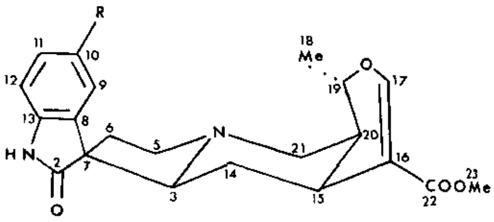
(c) In DMSO-d_6.

(d) Signal obscured by solvent.

(e)(f) Reversible assignments.

Two new oxindole alkaloids, palmirine (223) and rumberine (224), were isolated from Hamelia patens. The ^{13}C nmr spectrum of rumberime (224) was not obtained, but 224 was identified. Their structures are similar to isopteropodine (225) (119). See Table 30.

Table 30 (a)



223 R = OMe

224 R = OH

225 R = H

Table 30(a) (Continued)

	2	3	5	6	7	8	9
223	181.0	71.3	54.1	30.3	57.6	133.8	111.9
225	180.7	70.9	53.8	30.0	56.7	133.2	124.0

	10	11	12	13	14	15	16
223	156.0	112.2	109.9	135.3	34.9	30.7	110.0
225	121.0	127.2	109.3	139.5	34.7	30.7	109.5

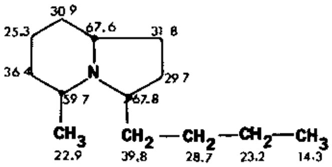
	17	18	19	20	21	22	23	Ar-OMe
223	155.1	18.6	72.3	38.2	53.6	167.6	51.0	55.7
225	154.4	18.5	71.8	37.8	53.3	166.9	50.7	-----

(a) In deuteriochloroform.

14. Indolizine Alkaloids

^{13}C nmr was used to study (5Z ,9Z)-3-butyl-5-methyloctatahydroindolizine (226), the attractant pheromone of the Pharaoh ant and three of the diastereomers. The conformations were determined (120). See Figure 35.

Figure 35(a)

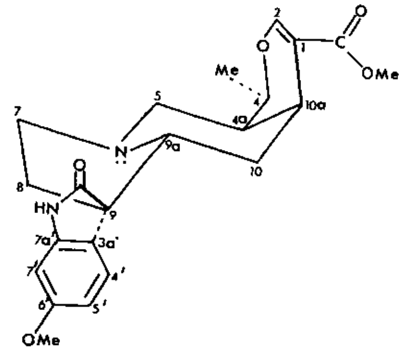


226

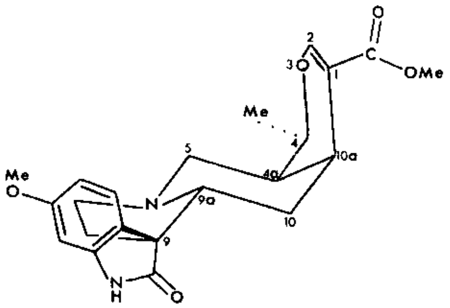
(a) In deuteriochloroform with TMS as internal reference.

The ^{13}C nmr shifts of the spiro oxindole alkaloids of the heteroyohimbine group, vinerine (227), vineridine (228), isovinerine (229), N-acetylvinerine (230), majdine (231), and isomajdine (232) have been assigned (121). See Table 31. Shift differences characteristic of the particular stereochemistry were noted. Note shifts of C-4, C-9, C-10a and C-21. Note that vinerine is of the epiallo series while N-acetylvinerine is of the allo series.

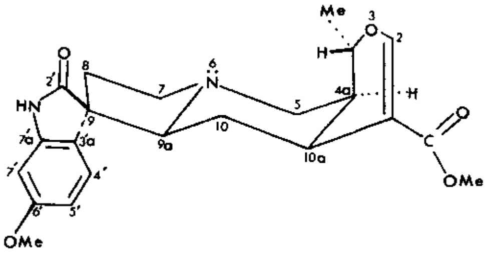
Table 31(a)



227

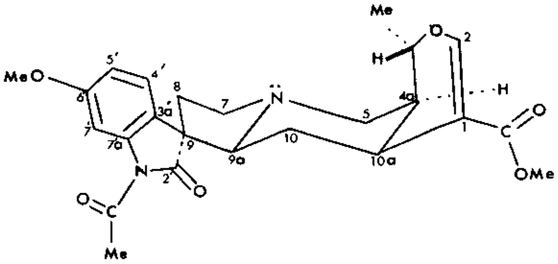


228

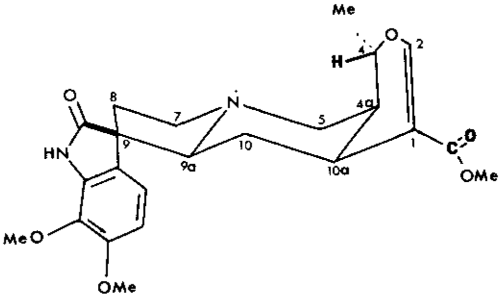


229

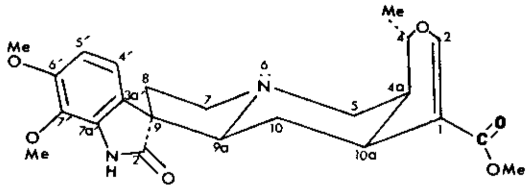
Table 31 (Continued)



230



231



232

Table 31 (Continued)

Carbon	227	228	229	230	231	232
1	104.9	105.	107.5	109.6	109.1	109.8
2	153.5	153.5	154.5	154.9	154.9	154.8
4	74.5	74.6	72.1	72.0	72.0	71.1
4a	36.8	36.5	37.9	37.8	38.1	38.0
5	53.7(b)	54.6(b)	55.0(b)	54.0(b)	54.6(b)	53.9(b)
7	53.2(b)	53.2(b)	53.6(b)	53.5(b)	53.3(b)	53.4(b)
8	34.8	34.2	34.6	36.6	33.7	35.1
9	56.0	55.3	55.4	56.6	55.9	57.1
9a	67.2	70.1	74.3	72.3	74.0	72.1
10	27.0	26.2	29.5	30.1	29.3	30.2
10a	24.8	25.1	31.0	30.4	30.8	30.4
2'	182.0	182.5	181.5	180.7	180.8	180.8
3a'	125.4	125.0	125.1	123.9	126.5	126.9
4'	125.3	123.0	123.3	124.3	117.8	119.4
5'	106.8	107.6	109.1	111.1	106.1	106.6
6'	159.6	159.8	159.7	159.6	152.2	152.1
7'	96.6	96.7	96.8	102.7	133.9	132.9
7a'	141.5	142.2	141.8	140.2	132.5	133.7
ester C=0	167.3	167.3	167.4	167.3	167.4	167.4
ester Me	50.7	50.3	50.7	50.8	50.6	50.8
6'-OMe	55.3	55.3	55.7	55.5	56.2	55.9
7'-OMe	-----	-----	-----	-----	60.5	60.7
4'-Me	18.4	18.5	18.9	18.5	18.6	18.4
amide C=0	-----	-----	-----	170.7	-----	-----
amide Me	-----	-----	-----	25.6	-----	-----

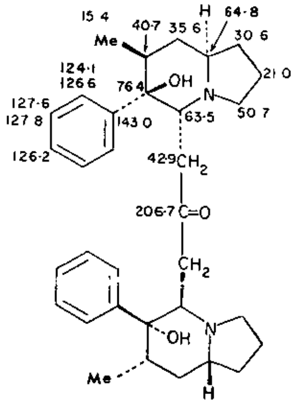
(a) All compounds were in deuteriochloroform. The central peak of deuteriochloroform was used as the shift reference.

(b) Reversible assignments.

The ^{13}C nmr shift assignments were made for dendrocrepine (233) isolated from Dendrobium crepidatum (122). The presence of six phenyl resonance peaks indicates hindered rotation of the phenyl group. See Figure 36.

