

compound (Sheldrick *et al.*, 1984). The amide group is planar as shown by the torsion angles C(7)—N(1)—C(8)—C(9) = 179.9 (3) and C(7)—N(1)—C(8)—O(8) = -0.7 (5)° and the carbonyl group nearly so with C(10)—C(11)—O(12)—C(12) = -177.3 (4) and O(11)—C(11)—O(12)—C(12) = 1.2 (6)°. The chain twists around C(8)—C(9), torsion angle N(1)—C(8)—C(9)—C(10) = -141.0 (4)°, allowing the H atoms of the CH₂ groups to adopt a staggered conformation, and curving the chain around to form a compact shape rather than an extended form.

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Structure of a Ten-Membered Macrocyclic Diester of (+)-Retronecine, C₁₂H₁₅NO₄: a Pyrrolizidine Alkaloid Analogue

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Abstract. (+)-7-Methyl-2,3,5,7a-tetrahydro-1H-pyrrolizine-1,8-diyl succinate, $M_r = 237.1$, orthorhombic, $P2_12_12_1$, $a = 7.934$ (1), $b = 10.786$ (3), $c = 13.246$ (2) Å, $V = 1133.5$ Å³, $Z = 4$, $D_m = 1.41$, $D_x = 1.39$ g cm⁻³, Mo Kα, $\lambda = 0.71069$ Å, $\mu = 1.12$ cm⁻¹, $F(000) = 504$, $T = 291$ K, final $R = 0.043$ for 1429 unique reflections. The conformation of the pyrrolizidine moiety in this novel ten-membered macrocyclic pyrrolizidine alkaloid analogue is similar to those found in 11- and 12-membered alkaloids. The ester-group carbonyls lie on either side of the macrocycle in a nearly antiparallel orientation. This conformation is similar to those observed in 12-membered pyrrolizidine alkaloids containing retronecine, whereas most 11-membered pyrrolizidine alkaloids have been found to possess ester carbonyl groups that are synparallel.

Introduction. Interest in pyrrolizidine alkaloids (PA's) stems from their widespread occurrence and their important biological activity, which includes hepatotoxicity. The most toxic PA's are macrocyclic diesters of (+)-retronecine, which occur with 11- and 12-membered ring sizes. Naturally occurring 13-membered diesters and 14-membered macrocyclic triesters of (+)-retronecine are also known (Robins, 1982). At present PA's containing ten-membered rings are un-

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known. Recently, a range of ten-membered macrocyclic diesters of (+)-retronecine was synthesized (Burton & Robins, 1985) and here we present the crystal structure of the parent compound, (+)-7,9-*O,O*-(succinyl)retronecine.

Experimental. Colourless plate-shaped crystals grown from hexane, crystal ca 0.4 × 0.4 × 0.1 mm used in data collection, CAD-4 diffractometer. Preliminary Weissenberg photographs indicated crystals to be orthorhombic, $P2_12_12_1$, D_m by flotation. 1589 independent intensities, θ limit 28°, $\omega/2\theta$ scan. 2 standard intensities used to monitor variations in intensity data; <3% variation observed. Least-squares technique based on 25 reflections, $\theta > 12^\circ$, used to refine lattice parameters. No absorption correction. h 0–10, k 0–14, l 0–17. Structure solution by direct methods with *MITHRIL* (Gilmore, 1984). Full-matrix least-squares refinement on F of coordinates and anisotropic thermal parameters for all non-hydrogen atoms converged to R and wR of 0.043 and 0.058 with $w = (1/\sigma_f^2)$. Hydrogen-atom parameters included in final least squares, but not refined. 1429 reflections, $I \geq 2.5\sigma_f$, used. $\Delta_{max}/\sigma = 0.10$; max. and min. heights in final difference Fourier synthesis = 0.15 and -0.2 e Å⁻³. Scattering factors from *International Tables for X-ray Crystallography* (1974). All calculations on a Gould SEL 32/27 computer using Glasgow *GX* package (Mallinson & Muir, 1985).

