Crystal Structure of Corynoline *p*-Bromobenzoate

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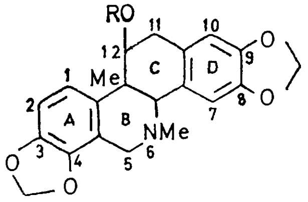
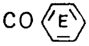
Crystals of the title compound (3) are monoclinic, space group $P2_1/c$ with $Z = 4$ in a unit cell of dimensions: $a = 12{\cdot}598(88)$, $b = 14{\cdot}868(67)$, $c = 13{\cdot}592(79)$ Å, $\beta = 115{\cdot}30(43)°$. The structure was solved from diffractometer data by the heavy-atom method and refined by least-squares methods, to R 0·165 for 2008 observed reflexions. The B/C ring junction is *cis*-fused and rings B and C take the half-chair and the twist-half-boat conformations, respectively.

CORYNOLINE,[1-5] one of the benzo[*c*]phenanthridine alkaloids isolated from *C. incisa* PERS., has been assigned structure (1) by Takao[6] on the basis of chemical evidence. The total synthesis has not yet been reported. However, it was deduced from i.r. absorption bands at 3100—3250 cm^{-1} that an intramolecular hydrogen bond is formed between the hydroxy-group at C-12 and the nitrogen atom and hence that the *cis* B/C ring junction should be *cis*-fused. N.m.r. spectral studies suggested the *cis* B/C half-chair–half-chair conformation for this alkaloid and the *cis* B/C half-chair–twist-half-boat conformation for its acetate (2).[3] From biogenic considerations, it has been concluded that the protoberberine alkaloid is the precursor of the benzophenanthridine alkaloid.[7,8] We have previously reported the *X*-ray analysis of some protoberberine alkaloids, in which the B/C junction is *cis*-fused.[9-11] In connection with this we wished to examine by *X*-ray crystallography the steric effect on ring conformation.



(1) R = H
(2) R = COMe
(3) R = CO  Br

EXPERIMENTAL

(±)-*Corynoline* p-*Bromobenzoate* (3).—Corynoline (1) (100 mg), *p*-bromobenzoyl chloride (70 mg), and dry pyridine (1·5 ml) were set aside overnight at room temperature. After removal of solvent, the residue was extracted with chloroform, washed with 10% sodium hydrogen carbonate solution and water, and dried (Na_2SO_4). Solvent was evaporated and the residue recrystallised from methanol to give (3) as pale yellowish plates, m.p. 179—180 °C (Found: C, 61·55; H, 3·65; N, 2·6. $C_{28}H_{18}BrNO_6$ requires C, 61·55; H, 3·7; N, 2·55%), δ ($CDCl_3$) 1·23 (3H, s, C-CH_3), 2·40 (3H, s, NCH_3), 3·04 (2H, d, 11α-H and 11β-H, J 7·5 Hz), 3·38 (1H, s, 6a-H), 3·40, 3·97 (2H, each d, 5α-H and 5β-H, J 16·5 Hz), 5·25 (2H, t, 12-H, J 7·5 Hz), 5·83 (4H, s, 2 × $O{\cdot}CH_2{\cdot}O$), 6·46 and 6·86 p.p.m. (2H, each s, 7-H and 10-H).

A crystal with dimensions 0·03 × 0·08 × 0·02 cm was mounted on a goniometer head with its *c* axis parallel to the ψ axis of a Rigaku four-circle diffractometer. Accurate unit-cell dimensions were obtained by use of the diffractometer data with Cu-K_α radiation. The intensities of 1161 independent reflexions were measured on a diffractometer at room temperature, and those of 847 reflexions having $I < 3\sigma(I)$ were considered unobserved. The crystal showed no observable decay, the intensities of three reference reflexions remaining constant throughout data collection.

