THE PAVINE AND ISOPAVINE ALKALOIDS

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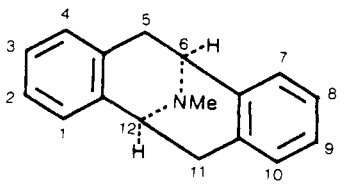
Twenty pavine and ten isopavine alkaloids are presently known, and their chemistry has been amply summarized. They are all derived biogenetically from benzylisoquinolines functionalized in ring B (1a-g).

Pavines are found in four plant families, namely the Papaveraceae, the Berberidaceae, the Lauraceae, and the Ranunculaceae. Within the ambit of the Papaveraceae, it is the genera *Argemone* and *Eschscholtzia* in which the pavines are known to occur. In the Berberidaceae, it is again two genera, *Berberis* and *Leontice*, which produce pavines. Only the genus *Cryptocarya* among the Lauraceae is known to possess pavines; and similarly within the Ranunculaceae, it is solely the genus *Thalictrum* that possesses pavines.

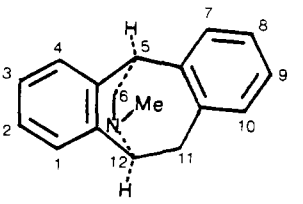
Interestingly enough, the genus *Thalictrum* also produces a wide variety of isopavines. It is, thus, a significant fact that only the genus *Thalictrum* (Ranunculaceae) generates both pavines and isopavines. Isopavines are also found in *Papaver* and *Roemeria* species (Papaveraceae).

The giant meadow Rue, *Thalictrum polygamum* Muhl., is presently the sole known source for the dimeric aporphine-pavine alkaloids pennsylpavine and pennsylpavoline. Because these two alkaloids have already been listed among the aporphine dimers, they are not included in the present review (1g).

Several of the pavines and isopavines are probably derived biogenetically from the tetrahydrobenzylisoquinoline (+)-reticuline, or a close analog thereof. They possess the corresponding stereochemistry, as indicated in the two structural expressions below (1d).



Pavine



Isopavine

The absolute configuration of the pavines was first established by degradation of *N*-benzyl-(−)-argemonine chloride to (−)-*N,N*-dimethyldi-*n*-propyl aspartate of known absolute configuration. That of the isopavines was settled by a study of the circular dichroism curve of (−)-amurensine, and application of the aromatic chirality rule (1d). An X-ray study has confirmed the absolute configuration of the pavines (23).

It will be noted that nearly all pavines and isopavines are levorotatory. The exceptions are the pavines argemonine and eschscholtzidine, which have also been reported in their dextrorotatory forms, and caryachine, which has been isolated in the levo as well as the racemic forms.

All uv data are in nm, with log ϵ values quoted in parentheses; ir frequencies are in cm^{-1}. ^{1}H-nmr chemical shift values are on the δ scale, and were measured at 60 MHz. Values with identical superscripts are interchangeable.

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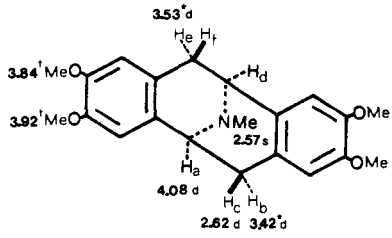
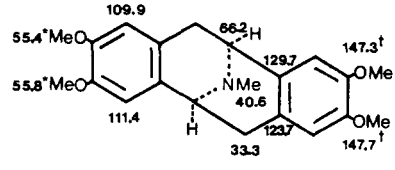
It is important to note that the data quoted below are as cited in the original literature. In particular, we have refrained from reinterpreting some of the nmr spectral information.

1. (−)-ARGEMONINE
((−)-N-Methylpavine)

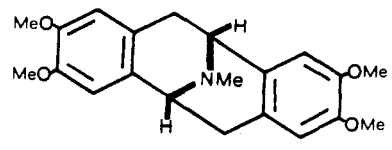


ArH δ 6.59 s(2H), and 6.76 s(2H)
J_{ab} 6 Hz, J_{ac} 0 Hz, J_{bc} 17 Hz



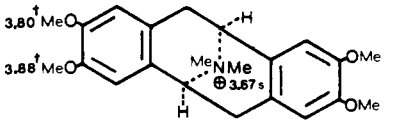
$C_{21}H_{25}O_4N$: 355.1783
MP: 147-148° (2)
152-154° (MeOH) (3)
152.5-153° (MeOH) (4)
153.5-155° (5)
155-156° (Et_2O) (6)
155.5-156.6° (EtOH) (7)
(hydrate) 125-135° (8)
$[\alpha]^{24}D$: −187.93° (c=1.01, $CHCl_3$) (4)
$[\alpha]D$: −202° ($CHCl_3$) (3)
$[\alpha]^{25}D$: −203° (c=3.31, $CHCl_3$) (5)
$[\alpha]^{21}D$: −208°±3° (c=0.5, $CHCl_3$) (9)
$[\alpha]^{27}D$: −209° (c=0.5, $CHCl_3$) (8)
$[\alpha]^{24}D$: −214.22° (c=1.01, EtOH) (4, 10)
$[\alpha]^{20}D$: −226° (c=0.1, $CHCl_3$) (7)
UV: 205 sh (4.94), 230 sh (4.15), 276 sh (3.79), 282 (3.91), 287 (3.93), 292 (3.89) (9, 10, 11, 12, 13a)
IR: ($CHCl_3$) 3010, 2960, 2940, 2910, 2860, 2835, 1618, 1519, 1510, 1470, 1458, 1410, 1373, 1358, 1343, 1311, 1290, 1258, 1178, 1130, 1113, 1100, 1018, 998, 973, 950, 920, 860, 826 (13a, 9, 14)
^{1}H-NMR: ($CDCl_3$) (11, 3, 6, 8, 15)
^{13}C-NMR: ($CDCl_3$) (16)
MS: 355, 354, 204 (100) (17)
ORD: (c=0.12, EtOH) $[\alpha]_{370}$ −779°, $[\alpha]_{294}$ −1,353° tr, $[\alpha]_{287}$ −123° pk, $[\alpha]_{273}$ −5,600° sh, $[\alpha]_{241}$ −18,360° tr, $[\alpha]_{228}$ +3,280° pk, $[\alpha]_{212}$ −29,100° tr, $[\alpha]_{207}$ −7,787° (10, 7)
CD: (EtOH) $[\theta]_{298}$ 0, $[\theta]_{292.5}$ −1,344, $[\theta]_{291}$ 0, $[\theta]_{278}$ +12,680, $[\theta]_{251}$ 0, $[\theta]_{236}$ −74,890, $[\theta]_{223}$ 0, $[\theta]_{206}$ −415,000 (10, 18, 19, 20)
Absolute Configuration: (18, 20, 21, 22)
X-RAY: Methiodide (23)
SOURCES: PAPAVERACEAE: *Argemone gracilenta* Greene (5), *A. hispida* Gray (4, 8, 14), *A. munita* Dur. and Hilg. (24), *A. munita* Dur. and Hilg. var. *Rotundata* (Rydb.) G. B. Ownb. (4, 14, 25, 26), *A. munita* Dur. and Hilg. var. *argentea* G. B. Ownb. (27), *A. platyceras* Link and Otto (9), *A. sanguinea* Greene (28)
BERBERIDACEAE: *Berberis buxifolia* Lam. (3)
RANUNCULACEAE: *Thalictrum revolutum* DC (6, 29, 30), *T. strictum* Ledeb. (2)

2. (+)-ARGEMONINE



$C_{21}H_{25}O_4N$: 355.1783
MP: 152-153° ($CHCl_3$) (31, 32)
$[\alpha]D$: +218° (c=2.11, EtOH) (31, 32)
Remaining physical properties resemble those of (−)-argemonine.
SOURCE: BERBERIDACEAE: *Leontice smirnovii* Trautv. (31, 32)

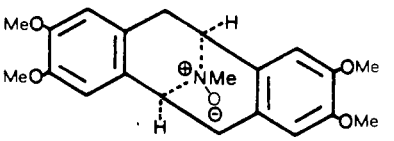
3. (−)-ARGEMONINE N-METHO SALT



ArH δ 6.53 s(2H), and 6.82 s(2H)
Aliph. CH δ 3.1-5.5 (6H)

