Tetrahedron Vol. 46, No. 23, pp. 7873-7884, 1990
Printed in Great Britain

0040-4020/90 $3.00+.00

STEREOSELECTIVE TOTAL SYNTHESES OF (±)-18,19-DIHYDROHUNTERBURNINE, (±)-10-O-METHYL-18,19-DIHYDROHUNTERBURNINE, (±)-10-HYDROXYCORYNATHEIDOL AND (±)-10-METHOXYCORYNANTHEIDOL

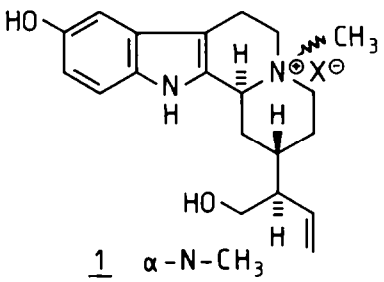
MAURI LOUNASMAA*, REIJA JOKELA AND LASSE-PEKKA TIAINEN

Laboratory for Organic and Bioorganic Chemistry,
Technical University of Helsinki, SF-02150 Espoo, Finland

(*Received in UK* 15 *June* 1990)

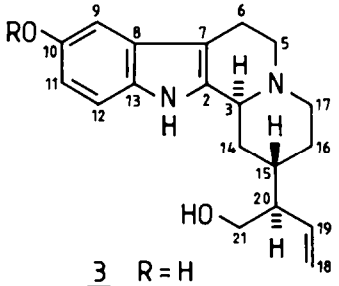
Abstract - Short, stereoselective total syntheses for (±)-18,19-dihydrohunterburnine, (±)-10-O-methyl-18,19-dihydrohunterburnine, (±)-10-hydroxycorynantheidol and (±)-10-methoxycorynantheidol are described.

Hunterburnine metho-salts 1 and 2, the initial representatives of a small group of indole alkaloids possessing the C(3)H-C(15)H[1] trans relationship with the C(15)H β-configuration,[2] were first isolated about thirty years ago by Bartlett, Taylor and coll. from the bark of Hunteria eburnea Pichon (Apocynaceae).[3,4] Since then, the presence of 1 and/or 2 has been indicated e.g. in Ochrosia sandwicensis[5] and in Pleiocarpa mutica[6]. The corresponding, long-sought tertiary base hunterburnine 3 (called 10-hydroxyantirhine), and its O-methyl derivative 10-O-methylhunterburnine 4 (called 10-methoxyantirhine), were quite recently isolated from the New Hebridian species Ochrosia alyxioides Guillaumin (Apocynaceae).[7]



1 α-N-CH_3

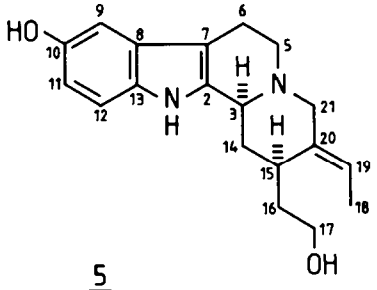
2 β-N-CH_3



3 R=H

4 R=CH_3

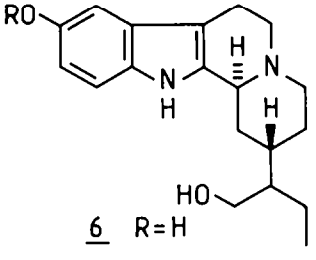
In connection with their work on Hunteria eburnea, Bartlett, Taylor and coll. also isolated a metho-salt of a third hydroxyindole alkaloid, which they called huntrabrine methochloride.[4] The corresponding tertiary base huntrabrine (= 10-hydroxygeissoschizol) 5 was later found in several other apocynaceous species, e.g. Amsonia elliptica[8], Rauwolfia vomitoria[9] and Ervatamia hainanensis[10].



5

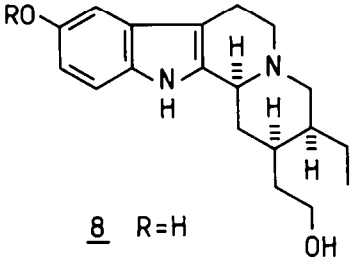
No direct total synthesis of hunterburnine 3, 18,19-dihydrohunterburnine 6 or the corresponding metho-salts has been presented, although attempts[11] at synthesis have been made. Nor has any direct total synthesis of huntrabrine 5 or its 19,20-dihydroderivatives (vide infra) been presented. There is, however, a report on the transformation of quinine into 18,19-dihydrohunterburnine 6 and its α-metho-salt.[12]

We recently developed a new synthetic method for indole alkaloids of the present type, which permits the C(3)H-C(15)H and/or C(3)H-C(20)H relationship(s) to be chosen at will.[13-18] Our method seemed to be applicable for a short synthesis of (±)-18,19-dihydrohunterburnine 6, (±)-10-O-methyl-18,19-dihydrohunterburnine 7, (±)-10-hydroxycorynantheidol 8 (= one of the two possible 19,20-dihydrohuntrabrines; vide supra) and (±)-10-methoxycorynantheidol 9. The present paper describes our results, which represent the first total syntheses of these four compounds (6, 7, 8 and 9).



