C14—C15—C18	123.1 (5)	C17—C27—C28	110.1 (9)
C14—C15—C16	121.8 (5)	C16—C27—C28	7.8 (4)
C26—C15—C28	115.3 (8)	C25—C28—C27	105.8 (6)
C25—C15—C28	135 (4)	C16—C28—C27	135 (2)
C25—C15—C26	47 (3)	C16—C28—C25	47 (2)
C18—C15—C28	107.6 (7)	C15—C28—C27	105.9 (6)
C18—C15—C26	7.9 (5)	C15—C28—C25	0.0 (2)
C18—C15—C25	51 (7)	C15—C28—C16	47 (2)
C16—C15—C28	10.0 (5)		

All reagents and solvents were of reagent grade and used without further purification. (2) was obtained as colourless needles, m.p. 469–470 K (crystallized from isobutyl methyl ketone) in 91% yield by treatment of 10 mmol of 3-(bromoacetyl)thiophene (McDowell & Greenwood, 1965) with 6 mmol of K_2CO_3 in DMF at room temperature for 6 h, water quenching, neutralization with 10% HCl and filtration. Analysis: calculated for $C_{18}H_{12}O_3S_3$ C 58.03, H 3.22, S 25.82%; found C 58.32, H 3.11, S 25.56%.

^1H (300 MHz) and ^{13}C (75 MHz) NMR spectra of (2) were recorded on a Varian VXR-300 spectrometer, with $CDCl_3$ or Me_2SO as solvents and TMS (tetramethylsilane) as the internal standard. ^1H NMR ($CDCl_3$, 300 MHz) δ: 8.42 (1H, *dd*, J = 1.2, 3 Hz), 8.14 (2H, *dd*, J = 1.2, 3 Hz), 7.68 (1H, *dd*, J = 1.2, 5.1 Hz), 7.54 (2H, *dd*, J = 1.2, 5.1 Hz), 7.38 (1H, *dd*, J = 1.2, 5.1 Hz), 7.28 (2H, *dd*, J = 3, 5.1 Hz), 4.04 (1H, *t*, J = 5.7 Hz), 3.58 (2H, *d*, J = 5.7 Hz). ^{13}C NMR ($CDCl_3$, 75 MHz): 189.7, 186.7, 141.8, 141.6, 134.2, 132.9, 126.9, 126.8, 126.7, 126.6, 36.6, 30.9.

Intensity data were corrected for Lorentz and polarization effects. H atoms were included in the structure-factor calculations in idealized positions (C—H = 0.95 Å), and were assigned isotropic displacement parameters 20% greater than the U_{eq} value of the atom to which they were bonded. Because the S3-thiophene ring in the molecule is disordered, the C_4S five-membered rigid-body rings were generated based on the average geometry of the other two thiophene rings, which were located from difference Fourier maps and refined by full-matrix least squares. The rigid-body rings were refined isotropically with populations of 0.65 (1) for the ring containing S3 and 0.35 (1) for the ring containing S23. H atoms were not included for the rigid-body rings owing to problems with disorder in the refinements. Program(s) used to solve structure: *MITHRIL* (Gilmore, 1984). Program(s) used to refine structure: *TEXSAN* (Molecular Structure Corporation, 1985). Molecular graphics: *ORTEP* (Johnson, 1965). Anomalous-scattering coefficients were taken from *International Tables for X-ray Crystallography* (1974, Vol. IV).

Lists of structure factors, anisotropic displacement parameters, H-atom coordinates and complete geometry have been deposited with the British Library Document Supply Centre as Supplementary Publication No. SUP 71592 (17 pp.). Copies may be obtained through The Technical Editor, International Union of Crystallography, 5 Abbey Square, Chester CH1 2HU, England. [CIF reference: LI1065]

References

Abraham, R. J., Fischer, J. & Loftus, P. (1988). *Introduction to NMR Spectroscopy*, p. 196. New York: John Wiley.

Gilmore, J. C. (1984). *J. Appl. Cryst.* **17**, 42–46.