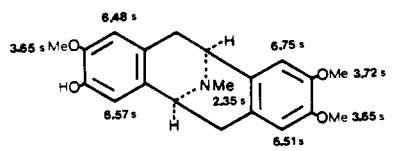
$C_{22}H_{28}O_4N^+$: 370.2018
MP: (Cl^-) 170-172° (EtOH) (29)
(I^-) 272-273° (dec.) (MeOH) (29)
(ClO_4^-) 274-275° (MeOH) (33)
$[\alpha]^{25}D$: (OH^-) −170° (c=2.81, $CHCl_3$) (5)
$[\alpha]^{25}D$: (I^-) −200°±6° (c=0.14, MeOH) (33)
UV: (Cl^-) (MeOH) 286 (3.86) (29)
(I^-) (MeOH) 230 sh (4.42), 285 (3.90) (29)
IR: (OH^-) ($CHCl_3$) 2950, 1616, 1466, 1370, 1253, 1159, 1122, 1110, 1031, 1010, 998, 949, 861 (5)
^{1}H-NMR: (OH^-) ($CDCl_3$) (5, 29)
MS: (Cl^-) 370 (0.4), 356 (10), 355 (41), 354 (26), 340 (5), 205 (15), 204 (100) (29)
(OH^-) 355 (54), 354 (36), 340 (6), 324 (5), 205 (22), 204 (100), 190 (6) (5)
CD: (c=5.7 x 10^{-3} M, MeOH) $[\theta]_{277}$ +7,490, $[\theta]_{239}$ −82,400 (29)
SOURCES: PAPAVERACEAE: *Argemone gracilenta* Greene (5), *A. platyceras* Link and Otto (33, 34)
RANUNCULACEAE: *Thalictrum revolutum* DC (29)

4. (−)-ARGEMONINE N-OXIDE



$C_{21}H_{25}O_5N$: 371.1732
MP: 140-160° (effervescence) (5)
$[\alpha]^{25}D$: −185° (c=2.81, $CHCl_3$) (5)
IR: ($CHCl_3$) 2959, 1618, 1511, 1466, 1366, 1344, 1159, 1131, 1110, 1072, 1012, 971, 951, 926, 911, 893 (5)
^{1}H-NMR: ($CDCl_3$) 2.58-4.65 (m, 6H, saturated ring H), 3.35 (s, 3H, NCH_3), 3.78 (s, 6H, OCH_3), 3.82 (s, 3H, OCH_3), 3.88 (s, 3H, OCH_3), 6.50 (s, 1H, ArH), 6.54 (s, 1H, ArH), 6.65 (s, 2H, ArH) (5, 15)
MS: 371 (1), 369 (3), 355 (45), 354 (18), 205 (10), 204 (100), 190 (8) (5)
SOURCE: PAPAVERACEAE: *Argemone gracilenta* Greene (5)

5. (−)-NORARGEMONINE



$C_{20}H_{23}O_4N$: 341.1627
MP: 241-242° ($CHCl_3$-MeOH) (9)
242-244° (C_6H_6-$CHCl_3$) (3)
244-250° (MeOH) (8)
255-256° (dec.) ($CHCl_3$) (35)
$[\alpha]^{20}D$: −147° (c=1.64, $CHCl_3$) (35)
$[\alpha]^{25}D$: −150° (c=0.34, $CHCl_3$) (36)
$[\alpha]^{27}D$: −151° (c=0.5, $CHCl_3$) (8)
$[\alpha]^{21}D$: −153°±3° (c=0.30, $CHCl_3$) (37)
$[\alpha]^{27}D$: −153.69° (c=2.786, $CHCl_3$) (14)
$[\alpha]D$: −154° (=2.79, $CHCl_3$) (10)
$[\alpha]^{20}D$: −154°±4° $CHCl_3$) (3)
UV: (EtOH) 205 sh (4.94), 230 sh (4.12), 278 sh (3.81), 283 (3.92), 287 (3.93), 293 (3.92) (10, 3, 9, 13b, 37)
IR: (Nujol) 1612, 1537, 1519, 1507, 1482, 1313, 1293, 1258, 1245, 1232,1214, 1190, 1172, 1136, 1110, 1053, 1030, 1020, 1002, 974, 950, 922, 874, 858, 843, 831, 819, 790, 764, 738 (13b, 9, 14, 37, 38)
^{1}H-NMR: (DMSO-d_6) (39, 3, 8, 38)
MS: 341 (61), 340 (38), 204 (100), 190 (79) (40, 3)

ORD: (c=0.10, EtOH) $[\alpha]_{360}$ −750, $[\alpha]_{289}$ +450°, $[\alpha]_{273}$ −6,000° sh, $[\alpha]_{241}$ −16,800° tr, $[\alpha]_{288}$ −750° pk, $[\alpha]_{212}$ −32,000° tr, $[\alpha]_{205}$ +30,000 (10)

CD: (EtOH) $[\theta]_{298}$ 0, $[\theta]_{280}$ +14,630, $[\theta]_{250}$ 0, $[\theta]_{235}$ −58,520, $[\theta]_{220}$ −22,510, $[\theta]_{206}$ −225,000 (10)

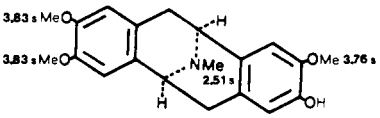
SOURCES: PAPAVERACEAE: *Argemone brevicornuta* G. B. Ownb. (41), *A. Hispida* Gray (4,8,14), *A. platyceras* Link and Otto (9, 36), *A. munita* Dur. and Hilg. var. *rotundata* (Rydb.) G. B. Ownb. (14, 25, 26, 29), *Eschscholtzia californica* Cham. (37), *E. glauca* Greene (37), *E. douglasii* (Hook. and Arn.) Walp. (37)

BERBERIDACEAE: *Berberis buxifolia* Lam. (3)

RANUNCULACEAE: *Thalictrum dasycarpum* Fisch. and Lall. (42)

LAURACEAE: *Cryptocarya longifolia* Kostermans (35)

6. (−)-ISONORARGEMONINE



ArH δ 6.45 bs(2H), and 6.58 bs(2H)

$C_{20}H_{23}O_4N$: 341.1627

MP: 219-221° (MeOH) (5)

$[\alpha]^{25}D$: −202° (c=3.31, $CHCl_3$) (5)

UV: (MeOH) 287 (3.96) (30)

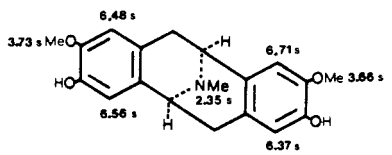
^{1}H-NMR: ($CDCl_3$) (8, 30, 39)

CD: (MeOH) $[\theta]_{293}$ −1,930, $[\alpha]_{275}$ +9,370, $[\theta]_{232}$ −26,700 (30)

SOURCES: PAPAVERACEAE: *Argemone gracilenta* Greene (5), *A. munita* Dur. and Hilg. var. *argentea* G. B. Ownb. (27)

RANUNCULACEAE: *Thalictrum revolutum* DC (30)

7. (−)-BISNORARGEMONINE ((−)-Rotundine)



$C_{19}H_{21}O_4N$: 327.1470

MP: 243-246° (EtOH) (8)
254-255° (MeOH) (37)

$[\alpha]^{20}D$: −134° (c=0.4, EtOH) (35)

$[\alpha]^{27}D$: −222° (c=0.3, $CHCl_3$) (8)

$[\alpha]^{20}D$: −244°±3° (c=0.32, MeOH) (37)

$[\alpha]^{20}D$: −244°±3° (c=0.19, $CHCl_3$) (37)

$[\alpha]^{25}D$: −265.8° (c=0.158, MeOH) (10, 25)

UV: (EtOH) 230 sh (4.07), 279 sh (3.83), 285 (3.92), 288 (3.93), 294 (3.89) (10, 13a, 37)

IR: (Nujol) 3480, 1610, 1540, 1517, 1508, 1320, 1287, 1264, 1248, 1223, 1214, 1175, 1143, 1125, 1108, 1025, 1011, 971, 950, 928, 871, 863, 836, 818, 783, 779, 738, 729 (13c, 37)

^{1}H-NMR: (DMSO-d_6) (39, 8)

MS: 328 (15), 327 (70), 326 (57), 312 (11), 311 (9), 191 (37), 190 (100), 177 (7), 176 (6), 175 (15), 162 (7), 137 (6) (39, 8)