6 R=H

7 R=CH_3

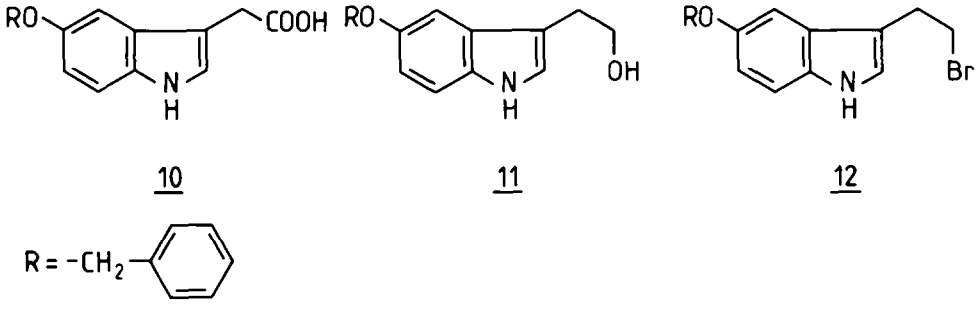


8 R=H

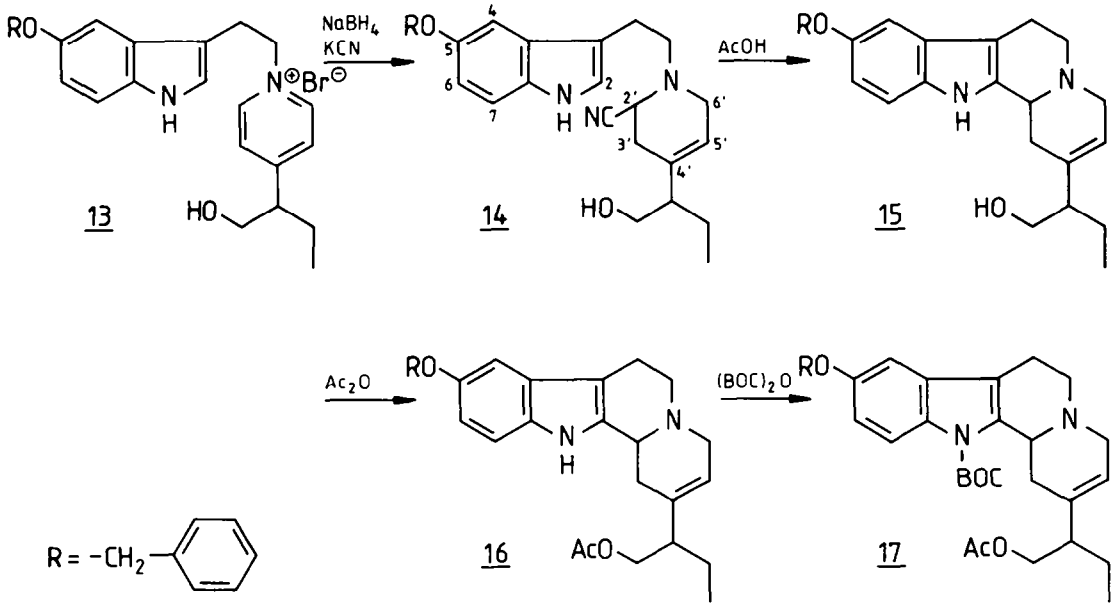
9 R=CH_3

RESULTS AND DISCUSSION

LAH reduction of 5-benzyloxyindole-3-acetic acid[19] 10 afforded 5-benzyloxytryptophol 11, which was transformed by PBr_3 treatment to 5-benzyloxytryptophyl bromide 12. Alkylation of 2-(4'-pyridyl)butanol[20] with 5-benzyloxytryptophyl bromide 12 yielded pyridinium salt 13.