Figure 36 (a)

233

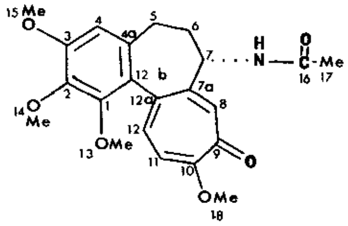


(a) In deuteriochloroform.

15. Colchicine

A ^{13}C nmr assignment of colchicine (234), an alkaloid of *Colchicum autumnale* was first published by Singh *et al*. (123). Two years later, Blade-Font *et al*. published the results of their study of 234. Their assignments differed from those of Singh *et al*. for ten of the twenty-two carbons of 234. They analyzed the reasons for these discrepancies (124). Subsequently, two reports were published dealing with the ^{13}C nmr spectra of *Colchicum* alkaloids and their derivatives (125, 126). One year after their original report, Blade-Font *et al*. published another study on the ^{13}C nmr spectroscopy of 234 (127) and related compounds in which they reversed four of the assignments that were made in their previous publication, now making a significant difference in eight assignments for those compared between their assignments and those of Singh's (123). See Table 32. Two additional reports on the ^{13}C nmr of 234 have been published, which were not available to the authors of this review (128,129).

Table 32



Assignments for colchicine (234)

Ref.	1	2	3	4	4a	5	6
(123)(a)	152.9	134.5	153.6	107.5	151.1	36.2	30.0
(124)(b)	150.7	141.1	153.2	108.0	134.4	29.4	36.0
(127)(b)	150.7	141.1	153.2	108.0	134.3	29.4	36.0

	7	7a	8	9	10	11	12
(123)(a)	52.9	137.2	130.5	179.6	164.1	113.2	135.8
(124)(b)	51.7	151.2	134.7	178.4	163.8	112.3	130.7
(127)(b)	51.7	151.2	130.7	178.4	163.8	112.3	134.7

	12a	12b	13	14	15	16	17	18
(123)(a)	141.6	125.7	56.4	61.3	56.4	170.3	22.6	56.1
(124)(b)	135.6	125.7	60.9(c)	60.7(c)	56.0(d)	168.9	22.4	55.9(d)
(127)(b)	135.6	125.7	60.9(c)	60.7(c)	55.9(d)	168.9	22.4	56.0(d)

(a) In deuteriochloroform.

(b) In DMSO-d_6.

(c)(d) Reversible assignments.

16. Morphine-like Compounds.

^{1}H and ^{13}C nmr signal multiplicities due to the 2,4,6-trinitrophenyl ring in several morphine-like compounds have been examined (130).

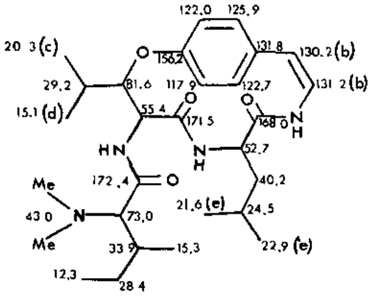
^{1}H and ^{13}C nmr spectra of brominated dihydrothebainones used for the synthetic closure of the oxygen bridge of morphinans to form morphine derivatives were studied (131).

The products of oxidation with Fremy's salt of several morphine derivatives were examined by ^{13}C nmr (132).

17. Cyclopeptide alkaloids.

Solvent-induced conformational changes in frangulanine (235) from Rhamnus frangula were observed by ^{1}H and ^{13}C nmr (133). See Figure 37.

Figure 37 (a)



235

(a) In deuteriochloroform.

(b) Ambiguous assignments.

(c) Pro-R

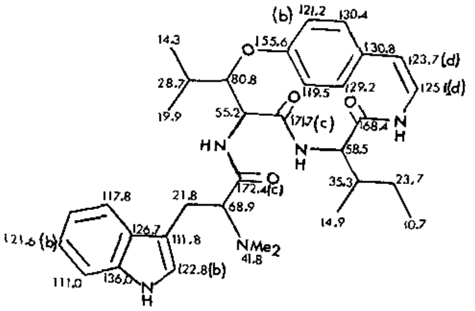
(d) Pro-S

(e) These were stereotopically indistinguishable.

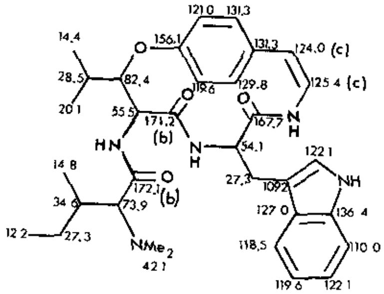
Several cyclopeptide alkaloids have been synthesized via an active ester cyclization. ^{13}C nmr was used to identify intermediates (134).

The ^{13}C nmr shifts of the cyclopeptide alkaloids, discarine A (236), discarine B (237), lasiodine A (238), lasiodine B (239), pandamine (240), pandaminine (241), and hymenocardine (242) have been assigned (135). See Figure 38.

Figure 38 (a)

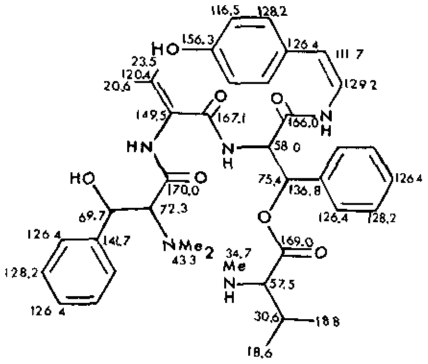


236

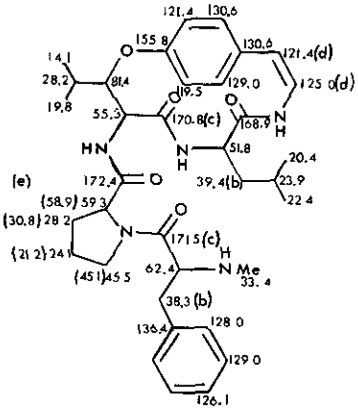


237

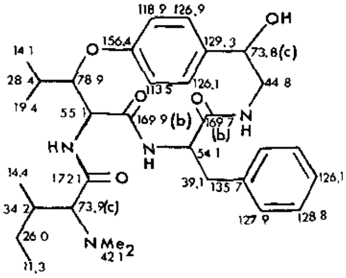
Figure 38 (a) (Continued)



238

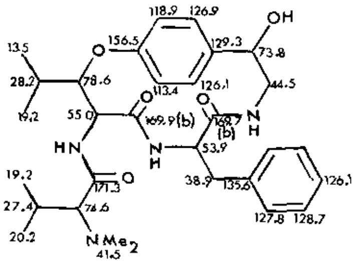


239

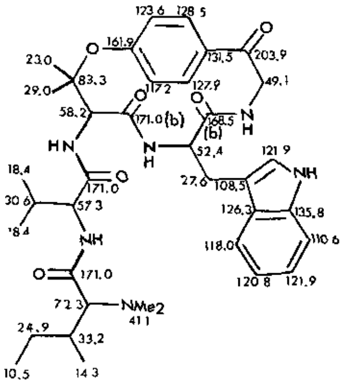


240

Figure 38 (a) (Continued)



241



242

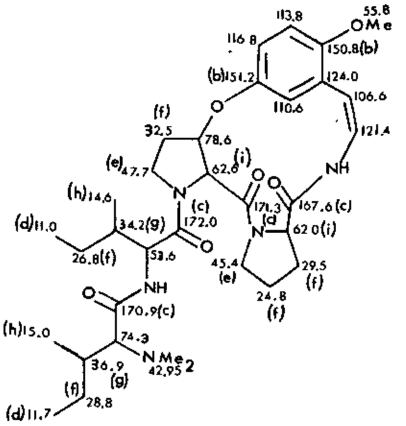
(a) In chloroform/methanol solutions 2:1 v/v.

(b-d) Interchangeable assignments.