Crystal Data.—$C_{28}H_{18}BrNO_6$, $M = 546{\cdot}37$. Monoclinic, $a = 12{\cdot}598(88)$, $b = 14{\cdot}868(67)$, $c = 13{\cdot}592(79)$ Å, $\beta = 115{\cdot}30(43)°$. $U = 2362{\cdot}65$ Å^3, $D_m = 1{\cdot}53$ (flotation), $Z = 4$, $D_c = 1{\cdot}54$, $F(000) = 1104$. Space group $P2_1/c$ from absent spectra: $h0l$ for l odd, $0k0$ for k odd. Cu-K_α radiation, $\lambda = 1{\cdot}54182$ Å; μ(Cu-K_α) = 30·3 cm^{-1}.

Structure Determination.—The structure was solved by the heavy-atom method. The positional parameters for the bromine atom were derived from a three-dimensional Patterson function. In the first three-dimensional Fourier synthesis phased by the bromine atom only, all non-hydrogen atom positions were identified, and the B/C ring junction was found to be *cis*-fused. Co-ordinates and the isotropic temperature factors were then refined by least squares with a block-diagonal matrix approximation. After three cycles, R decreased to 0·25. Anisotropic temperature factors were then assigned to the bromine atom only and after several cycles R was 0·171. Hydrogen atoms, except those of the methyl groups, were placed in calculated positions and included in the subsequent refinement. The final R was 0·165. Atomic scattering factors were taken from ref. 12. Final atomic co-ordinates and temperature factors with their standard deviations are given in Table 1. Computations were carried out on a HITAC

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8500 computer in the Tokyo Institute of Technology. The programs in the Universal Crystallographic Computation Program System (1967) were used with some modifications. Observed and calculated structure factors are listed in Supplementary Publication No. SUP 20656 (5 pp.).*

TABLE 1

Final atomic co-ordinates and temperature factors, with standard deviations in parentheses

	x/a	y/b	z/c	$B/Å^2$
Br	0·4387(3)	0·2889(2)	0·7265(4)	*
O(32)	0·3844(18)	0·5333(14)	0·3960(17)	4·24(49)
C(3)	0·1947(24)	0·5196(18)	0·3475(23)	2·57(56)
C(10)	0·2351(23)	1·0179(17)	0·3931(22)	2·21(53)
C(14)	0·2134(25)	0·9575(19)	0·5411(24)	3·04(65)
C(25)	0·1790(20)	0·4714(15)	0·6220(20)	1·44(47)
C(28)	0·4139(26)	0·4762(20)	0·7127(25)	3·35(65)
C(2)	0·0824(27)	0·5496(20)	0·3230(25)	3·53(68)
C(11)	0·2120(24)	1·0968(17)	0·4259(23)	2·24(53)
C(26)	0·2396(26)	0·3968(20)	0·6445(25)	3·42(66)
C(27)	0·3593(22)	0·3982(16)	0·6893(21)	1·60(50)
C(1)	0·0690(26)	0·6343(20)	0·3423(25)	3·27(64)
C(15)	0·2105(28)	0·8712(22)	0·5957(27)	4·27(76)
C(5)	0·2759(26)	0·6677(20)	0·4029(24)	3·30(66)
O(33)	0·2055(16)	1·1810(12)	0·3758(15)	3·06(42)
C(18)	0·1655(16)	0·6894(12)	0·3809(16)	1·00(37)
C(16)	0·1500(28)	0·7910(24)	0·5313(26)	4·55(75)
C(6)	0·3810(24)	0·7247(19)	0·4420(23)	3·02(63)
C(34)	0·1732(29)	1·2391(22)	0·4357(28)	4·39(79)
O(21)	0·2171(16)	0·7089(14)	0·5868(16)	3·54(42)
O(35)	0·1624(17)	1·1982(14)	0·5232(16)	3·83(45)
C(17)	0·1448(24)	0·7911(20)	0·4126(23)	3·01(57)
N(7)	0·3634(19)	0·8095(15)	0·4843(18)	2·81(50)
C(19)	0·0243(21)	0·8297(16)	0·3391(20)	1·79(51)
C(22)	0·1606(17)	0·6400(13)	0·5985(17)	1·00(35)
O(23)	0·0544(17)	0·6372(13)	0·5698(16)	3·22(42)
C(8)	0·2445(22)	0·8489(16)	0·4113(21)	1·70(49)
C(20)	0·4618(27)	0·8678(22)	0·5014(26)	3·90(73)
O(30)	0·2341(18)	0·4381(13)	0·3354(16)	3·61(45)
C(31)	0·3595(35)	0·4389(26)	0·3853(32)	6·06(95)
C(24)	0·2309(27)	0·5564(20)	0·6263(26)	3·38(68)
C(29)	0·3465(28)	0·5578(21)	0·6739(26)	3·67(68)
C(13)	0·1869(21)	1·0366(16)	0·5719(20)	1·42(48)
C(4)	0·2859(24)	0·5797(18)	0·3838(24)	2·78(62)
C(9)	0·2405(20)	0·9452(15)	0·4542(20)	1·32(47)
C(12)	0·1838(28)	1·1102(21)	0·5070(26)	3·98(74)