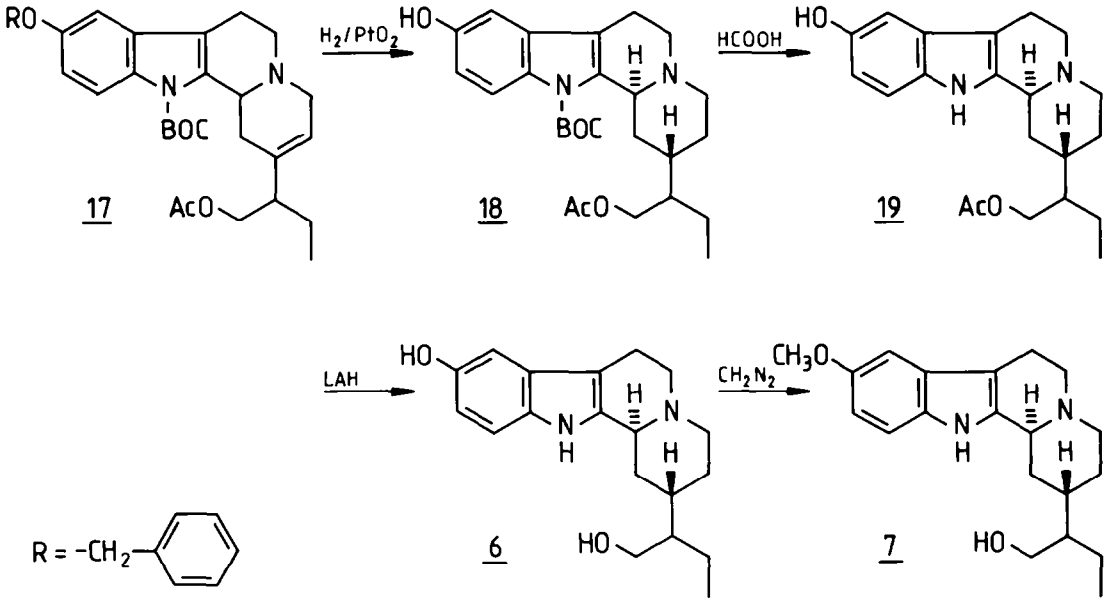


The pyridinium salt 13 was transformed by $NaBH_4$ reduction and cyanide trapping[13-16,21,22] to α-aminonitrile 14, which by AcOH treatment led to compound 15. Compound 15 was acetylated to compound 16, which was then transformed with di-t-butyl dicarbonate [$(BOC)_2O$] to the BOC-protected counterpart 17 (Scheme 1).



Scheme 1

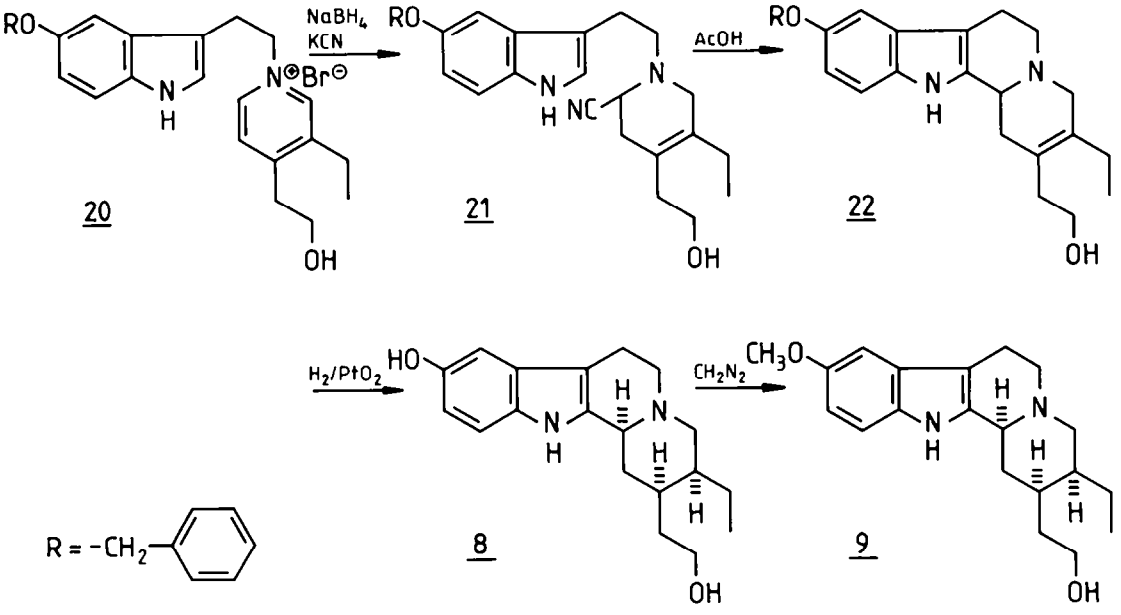
Catalytic hydrogenation (PtO_2) of the BOC-protected compound 17 led to compound 18 [C(3)H-C(15)H trans; [reduction of the C(15)-C(16) double bond and hydrogenolytic cleavage of the C(10) benzyloxy group]. Compound 18 yielded by acid induced cleavage (HCOOH) compound 19, which by LAH treatment afforded (±)-18,19-dihydrohunterburnine 6 in good yield. Treatment of the prepared (±)-18,19-dihydrohunterburnine 6 with CH_2N_2 led to (±)-10-O-methyl-18,19-dihydrohunterburnine 7, which is the dihydro derivative of the recently found[7] 10-O-methylhunterburnine 4 (Scheme 2).