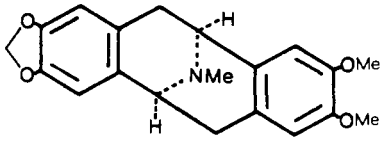
ORD: (c=0.10, EtOH) $[\alpha]_{260}$ −800°, $[\alpha]_{296}$ −1,225° tr, $[\alpha]_{288}$ +250° pk, $[\alpha]_{270}$ −6,800° sh, $[\alpha]_{240}$ −16,400° tr, $[\alpha]_{227}$ −5,000° pk, $[\alpha]_{212}$ −37,000° tr, $[\alpha]_{208}$ −11,500° (10)

CD: (EtOH) $[\theta]_{300}$ 0, $[\theta]_{294}$ −1,295, $[\theta]_{280}$ +13,810, $[\theta]_{250}$ 0, $[\theta]_{235}$ −47,470, $[\theta]_{224}$ −23,740, $[\theta]_{206}$ −287,500 (10)

SOURCES: PAPAVERACEAE: *Argemone hispida* Gray (8), *A. munita* Dur. and Hilg. var. *rotundata* (Rydb.) G. B. Ownb. (8, 25, 43), *Eschscholtzia californica* Cham. (37, 44), *E. douglasii* (Hook and Arn.) Walp. (37), *E. glauca* Greene (37)

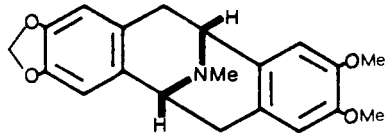
RANUNCULACEAE: *Thalictrum dasycarpum* Fisch. and Lall. (42)
LAURACEAE: *Cryptocarya longifolia* Kostermans (35)

8. (−)-ESCHSCHOLTZIDINE
((− -O-Methylcaryachine)



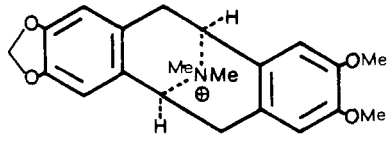
$C_{20}H_{21}O_4N$: 339.1470
MP: Amorphous
$[\alpha]^{24}D$: −194.2° (c=1.56, MeOH) (10, 46)
UV: (EtOH) 235 sh (4.01), 282 sh (3.88), 290 (3.97), 303 (3.72) (10)
^{1}H-NMR: ($CDCl_3$) 2.50 (s, 3H, NCH_3), 3.76 (s, 3H, OCH_3), 3.83 (s, 3H, OCH_3), 3.91 (s, 1H, CH), 4.01 (s, 1H, CH), 5.79 and 5.81 (ABq, J=1 Hz, 2H, OCH_2O), 6.41 (s, 2H, ArH), 6.58 (s, 2H, ArH) (6, 15, 45)
MS: 339, 338, 204, 188 (100) (17)
ORD: (c=0.10, EtOH) $[\alpha]_{360}$ −750°, $[\alpha]_{292}$ +150° pk, $[\alpha]_{275}$ −5,200° sh, $[\alpha]_{244}$ −10,400° tr, $[\alpha]_{232}$ −5,500° pk, $[\alpha]_{212}$ −33,500° tr, $[\alpha]_{199}$ +75,000° pk, $[\alpha]_{195}$ +56,250° (10)
CD: (EtOH) $[\theta]_{305}$ 0, $[\theta]_{301}$ −335, $[\theta]_{299}$ 0, $[\theta]_{285}$ +11,600, $[\theta]_{251}$ 0, $[\theta]_{240}$ −22,400, $[\theta]_{225}$ 0, $[\theta]_{207}$ −245,000, $[\theta]_{198}$ 0 (10)
SOURCES: PAPAVERACEAE: *Eschscholtzia californica* Cham. (46)
RANUNCULACEAE: *Thalictrum revolutum* DC (6, 29)

9. (+)-ESCHSCHOLTZIDINE
((+)-O-Methylcaryachine)



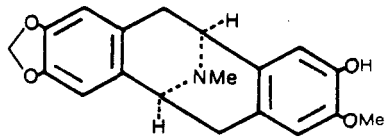
$C_{20}H_{21}O_4N$: 339.1470
MP: (Cl^-) 178-180° (H_2O) (47)
$[\alpha]^{25}D$: +195.1° (c=1.00, EtOH) (47)
Remaining physical properties resemble those of (−)-eschscholtzidine
SOURCE: LAURACEAE: *Cryptocarya chinensis* Hemsl. (47)

10. (−)-ESCHSCHOLTZIDINE N-METHO SALT



$C_{21}H_{24}O_4N^+$: 354.1705
MP: N.A.
$[\alpha]^{20}D$: (Cl^-) −170° (c=0.26, MeOH) (29)
UV: (Cl^-) (MeOH) 289 (3.74), 257 (3.46), 230 sh (3.91) (29)
^{1}H-NMR: (Cl^-) ($CDCl_3$) 3.68 (bs, 6H, $N(CH_3)_2$), 3.79 (s, 3H, OCH_3), 3.86 (s, 3H, OCH_3), 5.57 (bd, 2H, CH), 5.89 (bs, 2H, OCH_2O), 6.48 (s, 1H, ArH), 6.55 (s, 1H, ArH), 6.80 (s, 1H, ArH), 6.85 (s, 1H, ArH) (29)
CD: (Cl^-) (c=3.2 x 10^{-3}, MeOH) $[\theta]_{282}$ +6,440, $[\theta]_{241}$ −40,600 (29)
SOURCES: RANUNCULACEAE: *Thalictrum revolutum* DC (29)

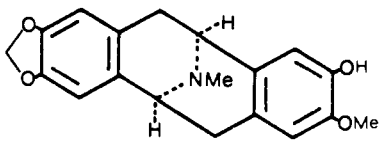
11. (−)-CARYACHINE



$C_{19}H_{19}O_4N$: 325.1314
MP: 170° (Et_2O) (19)
174-175° (48)
$[\alpha]^{21}D$: −269.6° (c=1.00, EtOH) (48)
$[\alpha]^{20}D$: −251° (c=0.43, EtOH) (19)
UV: (EtOH) 291.5 (4.02) (48)
(EtOH) 294 (3.95) (19)
(hexane) 303, 295, 290, 285, 278 (19)

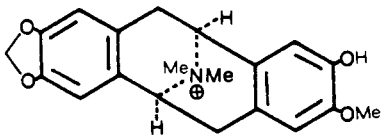
^{1}H-NMR: ($CDCl_3$) 2.49 (s, 3H, NCH_3), 2.49 and 2.54 (2 x d, J=16.2 Hz, 2H, CH_2), 3.41 (2 x q, J=5.4 Hz, J=16.2 Hz, 2H, CH_2), 3.79 (s, 3H, OCH_3), 3.96 (2 x d, J=5.4 Hz, 2H, 2CH), 5.78 and 5.84 (q, J=1.2 Hz, 2H, OCH_2O), 6.38 and 6.42 (2 x s, 2H, ArH), 6.54 (s, 2H, ArH) (48, 19)
MS: 326 (15), 325 (50), 324 (34), 282 (3), 190 (100), 188 (100) (19)
CD: (19)
SOURCE: LAURACEAE: *Cryptocarya chinensis* Hemsl. (47, 48)

12. (+)-CARYACHINE



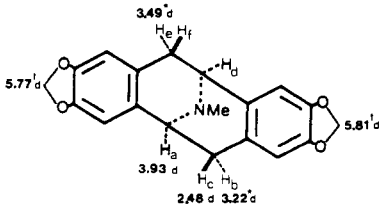
$C_{19}H_{19}O_4N$: 325.1314
MP: 241-242° (EtOH) (48)
$[\alpha]^{28}$D: 0° (c=0.27, EtOH) (48)
UV: (EtOH) 291.5 (3.97) (48)
^{1}H-NMR: ($CDCl_3$) 2.54 (s, 3H, NCH_3), 3.86 (s, 3H, OCH_3), 5.83 and 5.88 (q, J=1.8 Hz, 2H, OCH_2O), 6.40 and 6.48 (2 x s, 2H, ArH), 6.59 (s, 2H, ArH) (48)
SOURCE: LAURACEAE: *Cryptocarya chinensis* Hemsl. (47, 48)