* Anisotropic temperature factors in the form: $\exp[-(B_{11}h^2 + B_{22}k^2 + B_{33}l^2 + B_{12}hk + B_{13}hl + B_{23}kl)]$; coefficients ($\times 10^5$):

	B_{11}	B_{22}	B_{33}	B_{12}	B_{13}	B_{23}
Br	1009(34)	394(16)	1023(34)	933(46)	814(58)	363(50)

RESULTS AND DISCUSSION

Conformation.—A perspective drawing of the molecule (Figure 1) clearly shows that corynoline takes a *cis* B/C ring junction and has two methylenedioxy-groups at the 3,4- and 8,9-positions, a hydroxy-group at the 12-position, and an angular methyl group at the 12a-position. Thus, the structure (1) given by Takao was established unambiguously. A view of the molecule along the C(8)–C(17) bond (Figure 2) shows that the B/C ring fusion is *cis* and the conformation about this bond is almost completely staggered with internal rotation of *ca.* 60°. Ring B is in a half-chair and ring C in a twist-half-boat conformations (Figure 3).

In the n.m.r. spectrum of the benzoate, the methylene group at C-5 gave rise to a doublet with the coupling constant (J 16·5 Hz), similar to that for corynoline (1) and its *O*-acetate (2). On the other hand, the proton at C-12 was shown as a triplet, and the protons at C-11 were observed as a doublet with coupling constant ($J_{11\alpha,12}$, $J_{11\beta,12}$ 7·5 Hz). This pattern of signals is very

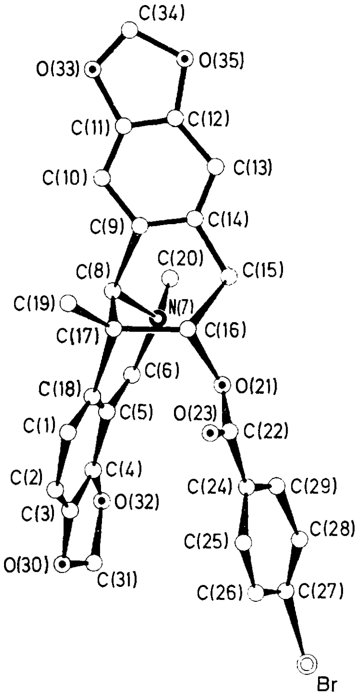

FIGURE 1 Perspective view of the molecule, showing the atom numbering system used

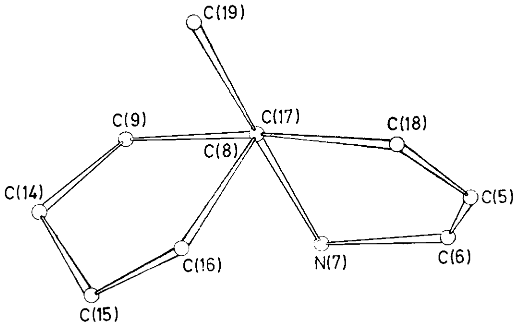

FIGURE 2 Conformation about the C(17)–C(8) bond

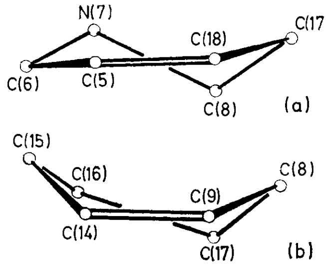

FIGURE 3 Conformations of rings B and C: (a) ring B viewed along the vector between the midpoints of C(5)–C(18) and C(8)–N(7), and (b) ring C viewed along the vector between the midpoints of C(9)–C(14) and C(16)–C(17)