Scheme 2

Analogously to the above, alkylation of 3-ethyl-4-(2'-hydroxyethyl)pyridine[23] with 5-benzyloxytryptophyl bromide 12 led to the pyridinium salt 20, which was transformed by $NaBH_4$ reduction and cyanide trapping[13-16,21,22] to α-aminonitrile 21. Treatment of the α-aminonitrile 21 with AcOH yielded compound 22. Catalytic hydrogenation (PtO_2) of compound 22 led directly to (±)-10-hydroxycorynantheidol 8 [C(3)H-C(15)H cis; C(3)H-C(20)H cis] [reduction of the C(15)-C(20) double bond and hydrogenolytic cleavage of the C(10) benzyloxy group]. Methylation of compound 8 with CH_2N_2 afforded (±)-10-methoxycorynantheidol 9, which is the racemic form of (-)-

10-methoxycorynantheidol prepared from (-)-10-methoxygeissoschizol by catalytic hydrogenation[23] (Scheme 3).



Scheme 3

^{13}C NMR data of all the compounds formed are given in Fig. 1.

Comparison of the chemical shifts found for compounds 6, 7, 8, 9, 15, 16, 17, 18, 19 and 22 with those of earlier experiments,[13,14] taking into account the conformational considerations, gives clear evidence of the stereostructures depicted in the formulae. The "double signals" found for several carbons in compounds 6, 7, 14, 15, 16, 17, 18 and 19 suggest that the samples consist of mixtures of C(20) epimers (See also the ^{1}H NMR spectrum of compound 16).

CONCLUSIONS

The present results clearly demonstrate the applicability of our recently developed method[13-17] to short syntheses of (±)-18,19-dihydrohunterburnine 6, (±)-10-O-methyl-18,19-dihydrohunterburnine 7, (±)-10-hydroxycorynantheidol (i.e. one of the two possible 19,20-dihydrohuntrabrines) 8 and (±)-10-