13. (−)-CARYACHINE N-METHO SALT



$C_{20}H_{22}O_4N^+$: 340.1549
MP: (ClO_4^-) 211-212° (H_2O) (15)
(I^-) 174-175° (MeOH) (15)
$[\alpha]^{25}$D: (ClO_4^-) −224° (c=0.13, MeOH) (15)
$[\alpha]^{24}$D: (I^-) −160° (c=0.12, MeOH) (15)
UV: (ClO_4^-) (MeOH) 291.5 (3.95), 225 sh (4.07) (15)
IR: (ClO_4^-) (KBr) 3400, 1628, 1600, 1506, 1485, 1447, 1392, 1355, 1303, 1270, 1246, 1112, 1036, 950, 930, 908, 879, 625 (15)
^{1}H-NMR: (ClO_4^-) (CD_3OD) 3.30 (s, 6H, $N(CH_3)_2$), 3.92 (s, 3H, OCH_3), 5.95 (ABq, J=1 Hz, 2H, OCH_2O), 6.60 (s, 2H, ArH), 6.82 (s, 1H, ArH), 6.95 (s, 1H, ArH) (15)
MS: (I^-) 339 (10), 338 (7), 326 (11), 325 (48), 324 (35), 311 (6), 310 (11), 309 (8), 204 (12), 191 (10), 190 (67), 189 (16), 188 (100), 176 (8), 175 (11), 142 (43), 127 (18) (15)
CD: (ClO_4^-) (MeOH) $[\theta]_{297}$ −39,400, $[\theta]_{279}$ +82,000, $[\theta]_{238}$ −380,400 (15)
SOURCE: LAURACEAE: *Cryptocarya chinensis* Hemsl. (15)

14. (−)-ESCHSCHOLTZINE
((−)-Crychine, (−)-Californine)

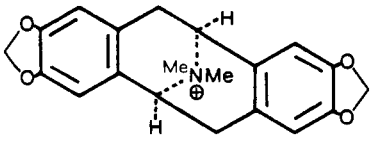


ArH δ 6.40 s(2H), and 6.58 s(2H)
J_{ab} 6 Hz, J_{ac} 0 Hz, J_{bc} 17 Hz

$C_{19}H_{17}O_4N$: 323.1157
MP: 128° (MeOH) (44)
127-128° (Et_2O) (49)
$[\alpha]^{20}$D: −184.5° (c=2.20, $CHCl_3$) (48)
$[\alpha]^{20}$D: −202° (c=1.00, MeOH) (10, 44)
$[\alpha]^{15}$D: −220.2° (c=1.00, EtOH) (48)
$[\alpha]^{19}$D: −240°±3° (c=0.50, MeOH) (49)
UV: (EtOH) 235 sh (3.80), 275 sh (3.93), 281 (4.03), 296 (4.04), 307 sh (3.96) (10, 12, 13d, 44, 48, 49)
IR: ($CHCl_3$) 3010, 2960, 2890, 2770, 1624, 1503, 1482, 1438, 1380, 1370, 1339, 1311, 1283, 1270, 1168, 1130, 1119, 1070, 1041, 1019, 973, 952, 939, 866, 838 (13d, 48)
^{1}H-NMR: ($CDCl_3$) (12, 48)

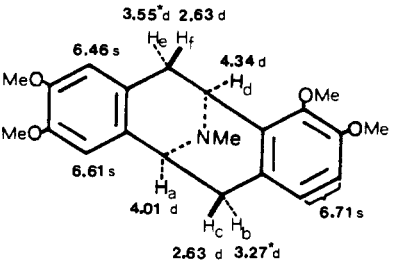
MS: 323, 188 (12, 17)
ORD: (c=0.10, EtOH) $[\alpha]_{360}$ −900°, $[\alpha]_{301}$ −1,250° tr, $[\alpha]_{292}$ +850° pk, $[\alpha]_{275}$ −7,200° sh, $[\alpha]_{245}$ −15,600° tr, $[\alpha]_{232}$ −4,000° pk, $[\alpha]_{215}$ −36,000° (10, 7)
CD: (EtOH) $[\theta]_{306}$ 0, $[\theta]_{300}$ −2,395, $[\theta]_{297}$ 0, $[\theta]_{286}$ +18,650, $[\theta]_{254}$ 0, $[\theta]_{240}$ −37,310, $[\theta]_{227}$ +17,050, $[\theta]_{205}$ −255,000 (10)
SOURCES: PAPAVERACEAE: *Eschscholtzia californica* Cham. (44, 50), *E. douglasii* (Hook. and Arn.) Walp. (49), *E. Glauca* Greene (49)
LAURACEAE: *Cryptocarya chinensis* Hemsl. (47, 48)

15. (−)-CALIFORNIDINE
((−)-Eschscholtzine N-metho salt)



$C_{20}H_{20}O_4N^+$: 338.1392
MP: (I^-) 285-286° (MeOH) (49)
(ClO_4^-) 324-326° (H_2O) (49)
(ClO_4^-) 327-329° (MeOH) (51)
$[\alpha]^{18}D$: (I^-) −212°±3° (c=0.5, MeOH) (49)
$[\alpha]^{19}D$: (ClO_4^-) −217° (c=0.2, EtOH) (49)
$[\alpha]^{23}D$: (ClO_4^-) −219°±10° (c=0.10, MeOH) (51)
UV: (I^-)(MeOH) 292 (4.02) (49, 13e)
IR: (Nujol) 1510, 1494, 1483, 1342, 1239, 1225, 1210, 1178, 1153, 1131, 1074, 1038, 1019, 1010, 983, 950, 924, 908, 900, 860, 850, 839, 742 (13e)
SOURCES: PAPAVERACEAE: *Eschscholtzia californica* Cham. (52), *E. douglasii* (Hook. and Arn.) Walp. (49), *E. glauca* Greene (49), *E. oregana* Greene (51)

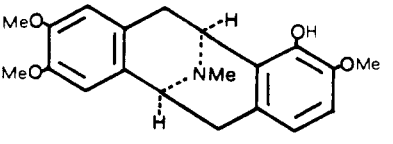
16. (−)-O-METHYLPLATYCERINE
((−)-O,O-Dimethylmunitagine)



Four OCH_3 δ 3.77, 3.80, 3.85 and 3.94.
$J_{ab=de}$ 6 Hz, $J_{ac=df}$ 0 Hz, $J_{bc=ef}$ 17 Hz

$C_{21}H_{25}O_4N$: 355.1783
MP: 124-125.5° (Et_2O + Skellysolve A) (8)
$[\alpha]^{27}D$: −292° (c=0.35, $CHCl_3$) (8)
$[\alpha]^{20}D$: −202° (c=0.14, $CHCl_3$) (9)
IR: (KBr) 2950, 2860, 1610, 1510 d, 1450, 1430, 1370, 1350, 1280, 1250 d, 1220, 1135, 1110, 1080, 1040,, 1015 d, 990, 978, 873, 863, 847, 820, 785, 770, 732 (8)
^{1}H-NMR: ($CDCl_3$) (8)
SOURCE: Semisynthetic (8, 9; See also 53)

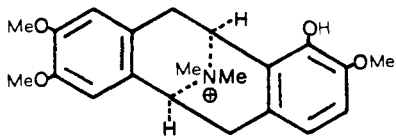
17. PLATYCERINE



$C_{20}H_{23}O_4N$: 341.1627
MP: 130-132° (Et_2O) (9)
$[\alpha]^{21}D$: −267°±3° (c=0.24, $CHCl_3$) (9)
$[\alpha]^{28}D$: −305° (c=0.2, MeOH) (30)
UV: (MeOH) 282 (3.85), 315 sh (3.38) (30, 9, 13f)
IR: ($CHCl_3$) 3550, 3010, 2965, 2940, 2910, 2850, 2840, 2810, 2775,, 1616, 1594, 1518, 1500, 1467, 1446, 1372, 1358, 1330, 1313, 1281, 1244, 1173, 1156, 1129, 1108, 1083, 1058, 1036, 1019, 1004, 985, 951, 931, 867, 858, 823 (13f, 9)
^{1}H-NMR: ($CDCl_3$) 2.51 (s, 3H, NCH_3), 3.72 (s, 3H, OCH_3), 3.77 (s, 3H, OCH_3), 3.81 (s, 3H, OCH_3), 3.95 (d, J=6 Hz, 1H, CH), 4.36 (d,

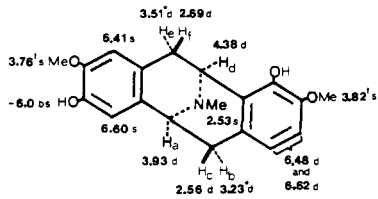
J=6 Hz, 1H, CH), 6.47 and 6.72 (ABq, J=8.5 Hz, 2H, ArH), 6.46 (s, 1H, ArH), 6.55 (s, 1H, ArH) (30, 5).
MS: 341 (33), 340 (22), 204 (100), 190 (30), 170.5 (3) (5)
CD: (MeOH) $[\theta]_{275}$ −15,800, $[\theta]_{240}$ +32,400 (30)
SOURCES: PAPAVERACEAE: *Argemone gracilenta* Greene (5), *A. platyceras* Link and Otto (9)
RANUNCULACEAE: *Thalictrum revolutum* DC (29, 30)