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Discussion. Final positional and equivalent isotropic thermal parameters are given in Table 1.* Bond lengths and angles with their standard deviations are given in Table 2. Torsion angles are also given in Table 2. An ORTEP (Johnson, 1976) diagram, Fig. 1, illustrates the numbering scheme and absolute configuration for the molecule. The absolute configuration of (+)-retronecine has already been determined (Adams & Fleš, 1959) and natural (+)-retronecine was used in the synthesis of the (+)-7,9-*O,O*-(succinyl)retronecine.

The degree of *exo*-puckering of the pyrrolizidine system as defined by the planes of atoms C(5), C(6), C(7) and C(5), N(4), C(8) is 43.7 (4)°, which is within the range (35 to 46°) found for 11- and 12-membered PA's. The angle between the least-squares planes defined by atoms C(1), C(2), C(3), N(4), C(8) and C(5), N(4), C(8), C(7) of the pyrrolizidine nucleus is 126.8 (3)°, about the average value for retronecine-derived PA's; as is the N(4)–C(8) ring-fusion distance of 1.492 (3) Å.

The X-ray structure of the ten-membered macrocycle shows that the carbonyls of the ester groups are nearly antiparallel on opposite sides of the ring system. This conformation of the ester groups is found in only three 11-membered macrocycles containing retronecine [granianine (Stoekli-Evans & Robins, 1984), 1,2-didehydrocrotalanine (Stoekli-Evans & Robins, 1983) and trichodesmine (Tashkhodzhaev, Yagudaev & Yunusov, 1979)] and all 12-membered macrocyclic PA's containing retronecine studied so far [*e.g.* jacobine (Pérez-Salazar,

Cano & García-Blanco, 1978) and retrorsine (Stoekli-Evans, 1979)]. The dihedral angle between the ester groups defined by the planes C(9), O(10), C(11), O(11) and O(14), C(14), O(15), C(7) is 159 (5)°. This is similar to the situation observed in 12-membered macrocyclic PA's with an average value of 163° between bonds (Mackay & Culvenor, 1982). The

Table 1. Final positional parameters ($\times 10^4$) and equivalent isotropic thermal parameters (Å^2) with *e.s.d.*'s in parentheses

$$U_{eq} = \frac{1}{3}(U_{11} + U_{22} + U_{33}).$$

	<i>x</i>	<i>y</i>	<i>z</i>	$U_{eq}(\text{Å}^2)$
O(10)	-0.5851 (2)	-0.0311 (2)	-0.9004 (1)	0.045 (1)
O(11)	-0.6767 (3)	-0.1121 (2)	-1.0473 (1)	0.055 (1)
O(14)	-0.6142 (2)	-0.2156 (2)	-0.6966 (1)	0.049 (1)
O(15)	-0.8367 (2)	-0.1688 (1)	-0.7958 (1)	0.0345 (8)
N(4)	-1.1212 (2)	0.0371 (2)	-0.8058 (1)	0.037 (1)
C(1)	-0.8661 (3)	0.0625 (2)	-0.8963 (2)	0.036 (1)
C(2)	-0.9901 (3)	0.0686 (2)	-0.9624 (2)	0.043 (1)
C(3)	-1.1577 (3)	0.0543 (3)	-0.9144 (2)	0.048 (1)
C(5)	-1.1761 (3)	-0.0799 (2)	-0.7624 (2)	0.044 (1)
C(6)	-1.0505 (3)	-0.1036 (2)	-0.6787 (2)	0.041 (1)
C(7)	-0.8863 (3)	-0.0680 (2)	-0.7282 (2)	0.033 (1)
C(8)	-0.9352 (3)	0.0457 (2)	-0.7910 (2)	0.033 (1)
C(9)	-0.6828 (3)	0.0813 (2)	-0.9187 (2)	0.045 (1)
C(11)	-0.6030 (3)	-0.1230 (2)	-0.9682 (2)	0.040 (1)
C(12)	-0.5243 (3)	-0.2418 (2)	-0.9313 (2)	0.047 (1)
C(13)	-0.6423 (3)	-0.3119 (2)	-0.8594 (2)	0.042 (1)
C(14)	-0.6940 (3)	-0.2302 (2)	-0.7724 (2)	0.036 (1)