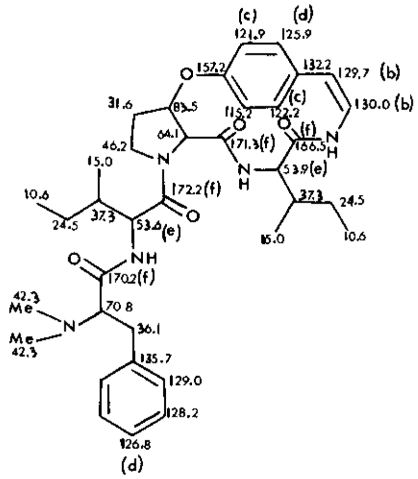
(e) Alternate set of signals from cis isomer of proline residue.

The ^{13}C nmr spectra of four cyclopeptide alkaloids zizyphine A (243), amphibine D (244), amphibine E (245), and zizyphine D (246) have been studied (136). See Figure 39.

Figure 39 (a)

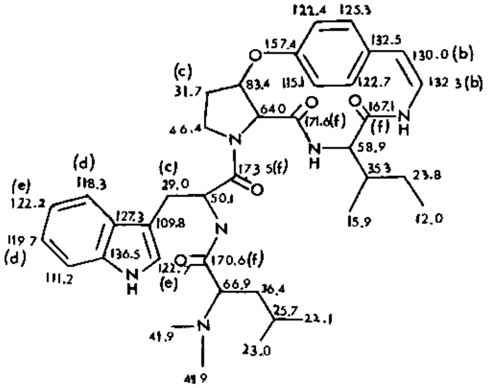


243

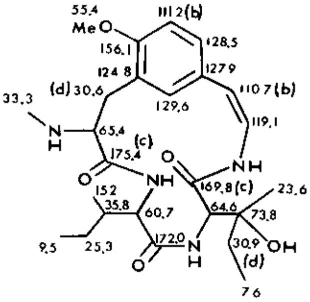


244

Figure 39 (Continued)



245



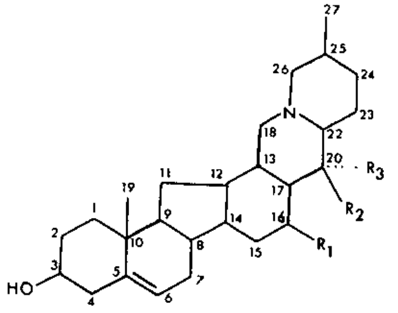
246

(a) In deuteriochloroform.
(b)-(f) Interchangeable assignments.

18. Steroid Alkaloids.

The ^{13}C nmr signals of seven cevanine alkaloids shinonomenine (247), veaflorizine (248), veramarine (249), verticine (250), verticinone (251), baimonidine (252), and isoverticine (253) from Veratrum and Fritillaria were assigned. Baimonidine (252) and isoverticine (253), isolated from Fritillaria verticillata, were new alkaloids (137). See Table 33.

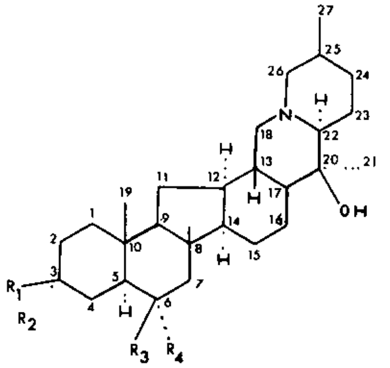
Table 33 (a)



247 $R_1 = R_3 = H$ $R_2 = Me$

248 $R_1 = H$ $R_2 = OH$ $R_3 = Me$

249 $R_1 = R_2 = OH$ $R_3 = Me$



250 $R_1 = R_4 = OH$ $R_2 = R_3 = H$

251 $R_1 = OH$ $R_2 = H$ $R_3,R_4 = {=}O$

252 $R_1 = R_4 = H$ $R_2 = R_3 = OH$

253 $R_1 = R_3 = OH$ $R_2 = R_4 = H$

Table 33 (Continued)

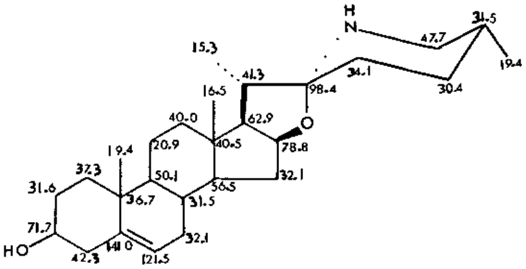
Carbon	**247**	**248**	**249**	**250**	**251**	**252**	**253**
1	38.1	38.2	38.2	37.9	37.1	35.1	38.8
2	31.4(b)	31.5	31.5(b)	30.8	30.5(b)	28.7	31.2
3	72.0	71.9	71.9	71.4	70.9	66.9	71.9
4	41.8	41.9	42.0	32.5	30.1(b)	32.8	35.0
5	142.4	142.0	141.7	52.1	56.5(c)	42.6	48.3
6	122.3	122.3	122.6	70.3	211.0	72.6	72.6
7	31.2(b)	31.5	31.3(b)	40.5	46.0	39.1	39.1
8	38.6	38.7	38.7	39.1	42.1	35.6	35.8
9	54.4	54.3	54.6	56.8	56.7(c)	57.6	57.5
10	37.0	37.0	37.0	35.2	38.4	36.2	35.5
11	30.3(c)	29.5(b)	29.2(c)	29.4	29.4(d)	29.5(b)	29.6(b)
12	41.5	41.7	41.5	41.1	41.1	41.0	41.0
13	37.9	37.6	32.7	39.3	39.3	39.1	39.3
14	45.3(d)	44.7	43.7	44.0	43.5	43.8	43.8
15	25.1	25.2	30.8	24.8	24.7	24.8	24.9
16	24.9(e)	20.8	66.1	20.8	20.6	20.9	20.9
17	45.5(d)	49.0	50.4	49.0	48.8	49.0	49.0
18	62.6(f)	61.9(c)	61.6(d)	61.8(b)	61.8(c)	62.0(c)	61.9(c)
19	19.1	19.0	19.1	13.0	12.8	14.1	15.0
20	36.2	71.1	73.2	71.1	71.0	71.1	71.1
21	8.6	20.4	19.9	20.3	20.4	20.6	20.5
22	68.0	70.4	70.0	70.3	70.3	70.6	70.5
23	24.3(e)	19.2	18.7	19.1	19.1	19.1	19.1
24	28.9(c)	29.3(b)	28.8(c)	29.4	29.2(d)	29.3(b)	29.5(b)
25	28.3	27.8	27.6	27.7	27.7	27.8	27.8
26	63.9(f)	62.7(c)	62.2(d)	62.5(b)	62.3(c)	62.5(c)	62.6(c)
27	17.9	17.4	17.3	17.3	17.3	17.5	17.4

(a) In deteriochloroform.

(b-f) Reversible assignments.

The synthesis of derivatives and the use of shift reagents have enabled the complete and unambiguous assignments of the ^{13}C nmr spectrum of solasodine (**254**) (138). See Figure 40.

Figure 40 (a)

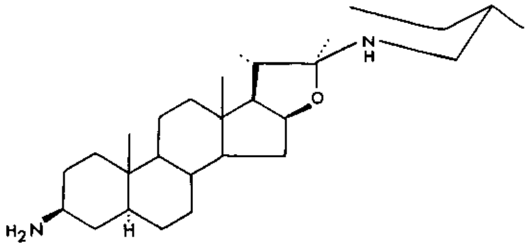


254

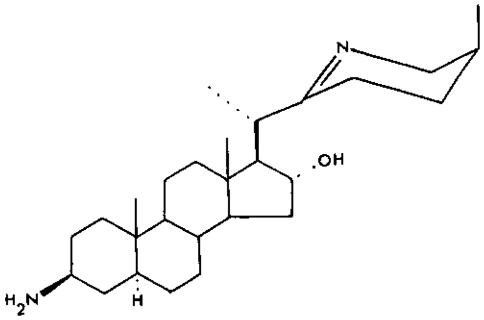
(a) In deuteriopyridine.

By the synthesis of derivatives, deuterium labelling, paramagnetic broadening and sford, the ^{13}C nmr spectra of solacallinidine (256) and soladunalinidine (255) were assigned (139). Also, the previously published (140) spectra of solanocapsine (257) and jurubidine (258) were reassigned. The reasons for the lack of agreement with that of the other group were discussed. See Table 34.