18. (−)-PLATYCERINE N-METHO SALT



$C_{21}H_{26}O_4N^+$: 356.1862
MP: (ClO_4^-) 160-164° (MeOH) (34)
(ClO_4^-) 152-175° (MeOH-Et_2O) (33)
$[\alpha]^{22}D$: (ClO_4^-) −257°±3° (c=0.26, MeOH) (33)
UV: (ClO_4^-) (MeOH) 227 (4.12), 234 (4.14), 260 (3.27), 284 (3.77) (33)
IR: (ClO_4^-) (Nujol) 3380, 3370 (33)
MS: (I^-) 341, 340, 204, 190, 142, 127 (33)
SOURCE: PAPAVERACEAE: *Argemone platyceras* Link and Otto (33, 34)

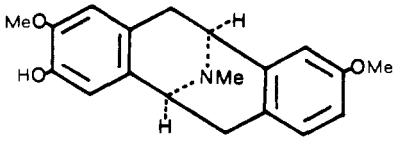
19. (−)-MUNITAGINE



$J_{ab=de}$ 6 Hz, $J_{ac=df}$ 0 Hz, $J_{bc=ef}$ 17 Hz, $J_{9,10}$ 8 Hz

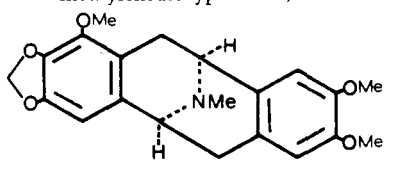
$C_{19}H_{21}O_4N$: 327.1470
MP: 167-169° (MeOH-Et_2O) (8)
$[\alpha]^{27}D$: −239° (c=0.5, $CHCl_3$) (8)
UV: (EtOH) 283 (3.63) (54)
IR: (KBr) 3580, 3470, 2950, 2870, 1620, 1500, 1455, 1370, 1335, 1285, 1250, 1135, 1123, 1080, 1020, 990, 960, 870, 828, 804, 783, 768, 730 (8)
^{1}H-NMR: ($CDCl_3$) (8)
MS: 328 (7), 327 (30), 326 (25), 312 (7), 192 (16), 191 (17), 190 (100), 177 (6), 175 (7), 156 (7), 147 (12), 145 (6) (8)
SOURCES: PAPAVERACEAE: *Argemone gracilenta* Greene (5), *A. munita* Dur. and Hilg. var. *rotundata* (Rydb.) G. B. Ownb. (8, 43)

20. (−)-2-HYDROXY-3,8-DIMETHOXYPAVINANE ((−)-2,9-Dimethoxy-3-hydroxypavinane)



$C_{19}H_{21}O_3N$: 311.1521
MP: 197-198° (MeOH) (43)
$[\alpha]^{27}D$: −254° (c=1.59, MeOH) (43)
IR: (KBr) 2920, 1625, 1530, 1505, 1460, 1430, 1330, 1260, 1120, 1020, 875 (43)
^{1}H-NMR: 2.46 (s, 3H, NCH_3), 3.73 (s, 6H, OCH_3), 2.35-4.06 (m, 2 ABX, 6H, saturated ring H), 6.45-6.80 (m, 5H, ArH) (43)
MS: 311 (55), 190 (100), 174 (63) (43)
SOURCE: PAPAVERACEAE: *Argemone munita* Dur. and Hilg. var. *rotundata* (Rydb.) G. B. Ownb. (43)

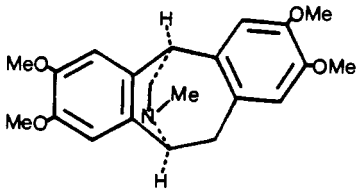
21. (−)-2,3-METHYLENENEDIOXY-4,8,9-TRIMETHOXYPAVINANE ((−)-2,3,7-Trimethoxy-8,9-methylenedioxypavinane)



$C_{21}H_{23}O_5N$: 369.1576
MP: 144-145° (Et_2O) (55)
$[\alpha]^{22}D$: −174° (c=0.977, MeOH) (55)
UV: (EtOH) 287 (3.84) (55)
^{1}H-NMR: ($CDCl_3$) 2.46 (s, 3H, NCH_3), 3.72 (s, 3H, OCH_3), 3.80 (s, 6H, OCH_3), 2.40-4.05 (m, 6H, saturated ring H), 5.75 and 5.80 (2 x d, J=1.5 Hz, 2H, OCH_2O), 6.23 (s, 1H, ArH), 6.36 (s, 1H, ArH), 6.54 (s, 1H, ArH) (55)

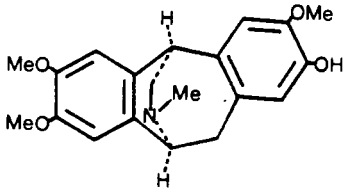
MS: 369, 368, 354, 204 (100), 218 (70) (55)
SOURCE: RANUNCULACEAE: *Thalictrum strictum* Ledeb. (55)

22. (−)-O-METHYLTHALISOPAVINE



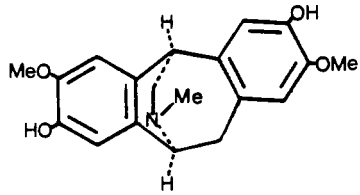
$C_{21}H_{25}O_4N$: 355.1783
MP: For synthetic racemate:
163-165° (MeOH-H_2O) (56)
165-166° (MeOH) (57)
164-166.5° (MeOH) (55)
IR: ($CHCl_3$) 1605 (42)
^{1}H-NMR: ($CDCl_3$) 2.46 (s, 3H, NCH_3), 3.75 (s, 3H, OCH_3), 3.84 (s, 9H, OCH_3), 2.60-4.00 (m, 6H, saturated ring H), 6.51 (s, 1H, ArH), 6.64 (s, 1H, ArH), 6.75 (s, 2H, ArH) (57, 42, 59)
MS: 355 (22), 354 (18), 312 (36), 281 (7), 269 (14), 204 (100) (59, 42, 56)
SOURCE: PAPAVERACEAE: *Papaver radicatum* Rottb. (=*P. nudicaule* L. var. *radicatum* Rottb.) (59)

23. (−)-THALISOPAVINE



$C_{20}H_{23}O_4N$: 341.1627
MP: 211-212° (EtOH) (42)
$[\alpha]^{25}D$: −210° (c=0.21, $CHCl_3$) (42)
UV: (EtOH) 289 (4.06) (42)
IR: ($CHCl_3$) 3571, 1610, 1600 (42)
^{1}H-NMR: 2.48 (s, 3H, NCH_3), 3.86 (s, 9H, OCH_3), 4.90 (bs, 1H, OH), 6.54 (s, 1H, ArH), 6.61 (s, 1H, ArH), 6.75 (s, 2H, ArH) (42)
MS: 341, 204 (100) (42)
SOURCE: RANUNCULACEAE: *Thalictrum dasycarpum* Fisch. and Lall. (42)

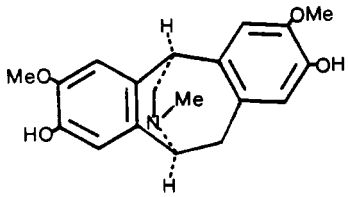
24. (−)-THALIDICINE



Structural determination is incomplete. Alkaloid may be identical with (−)-thalidine.