Table 2. Bond distances (Å), bond angles (°) and torsion angles (°) in the macrocyclic ring

O(10)–C(9)	1.460 (3)	O(10)–C(11)	1.345 (3)
O(11)–C(11)	1.206 (3)	O(14)–C(14)	1.197 (3)
O(15)–C(7)	1.462 (3)	O(15)–C(14)	1.347 (3)
N(4)–C(3)	1.478 (4)	N(4)–C(5)	1.454 (4)
N(4)–C(8)	1.492 (3)	C(1)–C(2)	1.319 (4)
C(1)–C(8)	1.509 (4)	C(1)–C(9)	1.498 (4)
C(2)–C(3)	1.482 (4)	C(5)–C(6)	1.513 (4)
C(6)–C(7)	1.509 (4)	C(7)–C(8)	1.532 (3)
C(11)–C(12)	1.507 (4)	C(12)–C(13)	1.534 (4)
C(13)–C(14)	1.507 (4)		
C(9)–O(10)–C(11)	116.4 (2)	C(7)–O(15)–C(14)	116.8 (2)
C(3)–N(4)–C(5)	115.8 (2)	C(3)–N(4)–C(8)	108.3 (2)
C(5)–N(4)–C(8)	107.3 (2)	C(2)–C(1)–C(8)	110.4 (3)
C(2)–C(1)–C(9)	125.9 (3)	C(8)–C(1)–C(9)	123.5 (3)
C(1)–C(2)–C(3)	112.3 (3)	N(4)–C(3)–C(2)	104.8 (2)
N(4)–C(5)–C(6)	103.9 (2)	C(5)–C(6)–C(7)	101.9 (2)
O(15)–C(7)–C(6)	108.0 (2)	O(15)–C(7)–C(8)	109.3 (2)
C(6)–C(7)–C(8)	102.8 (2)	N(4)–C(8)–C(1)	104.2 (2)
N(4)–C(8)–C(7)	105.8 (2)	C(1)–C(8)–C(7)	120.4 (2)
O(10)–C(9)–C(1)	111.7 (2)	O(10)–C(11)–O(11)	124.0 (3)
O(10)–C(11)–C(12)	111.5 (2)	O(11)–C(11)–C(12)	124.4 (3)
C(11)–C(12)–C(13)	111.6 (2)	C(12)–C(13)–C(14)	110.7 (2)
O(14)–C(14)–O(15)	124.9 (3)	O(14)–C(14)–C(13)	125.0 (3)
O(15)–C(14)–C(13)	109.9 (2)		
C(8)–C(1)–C(9)–O(10)	70.0 (3)		
C(1)–C(9)–O(10)–C(11)	73.7 (3)		
C(9)–O(10)–C(11)–C(12)	-168.8 (3)		
O(10)–C(11)–C(12)–C(13)	81.9 (3)		
C(11)–C(12)–C(13)–C(14)	-55.7 (3)		
C(12)–C(13)–C(14)–O(15)	-84.8 (3)		
C(13)–C(14)–O(15)–C(7)	-168.5 (3)		
C(14)–O(15)–C(7)–C(8)	133.7 (3)		
O(15)–C(7)–C(8)–C(1)	-24.4 (2)		
C(7)–C(8)–C(1)–C(9)	-64.5 (3)		

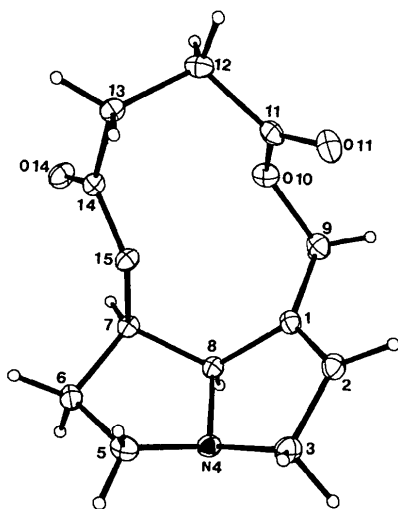


Fig. 1. A perspective view of the molecule showing the numbering scheme and vibrational ellipsoids (50% probability level).