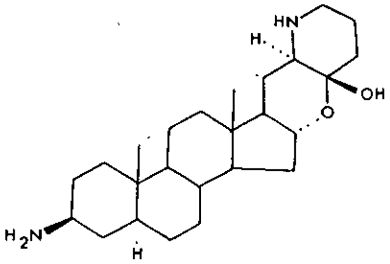
Table 34 (a)



255

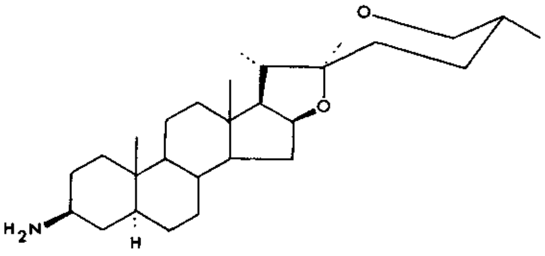


256



257

Table 34(a) (Continued)



258

Compound	1	2	3	4	5	6	7	8	9
255	37.9	32.5	51.5	39.4	45.7	29.3	32.5	35.3	54.7
256	37.7	32.6	51.2	39.5	45.6	28.8	32.1	35.1	54.4
257	37.5	32.5(b)	51.1	39.3	45.7	28.7	31.9(b)	35.0	55.0
258	37.7	32.3(b)	50.9	40.1(b)	45.5	28.6	31.7(b)	35.2	54.5

	10	11	12	13	14	15	16	17	18
255	35.8	21.4	40.5	41.1	56.0	33.0	78.8	62.4	17.2
256	35.6	21.0	40.4	44.3	53.4	35.3	76.7	63.8	14.0
257	35.7	20.5	39.3	41.8	55.0	30.2(b)	74.4	60.7	13.7
258	35.6	21.0	37.6(b)	40.6	56.4	30.9(b)	80.9	62.1	16.5

	19	20	21	22	23	24	25	26	27
255	12.5	43.0	16.2	99.4	27.0	29.0	31.4	50.6	19.8
256	12.4	44.8	19.0	176.9	29.8	28.0	27.5	56.2	19.2
257	12.4	33.1(b)	15.1	68.9	96.1	46.2(b)	28.4(b)	55.0	18.7
258	12.3	42.2	14.3	109.7	27.1	25.8	26.0	65.1	16.2

(a) In deuteriopyridine.

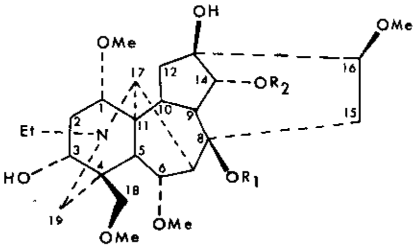
(b) Incorrectly assigned by Radeglia, _et al_..

19. Diterpenoid Alkaloids

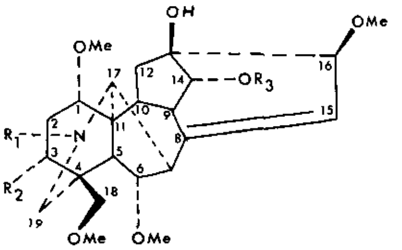
A. C-19 Diterpenoid Alkaloids

The ^{13}C nmr spectra of the aconitine-type alkaloids, pseudaconitine (259), indaconitine (260), veratroylpseudaconitine (261), falaconitine (262), mithaconitine (263), pyrodelphinine (264) and the lycoctonine-type alkaloids brownine (265), 14-acetylbrownine (266), delphatine (267), delcosine (268), 14-acetyldelcosine (269), delsoline (270), lycoctonine (271), tricornine (272), anthranoyllycoctonine (273), ajacine (274), methyllycaconitine (275), and "delsemine" (276) have been reported (141). Alkaloids 259-263 were isolated from the roots of *Aconitum falconeri*. The assignments of 264 were reported for the sake of comparison. Alkaloids 265-270 were isolated from the seeds of *Delphinium ajacis*. Compound 266 was a new alkaloid. Alkaloids 271-276 were isolated from *Delphinium tricorne*. Previously published (142) shift assignments of 265 and 271 were corrected. It was also shown that 276 is actually a mixture of two closely related alkaloids. See Table 35.

Table 35(a)

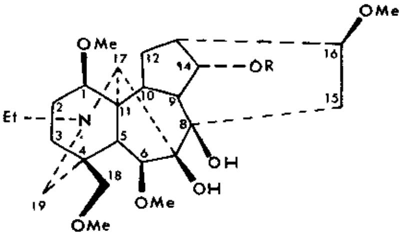


259 R_1 = Ac R_2 = Veratroyl
260 R_1 = Ac R_2 = Benzoyl
261 R_1 = H R_2 = Veratroyl

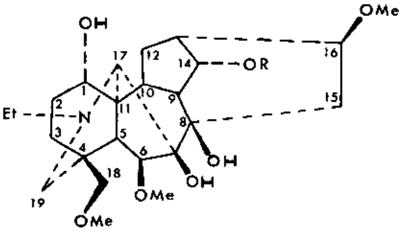


262 R_1 = Et R_2 = OH R_3 = Veratroyl
263 R_1 = Et R_2 = OH R_3 = Benzoyl
264 R_1 = Me R_2 = H R_3 = Benzoyl

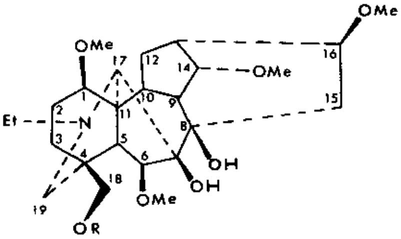
Table 35 (a) (Continued)



265 R = H
266 R = Ac
267 R = Me

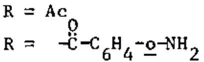


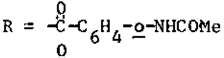
268 R = H
269 R = Ac
270 R = Me

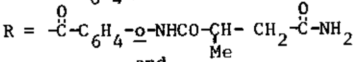


271 R = H

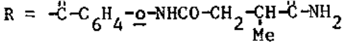
272 R = Ac

273

$\mathrm{R} = -\overset{\mathrm{O}}{\overset{\|}{\mathrm{C}}}-\mathrm{C_6H_4}-\underline{o}-\mathrm{NH_2}$

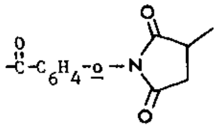
274

$\mathrm{R} = -\overset{\mathrm{O}}{\overset{\|}{\mathrm{C}}}-\mathrm{C_6H_4}-\underline{o}-\mathrm{NHCOMe}$

276

$\mathrm{R} = -\overset{\mathrm{O}}{\overset{\|}{\mathrm{C}}}-\mathrm{C_6H_4}-\underline{o}-\mathrm{NHCO}-\underset{\mathrm{Me}}{\mathrm{CH}}-\mathrm{CH_2}-\overset{\mathrm{O}}{\overset{\|}{\mathrm{C}}}-\mathrm{NH_2}$

and


$\mathrm{R} = -\overset{\mathrm{O}}{\overset{\|}{\mathrm{C}}}-\mathrm{C_6H_4}-\underline{o}-\mathrm{NHCO}-\mathrm{CH_2}-\underset{\mathrm{Me}}{\mathrm{CH}}-\overset{\mathrm{O}}{\overset{\|}{\mathrm{C}}}-\mathrm{NH_2}$