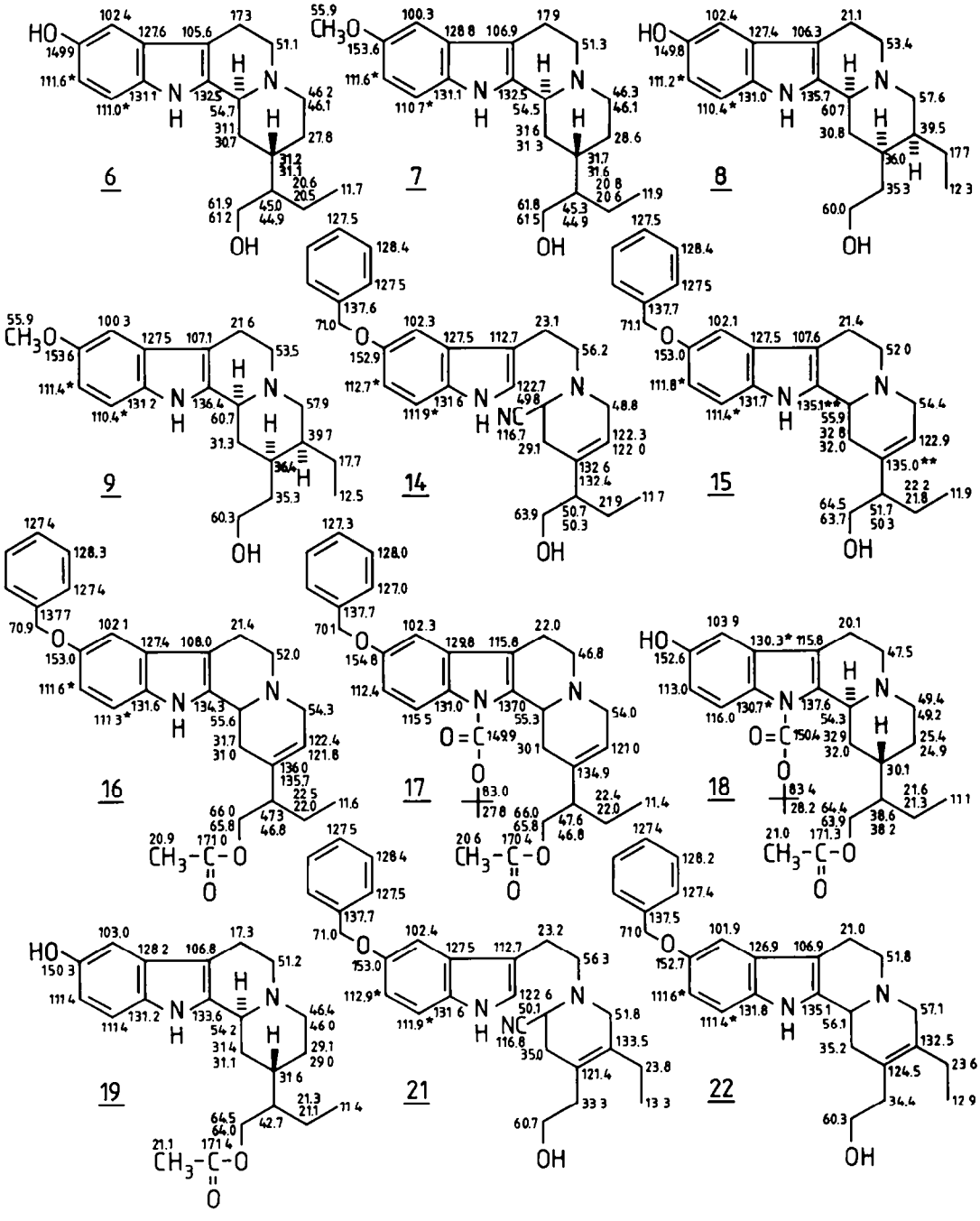


Fig. 1

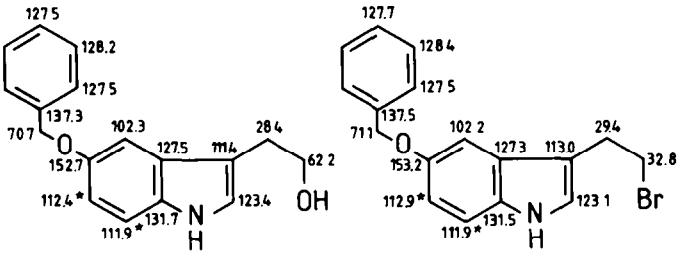


Fig. 1 (continued)

methoxycorynantheidol 9. The achievements described represent the first total syntheses of these four compounds.

EXPERIMENTAL

IR spectra were recorded with a Perkin-Elmer 700 spectrometer in $CHCl_3$, if not otherwise stated. IR absorption bands are expressed in reciprocal centimetres (cm^{-1}) using polystyrene calibration. ^1H and ^{13}C NMR spectra were recorded in $CDCl_3$ (compounds 11, 12, 14, 15, 16, 17, 18, 19 and 21), in $CDCl_3$/MeOH-d_4 (8/1) (compounds 7 and 9), in $CDCl_3$/MeOH-d_4 (5/1) (compounds 8 and 22) and in MeOH-d_4 (compound 6) on a Jeol JNM-FX 60 spectrometer working at 59.80 MHz (^1H NMR) and 15.04 MHz (^{13}C NMR). Chemical shift data are given in ppm downfield from TMS. Abbreviations s, d, t, q, m, br and def are used to designate singlet, doublet, triplet, quartet, multiplet, broad and deformed, respectively. For ^{13}C NMR data see Fig. 1. Mass spectrometry was done on a Jeol DX 303/DA 5000 instrument.

Preparation of compound 11

LAH reduction of commercial 5-benzyloxyindole-3-acetic acid[19] (3.00 g, 10.66 mmol) in abs. THF (200 ml) for 3.5 h (rt, Ar-atm) afforded pure compound 11. Y. 2.64 g (93%). Mp. 78-79 °C (MeOH).

IR: 3450 (OH) and (NH).

^1H NMR ($CDCl_3$): 1.83 (1H, br s, -OH), 2.92 (2H, t, J=6.5 Hz, -$\underline{CH_2}$-CH_2OH), 3.83 (2H, t, J=6.5 Hz, -CH_2-$\underline{CH_2}OH$), 5.06 (2H, s, -O-$\underline{CH_2}$-Ar), 6.92 (1H, d, J=3.0 Hz, H-2), 6.99-7.40 (8H, m, arom. H), 8.02 (1H, br s, NH).

MS: 267 (M^+), 236, 176, 158, 91 (100%); exact mass: 267.1262 (calc. for $C_{17}H_{17}NO_2$: 267.1259).

Preparation of compound 12

To compound 11 (2.64 g, 9.89 mmol) in abs. Et_2O (200 ml) (-5°C, Ar-atm) was added during 0.5 h PBr_3 (0.36 ml, 1.1 equiv.) in abs. Et_2O (10 ml). Stirring was continued for 1 h at -5°C. The reaction mixture was left standing in a refrigerator overnight. The solution was extracted with water and $NaHCO_3^{aq}$ and dried over Na_2SO_4 to afford pure compound 12.

Y. 1.67 g (51%). Mp. 74-75°C (MeOH).

IR: 3450 (NH).

^1H NMR ($CDCl_3$): 3.33 (2H, t, J=6.0 Hz, -$\underline{CH_2}$-CH_2Br), 3.56 (2H, t, J=6.0 Hz, -CH_2-$\underline{CH_2}Br$), 5.08 (2H, s, -O-$\underline{CH_2}$-Ar), 6.96 (1H, d, J=2.5 Hz, H-2), 7.07-7.38 (8H, m, arom. H), 8.02 (1H, br s, NH).

MS: 331, 329 (M^+), 240, 238, 159, 91 (100%); exact mass: 329.0398 (calc. for $C_{17}H_{16}NOBr$: 329.0415).

Preparation of compound 13

Alkylation of 2-(4'-pyridyl)butanol (1.35 g, 8.94 mmol) with bromide 12 (2.95 g, 8.97 mmol) afforded salt 13.

Y. 4.11 g (96%). Amorphous material.

IR (KBr): 3350 (OH) and (NH).