* Lists of structure factors, anisotropic temperature factors and hydrogen-atom coordinates have been deposited with the British Library Lending Division as Supplementary Publication No. SUP 42079 (13 pp.). Copies may be obtained through The Executive Secretary, International Union of Crystallography, 5 Abbey Square, Chester CH1 2HU, England.

torsion angle C(2)–C(1)–C(9)–O(10) is $-116.2(3)$, which again is similar to the values observed for the 12-membered alkaloids [e.g. jacobine -106° and swazine -108° (Laing & Sommerville, 1972)]. In 11-membered PA's, where the ester carbonyl groups are synparallel, the value of this torsion angle ranges from -63 to -88° .

The shortest transannular distances are O(10)⋯O(15) 2.847 (2) and O(10)⋯C(14) 2.867 (3) Å, which are comparable with the equivalent distances O(10)⋯O(16) 2.83 and O(10)⋯C(15) 2.83 Å in trichodesmine.

The chemical-shift difference ($\Delta\delta$) of 1.34 between the protons at C(9) for the ten-membered pyrrolizidine alkaloid analogue is similar to values reported for 12-membered diesters of (+)-retronecine, but is much higher than the values recorded for 11-membered alkaloids ($\Delta\delta$ 0–0.92), with the exception of dicrotaline ($\Delta\delta$ 1.24) (Brown, Devlin & Robins, 1983). Correlations between the position of the C(9) H atoms and the chemical shift in the NMR spectra have already been discussed (Stoekli-Evans & Crout, 1976). The large chemical-shift differences arise when one of the C(9) H atoms lies close to both the plane of the unsaturated ring and the plane of the ester group, resulting in a large deshielding effect. The proximity of H(91) to both these planes can be derived from the torsion angles H(91)–C(9)–O(10)–C(11) $-46(3)$ and H(91)–C(9)–C(1)–C(2) $6.9(3)^\circ$.

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Structure of Boc-Pro-Met-Gly-OBzl,* C₂₄H₃₅N₃O₆S

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Abstract. $M_r = 493.6$, monoclinic, $P2_1$, $a = 9.683(4)$, $b = 35.038(13)$, $c = 9.113(4)$ Å, $\beta = 118.6(1)^\circ$, $V = 2714.5$ Å³, $Z = 4$, $D_m = 1.18$, $D_x = 1.21$ g cm⁻³, $\lambda(\text{Cu } K\alpha_1) = 1.5405$ Å, $\mu(\text{Cu } K\alpha) = 13.05$ cm⁻¹, $F(000) = 1008$, $T = 293$ K, $R = 0.061$ for 3328 reflections with $|F_o| > \sigma(F)$. Two crystallographically independent peptide molecules which are related to each other by a pseudo twofold axis are in an extended form. They are alternately arranged to form an infinitely extended ribbon of an antiparallel β sheet. The mean torsion angles ϕ, ψ of the central Met are $-136, 138^\circ$,

and the hydrogen-bond length is 2.888 Å. A comparison of the Met side chains in related peptides shows that the preferred values are: $\chi^1 = \pm 60^\circ$, $\chi^2 = 180^\circ$, and $\chi^3 = 180^\circ$ or $\pm 60^\circ$.

Introduction. The systematic structural study of a sequentially related oligopeptide is of significance for the elucidation of a sequence–structure relation of peptide chains. Several oligopeptides with a Boc-Pro-*X*-Gly-*Y* sequence, where *X* is any amino acid and *Y* is OH, NH₂, or benzyl ester, have been studied by the X-ray method (Ashida, Tanaka, Yamane & Kakudo, 1981; Ashida, Tanaka & Yamane, 1981). In these peptides, β turns, antiparallel β sheets and poly-

* *N*-(*tert*-Butoxycarbonyl)-L-prolyl-L-methionylglycine benzyl ester.