275 R =



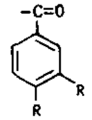
Carbon	259(b)	260	261(b)	262(b)	263	264
1	83.6	83.2	83.4	83.8(c)	83.6	86.1
2	35.1	35.1	35.8	38.0	38.2	25.3
3	70.9	71.2	71.3	71.4	71.8	35.3
4	43.1	43.0	43.3	44.0	44.1	40.0
5	48.7	48.6	47.5	48.0	48.3	48.5
6	82.1	82.0	82.5	83.7(c)	83.6	83.6
7	48.7	48.6	53.8	49.5	49.6	50.4
8	85.3	85.3	73.6	146.6	146.5	146.6
9	47.2	47.2	47.5	48.2	48.3	47.6
10	40.7	40.7	41.9	46.2	46.4	46.7
11	50.1	50.0	50.2	51.6	51.7	51.9
12	33.7	33.5	33.7	33.4	33.4	38.4
13	74.7	74.5	75.8	77.4	77.6	77.7
14	78.4	78.5	79.8	78.1	78.3	79.1
15	39.6	39.4	42.4	116.1	116.4	116.3
16	83.0	82.8	82.5	83.1	83.1	83.6
17	61.4	61.4	61.6	77.8	78.5	78.6
18	76.2	76.5	76.7	76.1	76.4	80.3
19	48.7	48.6	48.9	49.7	49.9	56.5
$N-CH_2$	47.2	47.2	47.5	47.7	47.9	42.7
Me	13.3	13.3	13.5	13.5	13.5	-----
1'	55.7	55.6	55.8	56.2	56.3	56.5
6'	57.6	57.5	57.5	58.0	58.1	58.1
16'	58.7	58.5	58.3	57.3	57.2	57.2
18'	58.9	58.9	59.1	59.2	59.2	59.2
-C=O	169.4	169.2	-----	-----	-----	-----
Me	21.5	21.5	-----	-----	-----	-----
-C=O	165.6	165.7	166.2	167.5	168.0	168.0
 R R	122.5	129.7	122.5	122.9	130.2	130.5
	110.2	129.2	110.5	110.3	130.0	130.0
	152.8	128.1	153.1	153.0	128.2	128.1
	148.4	132.7	148.6	148.5	132.8	132.7
	111.8	-----	112.3	112.5	-----	-----
R=OMe	55.7	-----	55.8	55.9	-----	-----

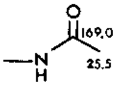
Table 35(a) Continued

Carbon	265	266	267	268	269	270
1	85.2	84.2	83.9(d)	72.7	72.6	72.6
2	25.5	26.2	26.2	27.5	27.2	27.2
3	32.5	32.4	32.4	29.4	29.9(d)	29.3
4	38.4	38.1	38.1	37.6	37.5	37.4
5	45.1	42.6	43.3	44.0	43.5(c)	43.9
6	90.1	90.3	90.6	90.1	90.2	90.4
7	89.1	88.3	88.4	87.9	87.6	87.8
8	76.3	77.1	77.5	78.1	78.4	78.5
9	49.6	51.2	49.8	45.3	44.9	44.9
10	36.4	38.1	38.1	39.4	38.0	37.7
11	48.2	49.5	48.9	48.9	49.2	49.3
12	27.5	28.2	28.7	29.4	29.4(d)	30.5
13	46.1	45.7	46.1	45.3	42.6(c)	43.3
14	75.3	76.0	84.3(d)	75.8	76.3	84.5
15	33.1	33.7	33.5	34.5	33.8	33.5
16	81.7	82.4	82.6	82.0	82.7	82.9
17	65.4	64.8	64.8	66.3	66.1	66.0
18	78.0	78.0	78.1	77.4	77.3	77.3
19	52.7	52.7	52.8	57.1	57.2	57.2
N-CH$_2$	51.3	48.8	51.1	50.4	50.3	50.3
CH$_3$	14.3	14.2	14.2	13.7	13.6	13.5
1'	56.0	55.8	55.7	-----	-----	-----
6'	57.5	57.3	57.3	57.4	57.2	57.2
14'	-----	-----	57.8	-----	-----	57.9
16'	56.5	56.2	56.3	56.4	56.3	56.3
18'	59.1	59.0	59.0	59.1	59.1	59.1
-C=0	-----	171.9	-----	-----	171.4	-----
Me	-----	21.5	-----	-----	21.4	-----

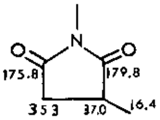
Carbon	271	272	273	274	275	276
1	84.2(d)	84.0	84.0	83.9	83.9	83.9
2	26.1	26.1	26.2	26.1	26.0	26.1
3	31.6	31.9	32.3	32.2	32.0	32.2
4	38.6	37.2	37.6	38.2	37.6	37.6
5	43.3	43.3	43.3	43.3	43.2	43.3
6	90.6	90.9	91.0	91.0	90.8	91.0
7	88.3	88.5	88.6	88.6	88.5	88.6
8	77.5	77.5	77.6	77.5	77.4	77.5
9	49.7	50.4	50.4	50.5	50.3	50.5
10	38.0	38.1	38.3	37.6	38.0	38.2
11	48.9	49.0	49.1	49.1	49.0	49.1
12	28.8	28.7	28.8	28.6	28.7	28.7
13	46.1	46.1	46.2	46.1	46.1	46.1
14	84.0(d)	84.0	84.0	83.9	83.9	83.9
15	33.7	33.7	33.7	33.8	33.6	33.8
16	82.7	82.6	82.6	82.6	82.5	82.6
17	64.8	64.6	64.6	64.5	64.5	64.5
18	67.6	69.1	68.7	69.8	69.5	69.8
19	52.9	52.4	52.6	52.5	52.3	52.4
N-CH$_2$	51.1	51.0	51.0	51.0	50.9	50.9
Me	14.1	14.1	14.1	14.0	14.0	14.0
1'	55.7	55.7	55.8	55.8	55.7	55.7
6'	57.7	57.8	57.9	57.8	57.8	57.8
14'	58.0	58.0	58.0	58.1	58.2	58.1
16'	56.2	56.3	56.3	56.3	56.3	56.3
-C=0	-----	170.9	-----	-----	-----	-----
Me	-----	20.8	-----	-----	-----	-----
-C=0	-----	-----	167.9	168.1	164.1	168.1
1	-----	-----	110.4	114.5	127.1	144.7, 114.8
2	-----	-----	150.9	141.9	133.1	141.9, 141.7
3	-----	-----	116.9(c)	120.6(c)	129.4	120.7(c)

Table 35 (a) (Continued)

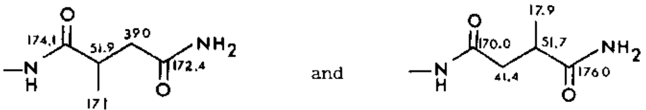
Carbon	271	272	273	274	275	276
4	-----	-----	134.4(d)	135.0(d)	133.6	134.9(d)
5	-----	-----	116.4(c)	122.5(c)	131.0	122.5(c)
6	-----	-----	130.8(d)	130.3(d)	130.0	130.3(d)



274



275



276

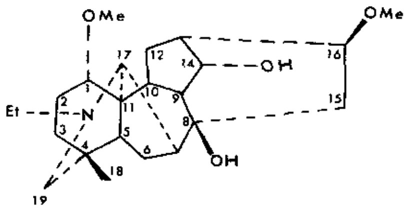
(a) All alkaloids in deuteriochloroform.

(b) There were only five signals reported for the aromatic carbons of the veratroyl groups and only one signal reported for their methoxy groups.

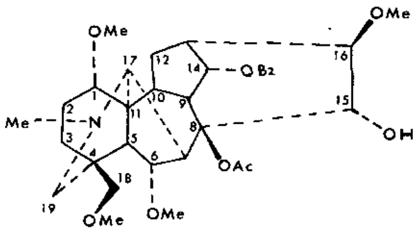
(c)(d) Reversible assignments.

Structures have been determined for the alkaloids, sachaconitine (277) and isodelphinine (278), isolated from the roots of <u>Aconitum miyabei</u>. These determinations were accomplished primarily by ^{13}C nmr spectral correlation with other C-19 diterpenoid alkaloids (143). See Table 36.