Preparation of compound 14

Hydrochloric acid (6N, 4.5 ml) was added dropwise to a stirred cooled solution (0°C) of KCN (3.25 g, 50.00 mmol) in H_2O (3.5 ml) and layered with Et_2O (20 ml). MeOH (6 ml) and salt 13 (4.11 g, 8.54 mmol) were added, after which $NaBH_4$ (0.36 g, 9.52 mmol) was added during 0.5 h (0°C). Stirring was continued for 3.5 h at rt. The ethereal layer was separated and the aqueous layer was extracted several times with Et_2O. The combined organic layers were dried over Na_2SO_4 and evaporated to yield compound 14, which was used without purification in the next step.

Y. 3.56 g (98%). Viscous oil.

IR: 3350 (OH) and (NH), 2260 (CN).

^1H NMR ($CDCl_3$): 0.85 (3H, t, J=6.0 Hz, $-CH_3$), 3.49 (2H, d, J=6.0 Hz, -$\underline{CH_2}$-OH), 3.92 (1H, m, H-2'), 5.08 (2H, s, -O-$\underline{CH_2}$-Ar), 5.51 (1H, br s, H-5'), 6.92 (1H, d, J=2.0 Hz, H-2), 7.12-7.40 (8H, m, arom. H), 8.26 (1H, br s, NH).

MS: 429 (M^+), 402, 250, 166, 91 (100%); exact mass (M^+ - HCN): 402.2315 (calc. for $C_{26}H_{30}N_2O_2$: 402.2307).

Preparation of compound 15

Compound 14 (3.56 g, 8.30 mmol) was stirred with 50% acetic acid (200 ml) for 72 h (rt, Ar-atm). After evaporation and neutralization (2N Na_2CO_3) the

solution was extracted with CH_2Cl_2. The combined organic extracts were dried over Na_2SO_4 and evaporated. The crude product was purified by column chromatography (alumina, CH_2Cl_2/MeOH; 98/2).
Y. 2.20 g (66%). Amorphous material.
IR: 3300 (OH) and (NH).
^1H NMR ($CDCl_3$): 0.88 (3H, t, J=6.0 Hz, $-CH_3$), 5.08 (2H, s, -O-$\underline{CH_2}$-Ar), 5.57 (1H, br s, H-16), 6.73-7.41 (8H, m, arom. H), 8.55 (1H, br s, NH).
MS: 402 (M^+), 371, 329, 311, 276, 185, 91; exact mass: 402.2274 (calc. for $C_{26}H_{30}N_2O_2$: 402.2307).

Preparation of compound 16
Compound 15 (2.20 g, 5.47 mmol), acetic anhydride (20 ml) and two drops of pyridine were stirred for 24 h (rt, Ar-atm). The solution was poured into ice water, neutralized (2 M NaOH) and extracted with CH_2Cl_2. The combined extracts were dried over Na_2SO_4 to afford pure compound 16.
Y. 2.28 g (94%). Amorphous material.
IR: 3400 (NH), 1740 (C=O).
^1H NMR ($CDCl_3$): 0.86 (3H, t, J=6.0 Hz, $-CH_3$), 1.99 and 2.02 (3H, two s,-OAc), 5.07 (2H, s, -O-$\underline{CH_2}$-Ar), 5.50 (1H, br s, H-16), 6.73-7.39 (8H, m, arom. H), 8.55 (1H, br s, NH).
MS: 444 (M^+), 353, 329, 276, 185, 91 (100%); exact mass: 444.2405 (calc. for $C_{28}H_{32}N_2O_3$: 444.2413).

Preparation of compound 17
To compound 16 (2.28 g, 5.14 mmol) in abs. CH_2Cl_2 (8 ml) were added p-dimethylaminopyridine (DMAP) (63 mg, 0.1 equiv.) and di-t-butyl dicarbonate [$(BOC)_2O$] (1.35 g, 1.2 equiv.) with stirring (rt, Ar-atm). After 2h the mixture was evaporated and purified by column chromatography (silica, CH_2Cl_2/MeOH/Et_3N; 99/0.75/0.25) to afford pure compound 17.
Y. 1.97 g (70%). Viscous oil.
IR: 1740 and 1730 (2 x C=O).
^1H NMR ($CDCl_3$): 0.84 (3H, t, J=7.0 Hz, $-CH_3$), 1.62 (9H, s, $-C(CH_3)_3$), 1.99 (3H, s, -OAc), 4.02 (1H, m, H-3), 5.04 (2H, s, -O-$\underline{CH_2}$-Ar), 5.49 (1H, br s, H-16), 6.86-7.40 (7H, m, arom. H), 7.95 (1H, m, H-12).
MS: 544 (M^+), 488, 487, 320, 210, 91 (100%); exact mass: 544.2973 (calc. for $C_{33}H_{40}N_2O_5$: 544.2937).