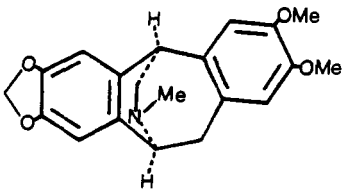
$C_{19}H_{21}O_4N$: 327.1470
MP: 200° (EtOH-Et_2O) (60)
UV: (EtOH) 221 (4.38), 290 (3.96) (60)
IR: (KBr) 3420, 2940, 1595, 1510, 1450, 1260, 1140, 1030, 760 (60)
^{1}H-NMR: (DMSO-d_6) 2.26 (s, 3H, NCH_3), 3.06-3.6 (m, 7H, saturated ring H and 1 OH), 3.70 (s, 6H, OCH_3), 6.36 (s, 1H, ArH), 6.60 (s, 1H, ArH), 6.66 (s, 1H, ArH), 6.73 (s, 1H, ArH), 8.58 (s, 1H, OH) (60)
MS: 327 (12), 326 (17), 284 (34), 241 (14), 190 (100) (60)
SOURCE: RANUNCULACEAE: *Thalictrum dioicum* L. (60)

25. (−)-THALIDINE



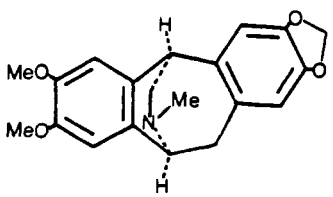
$C_{19}H_{21}O_4N$: 327.1470
MP: 205-207° (MeOH) (61)
$[\alpha]^{25}D$: −172° (c=0.7, MeOH) (61)
UV: (EtOH) 250 sh (4.08), 291 (4.30) (61)
^{1}H-NMR: (TFA-*d*) 3.00 (s, 3H, NCH_3), 3.99 (s, 6H, OCH_3), 6.70 (s, 1H, ArH), 6.83 (s, 1H, ArH), 7.00 (s, 1H, ArH), 7.12 (s, 1H, ArH) (61)
MS: 327, 284, 190 (100) (61)
CD: (MeOH) $[\theta]_{255}$ −2,753, $[\theta]_{250}$ −8,261, $[\theta]_{245}$ −26,848, $[\theta]_{240}$ −33,043, $[\theta]_{235}$ −30,290, $[\theta]_{230}$ −22,373, $[\theta]_{225}$ −13,768, $[\theta]_{220}$ −4,130, $[\theta]_{215}$ 0, $[\theta]_{210}$ 0 (62)
SOURCE: RANUNCULACEAE: *Thalictrum dioicum* L. (61)

26. (−)-AMURENSININE



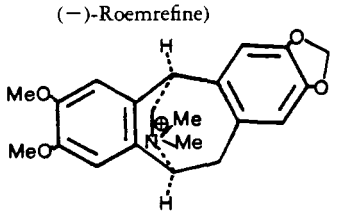
$C_{20}H_{21}O_4N$: 339.1470
MP: 136°-138° (Et_2O) (65)
144-146° (MeOH) (66)
143-144° (Et_2O) (64)
162-164° (63)
$[\alpha]^{22}D$: −102°±4° (c=0.14, MeOH) (66)
$[\alpha]^{21}D$: −108°±10° (c=0.14, MeOH) (64)
$[\alpha]^{22}D$: −42.6°±3° (c=0.16, $CHCl_3$) (66)
$[\alpha]^{22}D$: −142°±5° (c=0.10, MeOH) (65)
$[\alpha]^{22}D$: −162°±4° (c=0.80, $CHCl_3$) (63)
$[\alpha]^{22}D$: −175°±4° (c=0.750, MeOH) (63)
UV: (EtOH) 230 (4.07), 250 sh (3.67), 294 (3.95) (63-66)
IR: ($CHCl_3$) 1606 (63)
^{1}H-NMR: ($CDCl_3$) 2.50 (s, 3H, NCH_3), 3.14 (m, 4H, 2 x CH_2), 3.78 (s, 3H, OCH_3), 3.86 (s, 3H, OCH_3), 3.84, 3.93 and 4.02 (t, 2H, CH), 5.83, 5.85, 5.90 and 5.93 (ABq, 2H, OCH_2O), 6.53 (d, 1H, ArH), 6.63 (d, 1H, ArH), 6.73 (s, 2H, ArH) (63, 66, 67)
MS: 339 (20), 338 (19), 312 (4), 296 (27), 188 (100) (68, 40, 64-66)
SOURCES: PAPAVERACEAE: *Papaver tauricola* Boiss. (68), *P. anomalum* Fedde (66), *P. pseudocanescens M. Pop. (65), P. pyrenaicum* L. (Kerneri) (69), *P. pyrenaicum* L. (Kerneri) var. *rhoeaticum* (Ler.) Fedde (64), *P. alpinum* L. (69), *P. alpinum* L. var. *burseri* (64), *P. alpinum* L. var. *kerneri* (64), *P. alpinum* L. var. *tatricum* Nyár. (64, 69), *P. nudicaule* L. var. *xanthopetalum* (Trautv.) Fedde (69), *P. nudicaule* L. var. *leiocarpum* (Turz.) (69), *P. nudicaule* L. var. *rubroaurantiacum* DC (69), *P. radicatum* Rottb. (=*P. nudicaule* L. var. *radicatum* Rottb.) (59), *P. suaveolens* Lap. (69)

27. (−)-REFRAMINE



$C_{20}H_{21}O_4N$: 339.1470
MP: Amorphous
$[\alpha]^{24}D$: −146°±3° (c=0.50, MeOH) (70)
UV: (MeOH) 235 sh (4.00), 248 sh (3.75), 292 (3.83) (70)
IR: ($CHCl_3$) 1610-1460, 1145-945, 875, 865 (70)
^{1}H-NMR: ($CDCl_3$) 2.58 (s, 3H, NCH_3), 3.90 (s, 6H, OCH_3), 5.87 (q, J=2 Hz, 2H, OCH_2O), 6.55 (s, 1H, ArH), 6.70 (s, 1H, ArH), 6.83 (s, 1H, ArH), 6.90 (s, 1H, ArH) (57)
MS: 339, 338, 296, 253, 204 (100) (71)
SOURCE: PAPAVERACEAE: *Roemeria refracta* (Stev.) DC (=*R. rhoeadiflora* Boiss.) (70)

28. (−)-REMREFINE
((−)-Reframine N-metho salt, (−)-Roemrefine)

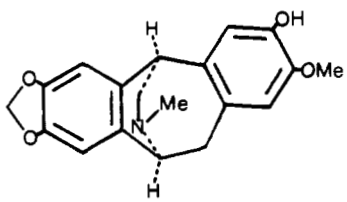


$C_{21}H_{24}O_4N^+$: 354.1704
MP: (Cl^-) 241-242° (EtOH-acetone) (72)
(I^-) 244-245° (H_2O-MeOH) (72)
(C^-) 258-259° (MeOH) (70)
(I^-) 265-266° (MeOH) (70)
$[\alpha]^{21}D$: (Cl^-) −147° (c=1.039, H_2O) (72)
$[\alpha]^{21}D$: (Cl^-) −188°±3° (c=0.33, H_2O) (70)
UV: (Cl^-) (MeOH) 234 (4.11), 250 sh (3.75), 291 (3.88) (70, 72)
^{1}H-NMR: (D_2O) 2.9 and 3.38 (2s, 6H, $N(CH_3)_2$, 3.83 (s, 3H, OCH_3), 3.88 (s, 3H, OCH_3), 5.72 and 5.84 (2s, 2H, OCH_2O), 6.28 (s, 1H, ArH),

6.67 (s, 1H, ArH), 7.05 (s, 1H, ArH), 7.17 (s, 1H, ArH) (72, 73)

SOURCE: PAPAVERACEAE: *Roemeria refracta* (Stev.) DC (=*R. rhoeadiflora* Boiss.) (70)

29. (−)-AMURENSINE
((−)-Xanthopetaline)



$C_{19}H_{19}O_4N$: 325.1314

MP: 206-208° (MeOH-Et_2O-hexane) (65)
213° (acetone) (74)
216-217° (acetone) (64)
221-223° (63)

$[\alpha]^{22}D$: −178°±4° (c=0.819, MeOH) (63)

$[\alpha]^{22}D$: −194° (c=0.25, $CHCl_3$) (74)

UV: (EtOH) 230 (4.07), 250 sh (3.67), 294 (3.95) (63, 13g, 64-66, 75)

IR: (Nujol) 3580, 1596, 1530, 1501, 1339, 1308, 1290, 1256, 1243, 1225, 1200, 1172, 1150, 1136, 1119, 1104, 1073, 1051, 1034, 990, 969, 929, 882, 871, 861, 843, 819, 773, 764, 729, 716, 703 (13g, 63)

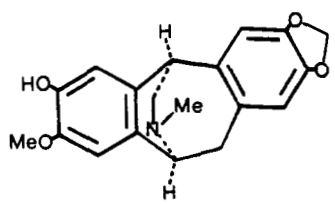
^{1}H-NMR: ($CDCl_3$) 2.50 (s, 3H, NCH_3), 2.69-3.63 (m, 4H, CH_2), 3.74, 3.81 and 3.88 (t, 2H, CH), 3.83 (s, 3H, OCH_3), 5.83, 5.85, 5.90 and 5.93 (ABq, 2H, OCH_2O), 6.53 (s, 1H, ArH), 6.58 (s, 1H, ArH), 6.70 (s, 2H, ArH) (63)