Table 36 (a)



277



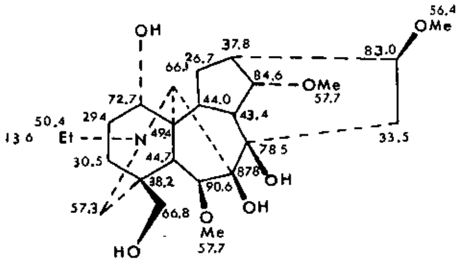
278

	1	2	3	4	5	6	7	8	9
277	86.7	26.3	37.8	34.7	49.5	25.2	45.9	72.9	47.1
278	85.1	26.4	34.9	39.3	47.9	83.7	44.5	92.1	44.7
	10	11	12	13	14	15	16	17	18
277	38.5	51.0	27.8	45.9	75.7	38.0	82.3	62.5	26.3
278	38.7	50.0	29.4	43.9	76.4	78.8	89.3	62.2	80.2
	19	NCH$_2$ -	Me	1'	6'	16'	18'	C=O(Ac)	CH$_3$(Ac)
277	57.5	49.5	13.7	56.3	-----	56.9	-----	-----	-----
278	56.5	42.6	-----	56.1	57.7	58.0	59.1	172.3	21.5
	Benzoyl C=O	<u>i</u>	<u>o</u>	<u>m</u>	<u>p</u>				
278	166.1	133.1	130.1	129.7	128.6				

(a) In deuteriochloroform.

The alkaloids, lycoctonine (271), atisine hydrochloride, and gigactonine (279) were isolated from <u>Aconitum gigas</u>. Gigactonine is a new alkaloid similar to delsoline (270) (144). See Figure 41.

Figure 41 (a)

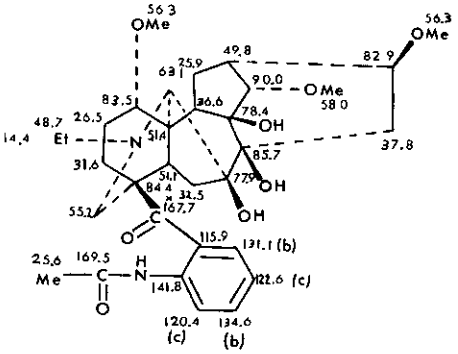


279

(a) Deuteriochloroform was the solvent; TMS was the internal standard.

The structure has been elucidated for the new alkaloid ranaconitine (280) by ^{13}C nmr. It was isolated from Aconitum ranunculaefolium (145). See Figure 42.

Figure 42 (a)



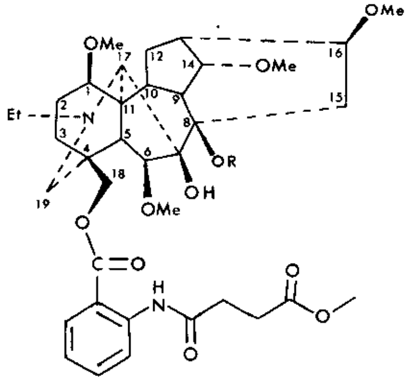
280

(a) In deuteriochloroform.

(b)(c) Reversible assignments.

Investigation of the alkaloids of <u>Aconitum septentrionale</u> led to the isolation and structural elucidation of two new alkaloids, septentrionine (281) and septentriodine (282) (146). See Table 37.

Table 37 (a)



281 R = Me (54.4 ppm)

282 R = H

	1	2	3	4	5	6	7	8	
281	83.1	25.6	31.9	37.7	40.6	91.5	90.4	80.9	
282	84.0	26.1	31.6	37.6	43.3	91.1	88.7	77.6	
	9	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**
281	51.9	37.7	47.6	27.9	46.7	83.5	27.9	82.8	66.2
282	50.4	38.1	49.1	28.7	46.1	84.0	33.7	82.7	64.6
	18	**19**	**N-CH_2**	**- CH_3**	**1'**	**6'**	**8'**	**14'**	**16'**
281	70.6	53.2	51.9	14.8	55.7	60.0	54.4	57.7	56.5
282	69.9	52.4	51.0	14.1	55.9	57.9	-----	58.1	56.4

anthranoyl

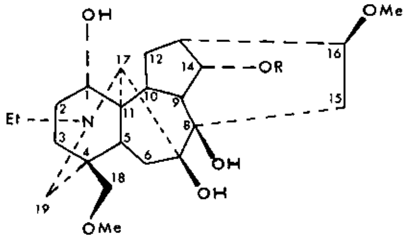
	C=O	1	2	3	4	5	
281	168.4	115.1	141.8	120.6	134.9	122.7	130.8
282	168.3	114.7	141.9	120.8	135.2	122.8	130.5

	-NH-$\overset{O}{C}$ -	CH_2 -	CH_2 -	$\overset{O}{C}$ -	OCH_3
281	170.6	29.0	32.7	173.3	51.9
282	170.6	28.9	32.7	173.3	51.9

(a) In deuteriochloroform.

The alkaloids, virescenine (283), 14-acetylvirescenine (284), brownine (265), and ajaconine were isolated from Delphinium virescens. Compounds, 283 and 284, are new; their structures were determined by ^{13}C nmr correlation (147). See Table 38.

Table 38 (a)



283 R = H
284 R = Ac

	1	2	3	4	5	6	7	8	9
283	72.4	28.5	29.3	37.7	41.9	33.5	86.1	76.2	48.0
284	72.4	29.0	29.4	37.7	41.7	33.7	85.9	76.9	45.9

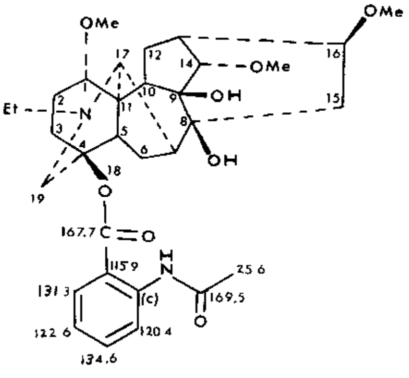
	10	11	12	13	14	15	16	17	18
283	39.7	49.4	26.9	43.6	75.5	36.0	81.9	64.9	78.7
284	37.7	50.0	26.8	42.9	77.1	35.9	82.1	64.9	78.8

	19	N-CH$_2$——	Me	16-OMe	18-OMe	14'-$\underset{\overset{\|}{O}}{C}$——	CH$_3$
283	55.8	50.5	13.9	56.4	59.4	----	----
284	56.1	50.6	13.9	56.3	59.4	170.9	21.3

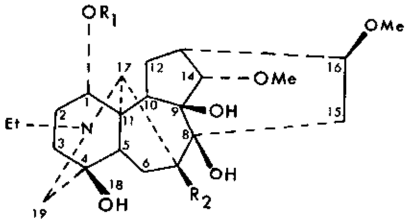
(a) In deuteriochloroform.

A report of the unambiguous ^{13}C nmr shift assignments for the alkaloids, lappaconitine (285), lappaconine (286), lapaconidine (287), ranaconine (288), brownine (265), and 14-dehydrobrownine (289) and other related compounds has been published (148). Solvent-induced conformational changes were noted. See Table 39.

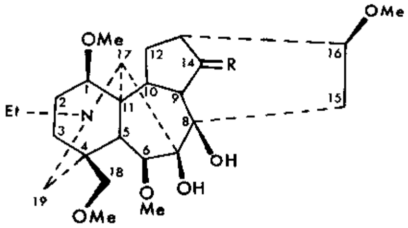
Table 39 (a)



285



286 R_1 = Me R_2 = H
287 $R_1 = R_2$ = H
288 R_1 = Me R_2 = OH



265 R = αH, β OH
289 R = =O

	285 (b)	286	287	287 (b)	288	289	265
1	84.2	85.2	72.5	73.0	84.9	85.5	85.2
2	26.2	26.6	29.8	30.7	27.1	25.5	25.5
3	31.9	36.3	33.5	34.6	36.8	32.5	32.5
4	84.7	71.1	70.7	70.0	71.1	38.5	38.4
5	48.6	50.8	48.2	48.3	51.1	46.1	45.1
6	26.8	26.9	27.4	27.9	32.4	89.8	90.1

Table 39(a) (Continued)