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* For details see Notice to Authors No. 7 in *J.C.S. Dalton*, 1972, Index issue.

similar to that for the *O*-acetate, but different from that for corynoline itself. If corynoline itself would adopt a half-chair conformation for ring B, a half-chair for ring C would enable the formation of an intramolecular hydrogen bond. The present *X*-ray analysis and the n.m.r. spectroscopy of all three compounds (1)—(3) have suggested that the benzoate and acetate have nearly the same conformation, but that corynoline itself adopts half-chair conformations in the B and C rings. The axial hydroxy-group at C-12 becomes *quasi-equatorial* by introduction of the bulky group, and hence the conformation of ring C must change from a half-chair to a twist-half-boat.

Molecular Geometry.—Intramolecular bond lengths and angles with their estimated standard deviations are listed in Table 2 and 3, respectively. On account of the large standard deviations, the variations in length of equivalent bonds of the same type may not be significant. Mean bond length are: 1·359 C(sp^2)–C(sp^2), 1·539 C(sp^2)–C(sp^3), 1·546 C(sp^3)–C(sp^3), 1·377 C(sp^2)–O(methylenedioxy), 1·432 C(sp^3)–O, and 1·472 Å for three C–N bonds. The three C–N–C bond angles range from 108·7—114·1°, indicating that the nitrogen atom is tetrahedrally hybridised.

TABLE 2

Bond lengths (Å) with standard deviations in parentheses

Br–C(27)	1·86(3)	C(5)–C(18)	1·33(4)
O(32)–C(31)	1·43(5)	C(5)–C(6)	1·47(5)
O(32)–C(4)	1·37(4)	C(5)–C(4)	1·35(5)
C(3)–C(2)	1·38(5)	O(33)–C(34)	1·38(5)
C(3)–O(30)	1·35(4)	C(18)–C(17)	1·63(4)
C(3)–C(4)	1·37(5)	C(16)–O(21)	1·50(5)
C(10)–C(11)	1·34(4)	C(16)–C(17)	1·63(5)
C(10)–C(9)	1·36(4)	C(6)–N(7)	1·45(4)
C(14)–C(15)	1·50(5)	C(34)–O(35)	1·42(5)
C(14)–C(13)	1·34(5)	O(21)–C(22)	1·30(3)
C(14)–C(9)	1·41(5)	O(35)–C(12)	1·37(4)
C(15)–C(26)	1·31(5)	C(17)–C(19)	1·54(4)
C(25)–C(4)	1·41(5)	C(17)–C(8)	1·53(4)
C(28)–C(27)	1·32(5)	N(7)–C(8)	1·52(4)
C(28)–C(29)	1·45(5)	N(7)–C(20)	1·45(5)
C(2)–C(1)	1·31(5)	C(22)–O(23)	1·22(3)
C(11)–O(33)	1·42(4)	C(22)–C(24)	1·48(4)
C(11)–C(12)	1·34(5)	C(8)–C(9)	1·56(4)
C(26)–C(27)	1·36(5)	O(30)–C(31)	1·43(5)
C(1)–C(18)	1·37(4)	C(24)–C(29)	1·32(5)
C(15)–C(16)	1·49(5)	C(13)–C(12)	1·41(5)