MS: 325, 309, 282, 239, 188 (100) (40)

CD: (EtOH) $\Delta\epsilon_{nm}$ -5.84_{295}, $+2.1_{275}$, -3.74_{245}, $+8.2_{230}$, -8.2_{215} (75, 19)

SOURCES: PAPAVERACEAE: *Papaver alpinum* L. (69), *P. alpinum* L. var. *tatricum* Nyár. (64), *P. alpinum* L. var. *burseri* (64), *P. alpinum* L. var. *kerneri* (Hay.) Fedde (64), *P. pseudocanescens* M. Pop. (65, 66), *P. nudicaule* L. var. *amurense* Hort. (74), *P. nudicaule* L. var. *xanthopetalum* (Trautv.) Fedde (69, 76), *P. nudicaule* L. var. *leiocarpum* (Turz.) (69), *P. nudicaule* L. var. *rubroaurantiacum* DC (69), *P. pyrenaicum* L. (Kerneri) (69), *P. tatricum* Nyár. (69), *P. suaveolens* Lap. (69), *P. anomalum* Fedde (76)

30. (−)-REFRAMOLINE



$C_{19}H_{19}O_4N$: 325.1314

MP: 160° (Et_2O), (19)

$[\alpha]^{20}D$: −144° (c=0.37, EtOH) (19)

$[\alpha]^{20}D$: −140°±5° (c=0.13, MeOH) (70)

UV: (MeOH) 230 sh (4.00), 248 (2,43), 290 (3.92) (70, 19)

IR: ($CHCl_3$) 3540, 1605-1450, 1140-940, 875, 865 (70)

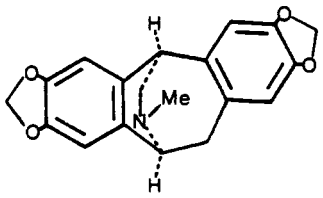
^{1}H-NMR: ($CHCl_3$) 2.55 (s, 3H, NCH_3), 2.8-3.8 (m, 6H, saturated ring H), 3.85 (s, 3H, OCH_3), 5.83 and 5.86 (2s, 2H, OCH_2O), 6.2 (bs, 1H, OH), 6.49 (s, 1H, ArH), 6.62 (s, 1H, ArH), 6.73 (s, 1H, ArH), 6.78 (s, 1H, ArH) (19)

MS: 326 (7), 325 (32), 324 (35), 282 (38), 190 (100), 188 (4) (19)

CD: (19)

SOURCE: PAPAVERACEAE: *Roemeria refracta* (Stev.) DC (=*R. rhoeadiflora* Boiss.) (70)

31. (−)-REFRAMIDINE



$C_{19}H_{17}O_4N$: 323.1157
MP: Amorphous (70)
$[\alpha]^{23}D$: $-123°\pm3°$ (c=0.4, MeOH) (70)
UV: (MeOH) 235 sh (4.00), 248 sh (3.72), 294 (3.93) (70)
IR: ($CHCl_3$) 1505-1485, 1155-945, 870 (70)
^{1}H-NMR: ($CDCl_3$) 2.45 (s, 3H, NCH_3), 2.60-3.92 (m, 6H, saturated ring H), 5.90 (m, 4H, OCH_2O), 6.55 (s, 1H, ArH), 6.65 (s, 1H, ArH), 6.75 (s, 2H, ArH) (57)
MS: 323, 322, 280, 237, 188 (100) (71, 57, 66)
SOURCES: PAPAVERACEAE: *Papaver anomalum* Fedde (66), *Roemeria refracta* (Stev.) DC (=*R. rhoeadiflora* Boiss.) (70)

Botanical Distribution of Pavine and Isopavine Alkaloids

(−)-argemonine
Berberidaceae: *Berberis buxifolia* Lam. (3).
Papaveraceae: *Argemone gracilenta* Greene (5), *A. hispida* Gray (4, 8, 14), *A. munita* Dur. and Hilg. (24), *A. munita* Dur. and Hilg. var. *argentea* G. B. Ownb. (27), *A. munita* Dur. and Hilg. var. *rotundata* (Rydb.) G. B. Ownb. (4, 14, 25, 26), *A. platyceras* Link and Otto (90), *A. sanguinea* Greene (28).
Ranunculaceae: *Thalictrum revolutum* DC (6, 29, 30), *T. strictum* Ledeb. (2).

(+)-argemonine
Berberidaceae: *Leontice smirnovii* Trautv. (31, 32).

(−)-argemonine N-metho salt
Papaveraceae: *Argemone gracilenta* Greene (5), *A. platyceras* Link and Otto (33, 34)
Ranunculaceae: *Thalictrum revolutum* DC (29).

(−)-argemonine N-oxide
Papaveraceae: *Argemone gracilenta* Greene (5).

(−)-norargemonine
Berberidaceae: *Berberis buxifolia* Lam. (3).
Papaveraceae: *Argemone brevicornuta* G. B. Ownb. (41), *A. hispida* Gray (4, 8, 14), *A. munita* Dur. and Hilg. var. *rotundata* (Rydb.) G. B. Ownb. (14, 25, 26, 29), *A. platyceras* Link and Otto (9, 36), *Eschscholtzia californica* Cham. (37), *E. douglasii* (Hook. and Arn.) Walp. (37), *E. glauca* Greene (37).
Ranunculaceae: *Thalictrum dasycarpum* Fisch. and Lall. (42).
Lauraceae: *Cryptocarya longifolia* Kostermans (35).

(−)-isonorargemonine
Papaveraceae: *Argemone gracilenta* Greene (5), *A. munita* Dur. and Hilg. var. *argentea* G. B. Ownb. (27).
Ranunculaceae: *Thalictrum revolutum* DC (30).

(−)-bisnorargemonine
Papaveraceae: *Argemone hispida Gray (8), A. munita* Dur. and Hilg. var. *rotundata* (Rydb.) G. B. Ownb. (8, 25, 43), *Eschscholtzia californica* Cham. (37, 44), *E. douglasii* (Hook. and Arn.) Walp. (37), *E. glauca* Greene (37).
Ranunculaceae: *Thalictrum dasycarpum* Fisch. and Lall. (42).
Lauraceae: *Cryptocarya longifolia* Kostermans (35).

(−)-eschscholtzidine
Papaveraceae: *Eschscholtzia californica* Cham. (46).
Ranunculaceae: *Thalictrum revolutum* DC (6, 29).

(+)-eschscholtzidine
Lauraceae: *Cryptocarya chinesis* Hemsl. (47).

(−)-eschscholtzidine N-metho salt
Ranunculaceae: *Thalictrum revolutum* DC (29).

(−)-caryachine
Lauraceae: *Cryptocarya chinensis* Hemsl. (47, 48).

(±)-caryachine
Lauraceae: *Cryptocarya chinensis* Hemsl. (47, 48).

(−)-caryachine N-metho salt
Lauraceae: *Cryptocarya chinensis* Hemsl. (15)

(−)-eschscholtzine
Papaveraceae: *Eschscholtzia californica* Cham. (44, 50), *E. douglasii* (Hook. and Arn.) Walp. (49), *E. glauca* Greene (49).

Lauraceae: *Cryptocarya chinensis* Hemsl. (47, 48).

(−)-californidine
Papaveraceae: *Eschscholtzia californica* Cham. (52), *E. douglasii* (Hook. and Arn.) Walp. (49), *E. glauca* Greene (49), *E. oregana* Greene (51).

(−)-platycerine
Papaveraceae: *Argemone gracilenta* Greene (5), *A. platyceras* Link and Otto (9).

Ranunculaceae: *Thalictrum revolutum* DC (29, 30).

(−)-platycerine N-metho salt
Papaveraceae: *Argemone platyceras* Link and Otto (33, 34).

(−)-munitagine
Papaveraceae: *Argemone gracilenta* Greene (5), *A. munita* Dur. and Hilg. var. *rotundata* (Rydb.) G. B. Ownb. (8, 43).

(−)-2-hydroxy-3,8-dimethoxypavinane
Papaveraceae: *Argemone munita* Dur. and Hilg. var. *rotundata* (Rydb.) G. B. Ownb. (43)

(−)-2,3-methylenedioxy-4,8,9-trimethoxypavinane
Ranunculaceae: *Thalictrum strictum* Ledeb. (55)

(−)-O-methylthalisopavine
Papaveraceae: *Papaver radicatum* Rottb. (=*P. nudicaule* L. var. *radicatum* Rottb.) (59).