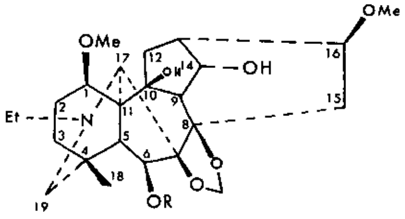
	285 (b)	286	287	287 (b)	288	289	265
7	47.6	47.8	47.0	47.6	78.0	88.9	89.1
8	75.6	75.7	76.3	75.5	86.5	85.5	76.3
9	78.6	78.8	77.6	78.2	78.7	53.8	49.6
10	36.4	37.4	36.3	37.1	37.5	43.9	36.4
11	51.0	51.0	50.4	51.0	51.4	49.0	48.2
12	24.2	23.7	23.1	24.0	26.3	29.7	27.5
13	49.0	49.0	48.4	47.9	51.1	49.5	46.1
14	90.2	90.3	90.4	90.8	90.2	216.3	75.3
15	44.9	44.7	45.1	44.2	38.1	33.1	33.1
16	82.9	83.1	83.0	83.9	83.0	85.5	81.7
17	61.5	61.7	63.1	62.9	63.2	65.9	65.4
18	-----	-----	-----	-----	-----	77.9	78.0
19	55.5	58.0	60.4	61.5	56.8	52.7	52.7
N-CH_2	49.9	49.9	46.5	50.2	50.0	51.4	51.3
Me	13.5	13.5	13.1	13.2	14.5	14.3	14.3
1'	56.5	56.5	-----	-----	56.3	56.1	56.0
6'	-----	-----	-----	-----	-----	57.6	57.5
14'	57.9	58.0	58.1	57.6	57.9	-----	-----
16'	56.1	56.1	56.3	56.0	56.3	56.3	56.5
18'	-----	-----	-----	-----	-----	59.2	59.1

(a) In deuteriochloroform except those otherwise noted. TMS was used as internal reference.

(b) In deuteriopyridine.

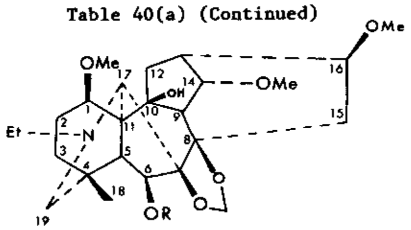
The ^{13}C nmr shift assignments have been made for the alkaloids, dictyocarpine (290), dictyocarpinine (291), deltaline (eldeline) (292), deltamine (eldelidine) (293), and delcorine (294) and eight derivatives (149). See Table 40.

Table 40 (a)

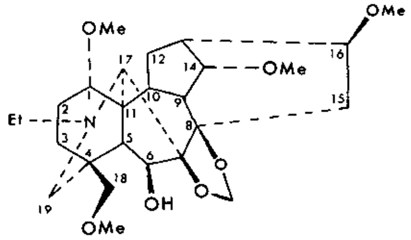


290 R = Ac
291 R = H

Table 40(a) (Continued)



292 R = Ac
293 R = H



294

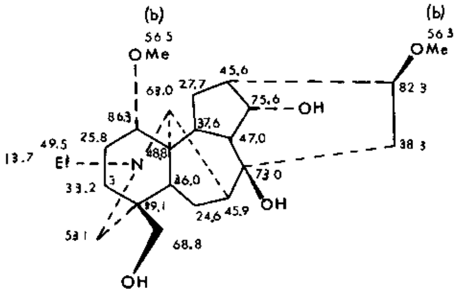
	290	291	292	293	294
C(1)	78.7	79.9	79.2	80.2	83.1
C(2)	26.4	26.4	27.1	27.0	26.4
C(3)	37.6	36.9	39.4	38.7	31.8
C(4)	34.0	33.9	33.7	33.6	38.1
C(5)	51.8	51.9	50.4	51.0	52.6
C(6)	77.2	77.3	77.3	77.4	78.9
C(7)	93.0	93.4	91.6	92.4	92.7
C(8)	82.9	82.8	83.8	83.5	83.9
C(9)	50.4	51.6	50.4	51.5	48.1
C(10)	79.9	80.5	81.6	82.4	40.3
C(11)	55.1	55.4	56.0	56.2	50.2
C(12)	36.5	36.7	36.5	36.8	28.1
C(13)	36.6	36.5	38.5	37.6	37.9
C(14)	72.8	72.6	81.7(b)	81.6	82.5
C(15)	32.9	33.2	34.8	34.3	33.3
C(16)	81.2	81.2	81.5(b)	81.6	81.8
C(17)	64.4	64.0	63.5	63.2	63.9
C(18)	25.5	25.4	25.7	25.6	78.9
C(19)	56.9	57.2	56.9	57.3	53.7
$N-CH_2$	50.4	50.5	50.2	50.4	50.7
Me	14.0	14.0	13.8	13.9	14.0
C(1)'	55.6	55.6	55.3	55.5	55.5
$O-CH_2-O$	94.0	93.4	93.9	93.3	92.9
C(14)'	-----	-----	57.7	57.9	57.8
C(16)'	56.3	56.3	56.2	56.2	56.3
C(18)'	-----	-----	-----	-----	59.6
C(6)-OC=O	170.2	-----	169.9	-----	-----
Me	21.8	-----	21.8	-----	-----

(a) In deuteriochloroform.

(b) Reversible assignments.

The configuration and the ^{13}C nmr shifts of cammaconine (295) assigned earlier (150) have been revised on the basis of spectral correlation with other diterpenoid alkaloids (151). See Figure 43.

Figure 43 (a)



295

(a) In deuteriochloroform.

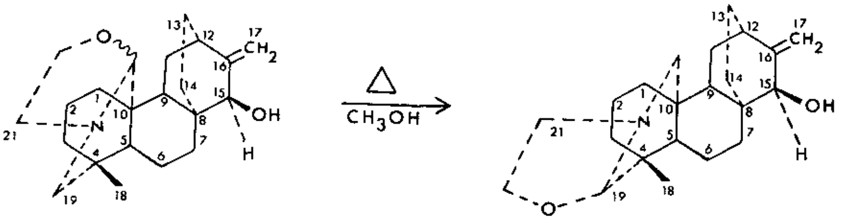
(b) Reversible assignments.

The new alkaloids, ajacusine, ajadine, ambiguine, and dihydroajaconine, were isolated from <u>Consolida ambigua</u> (formerly referred to and known as <u>Delphinium ajacis</u>). Two other new alkaloids were isolated and partially characterized. Eleven other known alkaloids were found to be present and were identified by ^{13}C nmr. Shift assignments were not reported. The fact that both C-20 and C-19 diterpenoid alkaloids were present is noteworthy (152).

B. C-20 Diterpenoid Alkaloids

Pelletier and Mody have shown by ^{13}C nmr that atisine (296), the major alkaloid of <u>Aconitum heterophyllum</u>, exists as a pair of epimers, differing in configuration at C-20. The <u>R</u>-20 epimer is more abundant (153). Later, they showed that the epimers are not interconverted <u>via</u> a zwitterion form as was concluded by some earlier workers (154). Pelletier and Mody claimed that the earlier group's observations were due to the conversion of 296 to isoatisine (297) (155). See Table 41.

Table 41 (a)



296

297

	1	2	3	4	5	6	7
296 R-20	42.0(b)	22.4	41.0(b)	33.8	51.6	17.8	34.6
296 S-20	42.0(b)	21.7	40.9(b)	28.2	48.9	18.5	32.0
297	40.6(b)	22.1	40.0(b)	38.1	48.6	19.2	31.9

	8	9	10	11	12	13	14
296 R-20	37.5	40.0	40.4	28.2	36.6	27.7	25.5
296 S-20	37.5	39.6	40.4	28.2	36.6	27.7	25.5
297	37.5	39.6	35.9	28.1	36.4	27.6	26.4

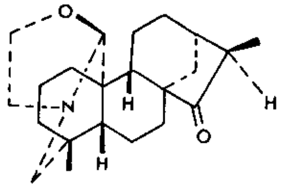
	15	16	17	18	19	20	21	22
296 R-20	77.0	157.5	108.9	26.7	56.4	93.9	50.3	64.1
296 S-20	77.0	157.5	108.4	26.1	53.3	94.2	50.3	59.2
297	76.8	156.2	109.6	24.3	98.4	49.8	54.9	58.6

(a) In deuteriochloroform with TMS used as internal standard.