Preparation of compound 18
Catalytic hydrogenation (PtO_2, 24 h) of compound 17 (370 mg, 0.68 mmol)

afforded crude compound 18, which was purified by TLC (silica, CH_2Cl_2/MeOH; 90/10).
Y. 233 mg (75%). Viscous oil.
IR: 3400 (OH), 1730 (2 x C=O).
^1H NMR ($CDCl_3$): 0.95 (3H, t, J=6.0 Hz, $-CH_3$), 1.63 (9H, s, $-C(CH_3)_3$), 2.02 (3H, s, -OAc), 4.10 (1H, br s, H-3), 6.42-6.75 (2H, m, H-9, 11), 7.67 (1H, m, H-12).
MS: 456 (M^+), 400, 399 (100%), 355, 285, 212; exact mass: 456.2639 (calc. for $C_{26}H_{36}N_2O_5$: 456.2625).

Preparation of compound 19
Compound 18 (160 mg, 0.35 mmol) was stirred in HCOOH (8 ml) for 70 h (rt, Ar-atm). After evaporation and neutralization (10% Na_2CO_3) the solution was extracted with CH_2Cl_2. The combined extracts were dried over Na_2SO_4 and evaporated to yield pure compound 19.
Y. 123 mg (98%). Amorphous material.
IR: 3400 (OH) and (NH), 1730 (C=O).
^1H NMR ($CDCl_3$): 0.89 (3H, def, $-CH_3$), 2.02 (3H, s, -OAc), 4.05 (1H, br s, H-3), 6.62-7.25 (3H, m, H-9, 11, 12), 8.14 (1H, br s, NH).
MS: 356 (M^+, 100%), 355, 297, 241, 212; exact mass: 356.2065 (calc. for $C_{21}H_{28}N_2O_3$: 356.2100).

Preparation of compound 6
LAH treatment of compound 19 (123 mg, 0.35 mmol) in abs. THF for 2.5 h (rt, Ar-atm) afforded compound 6, which was purified by TLC (silica, CH_2Cl_2/MeOH; 90/10).[24]
Y. 76 mg (70%). Amorphous material.
IR (KBr): 3350 (OH) and (NH).
^1H NMR (MeOH-d_4): 0.93 (3H, def, $-CH_3$), 3.85 (3H, s, $-OCH_3$), 4.09 (1H, br s, H-3), 6.56-7.20 (3H, m, H-9, 11, 12).
MS: 314 (M^+), 313 (100%), 241, 213; exact mass: 314.1992 (calc. for $C_{19}H_{26}N_2O_2$: 314.1990).

Preparation of compound 7
To compound 6 (20 mg, 0.06 mmol) in MeOH (5 ml) was added gradually diazomethane/Et_2O (total reaction time 3 h) to afford compound 7.
Y. 18 mg (85%). Amorphous material.
IR: 3350 (OH) and (NH).

^{1}H NMR ($CDCl_3$/MeOH-d_4; 8/1): 0.93 (3H, def, -CH_3), 3.85 (3H, s, -OCH_3), 4.10 (1H, br s, H-3), 6.68-7.31 (3H, m, H-9, 11, 12).
MS: 328 (M^+, 100%), 327, 313, 255; exact mass: 328.2132 (calc. for $C_{20}H_{28}N_2O_2$: 328.2151).

Preparation of compound 20
Alkylation of 3-ethyl-4-(2'-hydroxyethyl)pyridine (1.15 g, 7.62 mmol) with compound 12 (2.52 g, 7.63 mmol) afforded compound 20.
Y. 3.29 g (90%). Amorphous material.

Preparation of compound 21
Compound 21 was prepared from compound 20 (2.64 g, 5.49 mmol) using the procedure described for compound 14 (vide supra).
Y. 2.30 g (98%). Viscous oil.
IR: 3450 (OH) and (NH), 2270 (CN).
^{1}H NMR ($CDCl_3$): 1.01 (3H, t, J=7.0 Hz, -CH_3), 3.64 (2H, t, J=6.5 Hz, -$\underline{CH_2}$-OH), 3.92 (1H, m, H-2'), 5.09 (2H, s, -O-$\underline{CH_2}$-Ar), 6.97 (1H, d, J=2.4 Hz, H-2), 7.11-7.52 (8H, m, arom. H), 8.13 (1H, br s, NH).
MS: 429 (M^+), 402, 357, 250, 166, 91 (100%); exact mass (M^+ - HCN): 402.2321 (calc. for $C_{26}H_{30}N_2O_2$: 402.2307).

Preparation of compound 22
Compound 22 was prepared from compound 21 (2.00 g, 4.66 mmol) using the procedure described for compound 15 (vide supra).
Y. 1.03 g (55%). Mp. 207-208°C (MeOH).
IR: 3300 (OH) and (NH).
^{1}H NMR ($CDCl_3$/MeOH-d_4; 5/1): 1.02 (3H, t, J=7.0 Hz, -CH_3), 3.65 (2H, t, J=6.5 Hz, -$\underline{CH_2}$-OH), 5.08 (2H, s, -O-$\underline{CH_2}$-Ar), 6.74-7.52 (8H, m, arom. H).
MS: 402 (M^+), 311, 276 (100%), 185, 91; exact mass: 402.2280 (calc. for $C_{26}H_{30}N_2O_2$: 402.2307).