TABLE 3

Bond angles (deg.) with standard deviations in parentheses

C(31)–O(32)–C(4)	109·2(2·8)	O(21)–C(16)–C(17)	107·8(2·6)
O(30)–C(3)–C(4)	109·8(2·8)	C(5)–C(6)–N(7)	112·8(2·7)
C(13)–C(14)–C(9)	125·2(3·0)	O(33)–C(34)–O(35)	114·5(2·9)
O(33)–C(11)–C(12)	107·4(2·8)	C(16)–O(21)–C(22)	119·8(2·3)
C(28)–C(27)–C(26)	118·3(2·9)	C(18)–C(17)–C(19)	113·5(2·3)
C(6)–C(5)–C(4)	119·0(3·0)	C(16)–C(17)–C(8)	108·8(2·5)
C(5)–C(18)–C(17)	116·0(2·4)	C(6)–N(7)–C(20)	108·9(2·5)
C(18)–C(17)–C(16)	109·1(2·4)	O(21)–C(22)–C(24)	113·1(2·3)
C(16)–C(17)–C(19)	106·6(2·5)	C(17)–C(8)–C(9)	111·1(2·4)
C(6)–N(7)–C(8)	109·9(2·3)	O(32)–C(31)–O(30)	102·3(3·1)
O(21)–C(22)–O(23)	124·5(2·3)	C(25)–C(24)–C(22)	121·8(2·8)
C(17)–C(8)–N(7)	111·4(2·3)	C(28)–C(29)–C(24)	122·3(3·4)
N(7)–C(8)–C(9)	106·4(2·2)	C(14)–C(13)–C(12)	114·8(2·9)
C(3)–O(30)–C(31)	108·3(2·7)	O(32)–C(4)–C(3)	107·0(2·8)
C(22)–C(24)–C(29)	122·5(3·1)	C(10)–C(9)–C(14)	118·0(2·7)
C(3)–C(4)–C(5)	124·4(3·1)	C(11)–C(12)–O(35)	115·3(3·1)
C(14)–C(9)–C(8)	120·3(2·6)	C(2)–C(3)–C(4)	119·5(3·0)
O(35)–C(12)–C(13)	126·1(3·1)	C(15)–C(14)–C(9)	113·2(2·9)
C(2)–C(3)–O(30)	130·5(3·0)	C(10)–C(11)–C(12)	126·9(3·2)
C(11)–C(10)–C(9)	116·4(2·8)	Br–C(27)–C(26)	118·2(2·3)
C(15)–C(14)–C(13)	121·6(3·0)	C(18)–C(5)–C(4)	111·7(2·9)
C(26)–C(25)–C(24)	122·6(2·9)	C(1)–C(18)–C(17)	116·4(2·3)
C(27)–C(28)–C(29)	119·1(3·1)	C(15)–C(16)–C(17)	114·0(2·9)
C(3)–C(2)–C(1)	117·8(3·2)	C(34)–O(35)–C(12)	99·7(2·6)
C(10)–C(11)–O(33)	125·6(2·8)	C(18)–C(17)–C(8)	107·0(2·3)
C(25)–C(26)–C(27)	121·4(3·1)	C(19)–C(17)–C(8)	111·7(2·5)
Br–C(27)–C(28)	123·2(2·4)	C(8)–N(7)–C(20)	114·4(2·4)
C(2)–C(1)–C(18)	119·1(3·1)	O(23)–C(22)–C(24)	120·7(2·4)
C(14)–C(15)–C(16)	120·0(3·1)	C(25)–C(24)–C(29)	114·5(3·1)
C(18)–C(5)–C(6)	129·4(3·0)	O(32)–C(4)–C(5)	128·7(3·0)
C(11)–O(33)–C(34)	103·0(2·4)	C(10)–C(9)–C(8)	119·9(2·5)
C(1)–C(18)–C(5)	127·5(2·7)	C(11)–C(12)–C(13)	118·5(3·2)
C(15)–C(16)–O(21)	108·7(2·8)		

The equations of the least-squares planes in the three benzene rings A, D, and E are: $0{\cdot}275x' + 0{\cdot}222y' - 0{\cdot}936z' + 2{\cdot}265 = 0$, $-0{\cdot}796x' - 0{\cdot}166y' - 0{\cdot}582z' + 5{\cdot}9070 = 0$, and $0{\cdot}430x' - 0{\cdot}077y' - 0{\cdot}899z' + 8{\cdot}151 =$