(b) Reversible assignments.

The structure of cuauchichicine (298) has been established by ^{13}C nmr correlation and X-ray crystallography (156). See Figure 44.

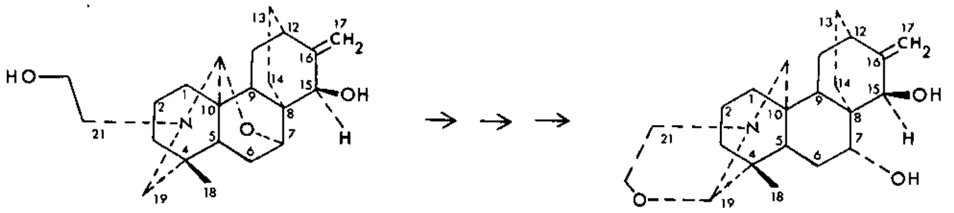
Figure 44



298

Pelletier and Mody have reported the rearrangment of ajaconine (299) into 7α-hydroxyisoatisine (300) as an unusual example of a Baldwin-rule-disfavored 5-endo-trig.-ring closure (157). See Table 42.

Table 42 (a)



299

300

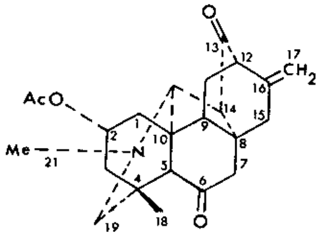
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
299	41.3	21.1	40.3	33.6	44.4	25.1	75.5	41.6	37.0	35.4	30.1	26.8	27.0	26.6	72.2	157.3	108.0	25.3	51.7	87.8	57.3	58.0
300	40.3	22.0	39.6	38.1	46.4	20.7	70.6	42.6	39.6	35.7	28.4	36.2	28.3	25.5	71.9	155.8	110.1	24.3	98.3	49.5	54.9	58.8

(a) In deuteriochloroform.

The acid-catalyzed rearrangement of garryfoline to cuauchichicine (298) has been studied by deuterium labelling and ^{13}C nmr spectroscopy to establish its mechanism (158).

The structure and absolute configuration of heterophylloidine (301), a new C-20 diterpenoid alkaloid isolated from Aconitum heterophylloides, have been determined by ^{13}C nmr data and single crystal X-ray analysis of a chemical degradation product. The ^{13}C nmr assignments were to be published later (159). See Figure 45.

Figure 45

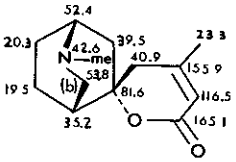


301

20. Miscellaneous Alkaloids

Labeled nicotinic acid (C-2) administered to Dioscorea hispida afforded dioscorine (302) labeled at C-3. A biosynthetic scheme representing a novel utilization of nicotinic acid was proposed (160). See Figure 46.

Figure 46 (a)



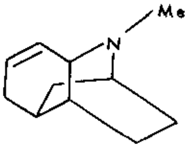
302

(a) In deuteriochloroform.

(b) Labeled carbon.

A proposed structure, 303 (161), for the alkaloid cannivonine, isolated from Vaccinium oxycoccus, has been shown to be incorrect by total synthesis of the misassigned structure (162). ^{13}C nmr and X-ray diffraction were used to identify the intermediates. See Figure 47.

Figure 47



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21. Addenda

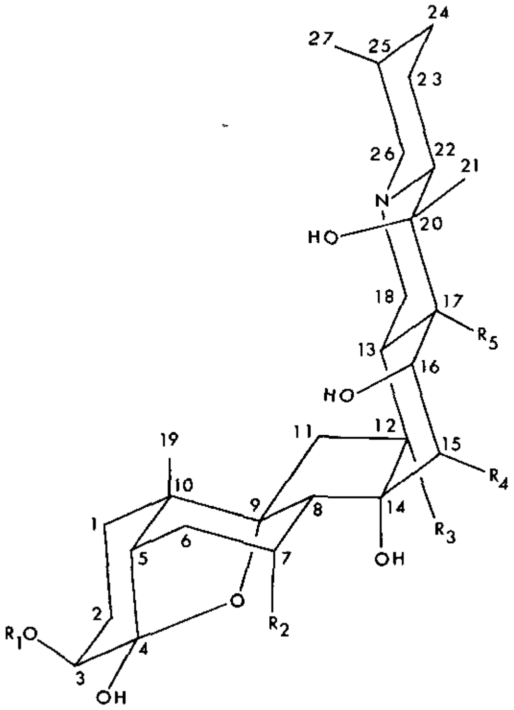
^{13}C nmr single frequency off-resonance decoupled (sford) C-H multiplet resonances, which deviate from normally assumed isolated A_nX spin descriptions, have been characterized. Qualitative criteria that allow the classification of degrees of second order coupling have been established and utilized in signal assignment and structural analysis. Cleavamine (192) and cularine were used as examples (163).

A report titled, "Carbon-13 NMR Analysis of Some 4-Quinazolinone Alkaloids and Related Compounds", has been published (164). There also has been published a report titled "Carbon-13 Nuclear Magnetic Resonance Spectroscopy of Tropane Alkaloids" (165). Neither of these were available to the authors of this review at the time of its completion.

The ^{13}C nmr spectra of some dihydrolysergic acid derivatives have been reported. The conformations were inferred (166).

The ^{13}C nmr spectral assignments were determined for the C-nor-D-homosteroidal ("abnormal" steroidal) alkaloids, veracevine (304), germine (305) and zygacine (306). Assignment was aided by the partially relaxed spectrum of a derivative (167). See Table 43.

Table 43(a)



304 $R_1 = R_2 = R_4 = H$ $R_3 = R_5 = OH$

305 $R_1 = R_3 = R_5 = H$ $R_2 = R_4 = OH$

306 $R_1 = Ac$ $R_2 = R_3 = R_5 = H$ $R_4 = OH$

	1	2	3	4	5	6	7	8	9
304	32.1(c)	28.3	73.4	106.4	44.7(d)	18.9(e)	16.9	44.4(d)	94.0
305	32.2(c)	28.6(d)	72.7	106.5	44.0	29.5(d)	67.5	44.8	93.1
306(b)	32.5(c)	26.6	75.3	104.4	44.0(d)	18.9(e)	(h)	44.2(d)	96.2

	10	11	12	13	14	15	16	17	18
304	45.7	41.9	75.9	36.9	80.6(f)	31.1(c)	71.1	81.8(f)	51.3
305	46.8	33.2(c)	45.9(e)	33.4	82.3	69.9(f)	70.4(f)	47.7(e)	61.7(g)
306(b)	45.7	33.2(c)	46.0(f)	33.9	80.9	69.9(g)	69.9(g)	46.2(f)	61.5

	19	20	21	22	23	24	25	26	27
304	18.5	72.1	16.0	64.1	19.0(e)	29.2	27.6	61.6	17.2
305	18.7	73.4	20.7	70.4(f)	19.2	29.3	27.6	61.9(g)	17.3
306(b)	18.4	73.3	20.2	70.3	19.0(e)	29.0	27.4	61.5	17.2

(a) In deuteriochloroform with deteriomethanol.

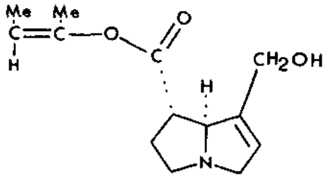
(b) Additional signals: acetate methyl 21.4 ppm; acetate carbonyl 171.7 ppm.

(c-g) Interchangeable assignments.

(h) Signal not detected; it is believed to be coincident with the C-27 signal.

The pyrrolizidine alkaloid 0^7-angelheliotridine (307) has been isolated from Senecio oxirensis (168). The structure was detected by ^{13}C nmr and other spectroscopic methods. See Figure 47.

Figure 48



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Although the authors of this review have made every effort to make this review complete for its time period (1977 through 1980), omissions may still occur. We apologize in advance for any such omission.

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