Preparation of compound 8
Catalytic hydrogenation (PtO_2, 30 h) of compound 22 (324 mg, 0.81 mmol) afforded crude compound 8, which was purified by TLC (silica, CH_2Cl_2/MeOH; 90/10).
Y. 153 mg (60%). Amorphous material.
IR: 3400 (OH), 2830 and 2780 (Bohlmann bands).
^{1}H NMR ($CDCl_3$/MeOH-d_4; 5/1): 0.92 (3H, def, -CH_3), 6.59-7.50 (3H, H-9, 11, 12).

MS: 314 (M^+), 313 (100%), 269, 186; exact mass: 314.1987 (calc. for $C_{19}H_{26}N_2O_2$: 314.1990).

Preparation of compound 9

To compound 8 (24 mg, 0.08 mmol) in MeOH (5 ml) was added gradually diazomethane/Et_2O (total reaction time 3 h) to afford compound 7.

Y. 23 mg (88%). Amorphous material.

IR: 3350 (OH), 2820 and 2760 (Bohlmann bands).

^1H NMR ($CDCl_3$/MeOH-d_4; 8/1): 0.91 (3H, def, $-CH_3$), 3.84 (3H, s, $-OCH_3$), 6.68-7.43 (3H, m, H-9, 11, 12).

MS: 328 (M^+, 100%), 327, 283, 255, 200; exact mass: 328.2151 (calc. for $C_{20}H_{28}N_2O_2$: 328.2151).

REFERENCES AND NOTES

1. Biogenetic numbering. Le Men, J.; Taylor, W. Experientia 1965, 21, 508.
2. Other basic compounds of the group are antirhine[25] (= 10-deoxyhunterburnine) and vallesiachotamine[26].
3. Asher, J.D.M.; Robertson, J.M.; Sim, G.A.; Bartlett, M.F.; Sklar, R.; Taylor, W.I. Proc. Chem. Soc. 1962, 72.
4. Bartlett, M.F.; Korzun, B.; Sklar, R.; Smith, A.F.; Taylor, W.I. J. Org. Chem. 1963, 28, 1445.
5. Jordan, W.; Scheuer, P.J. Tetrahedron 1965, 21, 3731.
6. Khan, Z.M.; Hesse, M.; Schmid, H. Helv. Chim. Acta 1965, 48, 1957.
7. Boughandjioua, N.; Bengaouer, L.; Hotellier, F.; Seguin, E.; Tillequin, F.; Koch, M.; Sevenet, T. J. Nat. Prod. 1989, 52, 1107.
8. Sakai, S.; Ohtani, H.; Ido, H.; Haginiwa, J. Yakugaku Zasshi 1973, 93, 483; C.A. 1973, 79, 63538h.
9. Iwu, M.M.; Court, W.E. Planta Medica 1982, 45, 105.
10. Feng, X.Z.; Kan, C.; Potier, P.; Kan, S.-K.; Lounasmaa, M. Planta Medica 1982, 44, 212.
11. Kimura, T.; Ban, Y. Chem. Pharm. Bull. 1969, 17, 296.
12. Sawa, Y.K.; Matsumura, H. Tetrahedron 1969, 25, 5319.
13. Lounasmaa, M.; Jokela, R.; Tetrahedron 1989, 45, 3975.
14. Lounasmaa, M.; Jokela, R.; Tetrahedron 1989, 45, 7449.
15. Lounasmaa, M.; Jokela, R.; Tirkkonen, B.; Tamminen, T. Tetrahedron 1989, 45, 7615.
16. Lounasmaa, M.; Jokela, R. Tetrahedron 1990, 46, 615.
17. Lounasmaa, M.; Jokela, R.; Mäkimattila, P.; Tirkkonen, B. Tetrahedron 1990, 46, 2633.
18. Lounasmaa, M.; Jokela, R. Heterocycles (in press).
19. Sigma, Compound B 0626.
20. Pailer, M.; Beier, G. Monatsh. Chem. 1957, 88, 830.
21. Fry, E.M. J. Org. Chem. 1964, 29, 1647.
22. Fry, E.M.; Beisler, J.A. J. Org. Chem. 1970, 35, 2809.
23. Dastoor, N.J.; Gorman, A.A.; Schmid, H. Helv. Chim. Acta 1967, 50, 213.
24. Our attempts to separate the C(20) epimers (vide supra) of compound 6 were unsuccessful. This prevented a more direct comparison with the quinine derived compound (+)-6[12].
25. Johns, S.R.; Lamberton, J.A.; Occolowitz, J.L. Aust. J. Chem. 1967, 20, 1463.
26. Djerassi, C.; Monteiro, H.J.; Walser, A.; Durham, L.J. J. Am. Chem. Soc. 1966, 88, 1792.