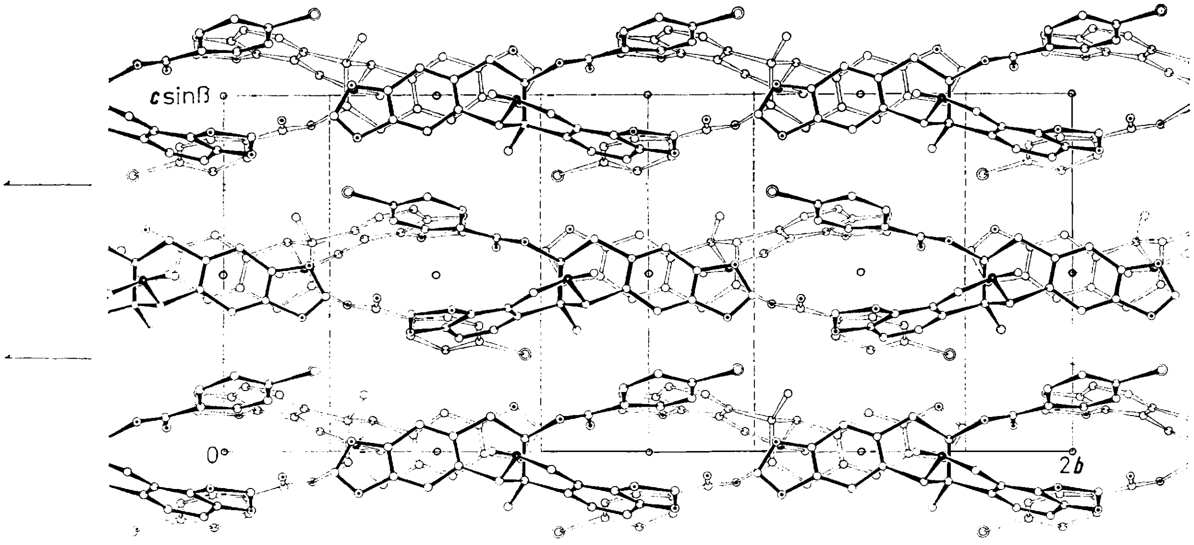
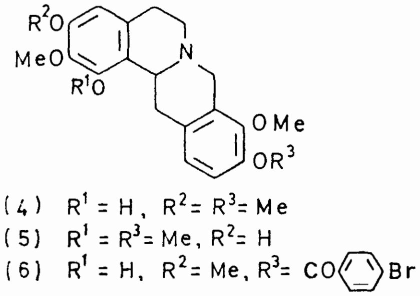


FIGURE 4 The crystal structure projected along the *a* axis

0 respectively, where $x' = x + z \cos \beta$, $y' = y$, and $z' = z \sin \beta$.

Each ring is planar. The dihedral angle between the planes of rings A and D is 73·2°, comparable to 70·7, 67·2, and 61·6° in the hydrobromide of capaurine (4), compound (5), and capaurimine mono-*p*-bromobenzoate (6) which have the *cis* B/C ring system.



Crystal Structure.—The packing diagram of the crystals viewed along the *a* axis is shown in Figure 4. The long axis of the alkaloid nucleus is nearly parallel to the *b* axis. Intermolecular distances $<3·6$ Å are listed in Table 4.

TABLE 4

Intermolecular distances $\leqslant 3·6$ Å

Br · · · C(28^{I})	2·80	O(35) · · · C(26^{III})	3·34
Br · · · C(26^{I})	2·78	C(1) · · · O(33^{IV})	3·56
O(33) · · · C(1^{II})	3·56	O(30) · · · C(19^{IV})	3·51
C(19) · · · O(30^{II})	3·51	C(13) · · · O(30^{V})	3·49
C(34) · · · C(26^{III})	3·55	C(10) · · · C(24^{V})	3·54
C(34) · · · O(30^{III})	3·50		

Roman numeral superscripts refer to the following equivalent positions, relative to the reference molecule at x, y, z:

I x, y, z
II $-x, \frac{1}{2} + y, -z$
III $x, 1 + y, z$
IV $-x, -\frac{1}{2} + y, \frac{1}{2} - z$
V $x, 1\frac{1}{2} - y, \frac{1}{2} + z$

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