(−)-thalisopavine
Ranunculaceae; *Thalictrum dasycarpum* Fisch. and Lall. (42)

(−)-thalidicine
Ranunculaceae: *Thalictrum dioicum* L. (60).

(−)-thalidine
Ranunculaceae: *Thalictrum dioicum* L. (61)

(−)-amurensinine
Papaveraceae: *Papaver tauricola* Boiss. (68), *P. anomalum* Fedde (66), *P. pseudocanescens* M. Pop. (65), *P. pyrenaicum* L. (Kerneri) (69), *P. pyrenaicum* L. (Kerneri) var. *rhoeaticum* (Ler.) Fedde (64), *P. alpinum* L. (69), *P. alpinum* L. var. *burseri* (64), *P. alpinum* L. var. *kerneri* (64), *P. alpinum* L. var. *tatricum* Nyár (64, 69), *P. nudicaule* L. var. *xanthopetalum* (Trautv.) Fedde (69)., *P. nudicaule* L. var. *leiocarpum* (Turz.) (69), *P. nudicaule* L. var. *rubroaurantiacum* DC (69), *P. radicatum* Rottb. (=*P. nudicaule* L. var. *radicatum* Rottb.) (59), *P. suaveolens* Lap. (69).

(−)-reframine
Papaveraceae: *Roemeria refracta* (Stev.) DC (=*R. rhoeadiflora* Boiss.) (70).

(−)-remrefine
Papaveraceae: *Roemeria refracta* (Stev.) DC (=*R. rhoeadiflora* Boiss.) (70).

(−)-amurensine
Papaveraceae: *Papaver alpinum* L. (69), *P. alpinum* L. var. *tatricum Nyár (64), P. alpinum L. var.* burseri (64), *P. alpinum* L. var. *kerneri* (Hay.) Fedde (64), *P. pseudocanescens* M. Pop. (65,

66), *P. nudicaule* L. var. *amurense* Hort. (74), *P. nudicaule* L. var. *xanthopetalum* (Trautv.) Fedde (69, 76), *P. nudicaule* L. var. *leiocarpum (Turz.)* (69), *P. nudicaule* L. var. *rubroaurantiacum* DC (69), *P. pyrenaicum* L. (Kerneri) (69), *P. tatricum* Nyar (69), *P. suaveolens* Lap. (69), *P. anomalum* Fedde (76).

(−)-reframoline
Papaveracerae: *Roemeria refracta* (Stev.) DC (=*R. rhoeadiflora* Boiss. (70)

(−)-reframidine
Papaveraceae: *Papaver anomalum* Fedde (66), *Roemeria refracta* (Stev.) DC (=*R. rhoeadiflora* Boiss.) (70).

Occurrence of Pavines and Isopavines by Plant Sources

Family Berberidaceae	
Genus *Berberis*	
B. buxifolia Lam.	(−)-argemonine, (−)-norargemonine
Genus *Leontice*	
L. smirnovii Trautv.	(+)-argemonine
Family Lauraceae	
Genus *Cryptocarya*	
C. chinensis Hemsl.	(+)-caryachine, (−)-caryachine, (−)-caryachine N-metho salt, (+)-eschscholtzidine, (−)-eschscholtzine
C. longifolia Kostermans	(−)-bisnorargemonine, (−)-norargemonine
Family Papaveraceae	
Genus *Argemone*	
A. brevicornuta G. B. Ownb.	(−)-norargemonine
A. gracilenta Greene	(−)-argemonine, (−)-argemonine N-metho salt, (−)-argemonine N-oxide, (−)-isonorargemonine, (−)-munitagine, (−)-platycerine
S. hispida Gray	(−)-argemonine, (−)-bisnorargemonine, (−)-norargemonine
A. munita Dur. and Hilg.	(−)-argemonine
var. *argentea* G. B. Ownb.	(−)-argemonine, (−)-isonorargemonine
var. *rotundata* (Rydb.) G. B. Ownb.	(−)-argemonine, (−)-bisnorargemonine, (−)-2-hydroxy-3,8-dimethoxypavinane, (−)-munitagine, (−)-norargemonine
A. platyceras Link and Otto	(−)-argemonine, (−)-argemonine N-metho salt, (−)-norargemonine, (−)-platycerine, (−)-platycerine N-metho salt
A. sanguinea Greene	(−)-argemonine
Genus *Eschscholtzia*	
E. californica Cham.	(−)-bisnorargemonine, (−)-californidine, (−)-eschscholtzidine, (−)-eschscholtzine, (−)-norargemonine
E. douglasii Hook. and Arn.	(−)-bisnorargemonine, (−)-californidine, (−)-eschscholtzine, (−)-norargemonine
E. glauca Greene	(−)-bisnorargemonine, (−)-californidine, (−)-eschscholtzine, (−)-norargemonine
E. oregana Greene	(−)-californidine
Genus *Papaver*	
P. alpinum L.	(−)-amurensine, (−)-amurensinine
P. anomalum Fedde	(−)-amurensine, (−)-amurensinine, (−)-reframidine
P. nudicaule L.	
var. *amurense* Hort.	(−)-amurensine
var. *leiocarpum* (Turz.)	(−)-amurensine, (−)-amurensinine
var. *rubro-aurantiacum* DC	(−)-amurensine, (−)-amurensinine
var. *xanthopetalum* (Trautv.) Fedde	(−)-amurensine, (−)-amurensinine
P. pyrenaicum L. (Kerneri)	(−)-amurensine, (−)-amurensinine
var. *rhoeaticum* (Ler.) Fedde	(−)-amurensinine
P. radicatum Rottb. (=*P. nudicaule* L. var. *radicatum* Rottb.)	(−)-amurensinine, (−)-O-methylthalisopavine

P. suaveolens Lap.	(−)-amurensine, (−)-amurensinine
P. tatricum Nyár	(−)-amurensine
P. tauricola Boiss.	(−)-amurensinine
P. alpinum L.	
var. *tatricum* Nyár	(−)-amurensine, (−)-amurensinine
var. *burseri*	(−)-amurensine, (−)-amurensinine
var. *kerneri* (Hay.) Fedde	(−)-amurensine, (−)-amurensinine
P. pseudocanescens M. Pop.	(−)-amurensine, (−)-amurensinine
Genus *Roemeria*	
R. refracta (Stev.) DC (=*R. rhoeadiflora* Boiss.)	(−)-reframidine, (−)-reframine, (−)-reframoline, (−)-remrefine
Family Ranunculaceae	
Genus *Thalictrum*	
T. dasycarpum Fisch. and Lall.	(−)-bisnorargemonine, (−)-norargemonine, (−)-thalisopavine
T. dioicum L.	(−)-thalidicine, (−)-thalidine
T. revolutum DC	(−)-argemonine, (−)-argemonine N-metho salt, (−)-eschscholtzidine, (−)-eschscholtzidine N-metho salt, (−)-isonorargemonine, (−)-platycerine
T. strictum Ledeb.	(−)-argemonine, (−)-2,3-methylenedioxy-4,8,9-trimethoxypavinane

Alphabetical List of Pavine Alkaloids

(−)-Argemonine (**1**)
(+)-Argemonine (**2**)
(−)-Argemonine *N*-metho salt (**3**)
(−)-Argemonine *N*-oxide (**4**)
(−)-Bisnorargemonine (**7**)
(−)-Californidine (**15**)
(−)-Caryachine (**11**)
(±)-Caryachine (**12**)
(−)-Caryachine *N*-metho salt (**13**)
(−)-Eschscholtzidine (**8**)
(+)-Eschscholtzidine (**9**)
(−)-Eschscholtzidine *N*-metho salt (**10**)
(−)-Eschscholtzine (**14**)
(−)-2-Hydroxy-3,8-dimethoxypavinane (**20**)
(−)-Isonorargemonine (**6**)
(−)-2,3-Methylenedioxy-4,8,9-trimethoxypavinane (**21**)
(−)-Munitagine (**19**)
(−)-*O*-Methylplatycerine (**16**)
(−)-Norargemonine (**5**)
(−)-Platycerine (**17**)
(−)-Platycerine *N*-metho salt (**18**)

Alphabetical List of Isopavine Alkaloids

(−)-Amurensine (**29**)
(−)-Amurensinine (**26**)
(−)-*O*-Methylthalisopavine (**22**)
(−)-Reframidine (**31**)
(−)-Reframine (**27**)
(−)-Reframoline (**30**)
(−)-Remrefine (**28**)
(−)-Thalidicine (**24**)
(−)-Thalidine (**25**)
(−)-Thalisopavine (**23**)

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