Johnson, C. K. (1965). *ORTEP*. Report ORNL-3794. Oak Ridge National Laboratory, Tennessee, USA.

McDowell, D. W. M. & Greenwood, T. D. (1965). *J. Heterocycl. Chem.* **2**, 44–48.

Molecular Structure Corporation (1985). *TEXSAN. TEXRAY Structure Analysis Package*. MSC, 3200 Research Forest Drive, The Woodlands, TX 77381, USA.

Saba, A. (1990). *J. Chem. Res. (S)*, pp. 288–289.

Acta Cryst. (1994). C**50**, 274–276

Structure of a Model for the Aranorosin Nucleus

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(*Received* 5 *May* 1993; *accepted* 31 *August* 1993)

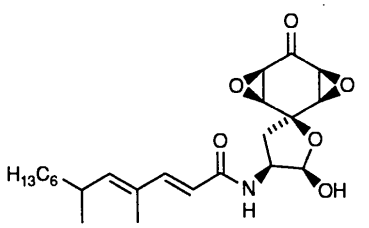
Abstract

The structure of a synthetic model system, 2-hydroxy-6,7;9,10-*cis*,*cis*-diepoxy-1-oxaspiro[4.5]decan-8-one, $C_9H_{10}O_5$, for the spirocyclic headgroup of the natural product aranorosin has been determined and shown to possess the natural product stereochemistry. Two crystallographically independent molecules cocrystallize in a centrosymmetric space group. The *syn* arrangement of the diepoxides and the lactol O atom about the cyclohexanone ring has been confirmed in both molecules. The cyclohexanone ring adopts a boat conformation with the carbonyl O atom *anti* to the lactol O atom.

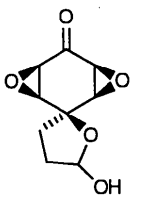
Comment

The recently isolated natural product aranorosin (1) displays antibiotic, antifungal and antitumor properties (Roy, Mukhopadhyay, Reddy, Desikan, Rupp & Ganguli, 1988; Felhaber, Kogler, Mukhopadhyay, Vijayakumar, Roy, Rupp & Ganguli, 1988; Felhaber, Kogler, Mukhopadhyay, Vijayakumar & Ganguli, 1988). The novel spirocyclic cyclohexanone diepoxide moiety of this molecule provides a particularly challenging synthetic target. This challenge, as well as the biological properties of aranorosin (1), have stimulated interest in its synthesis (Rama Rao, Gurjar & Sharma, 1991) and a highly stereoselective route to the model aranorosin nucleus (2) has

been reported from our laboratories (McKillop, Taylor, Watson & Lewis, 1992*a*,*b*; McKillop, McLaren, Taylor, Watson & Lewis, 1992). Before continuing our total synthesis of aranorosin, we sought confirmation that the relative stereochemistry of the model system (2), assigned by spectroscopic methods, was correct for the natural product. To this end, (2) was purified by column chromatography over silica gel and crystallized from ethyl acetate/*n*-hexane.



(1)



(2)

The crystal structure is centrosymmetric with two molecules, arbitrarily chosen to display opposite stereochemistry at the lactol C atom, C9, defining the asymmetric unit. The conformations of both molecules are similar with the two epoxide rings and the ether O atom of the lactol positioned on the one side of the cyclohexanone ring and the carbonyl O atom on the other. The lactol rings both adopt virtually undistorted envelope conformations. In the unprimed molecule, atom C8 is at the flap while in the primed one atom C9 is at the flap. The ring asymmetry parameters (ΔC_s; Duax, Weeks & Rohrer, 1976) are 1.8 for the unprimed and 0.7 for the primed molecule. The hydroxyl group is roughly perpendicular to the best four-atom plane in each lactol ring. The cyclohexanone ring adopts a virtually undistorted boat conformation in both molecules (see Fig. 2) with atoms C1, C2, C4 and C5 coplanar, and atoms C3 and C6 displaced to the same side of this ring. The cyclohexanone ring asymmetry parameters are 1.3 for the unprimed and 0.8 for the primed molecule.

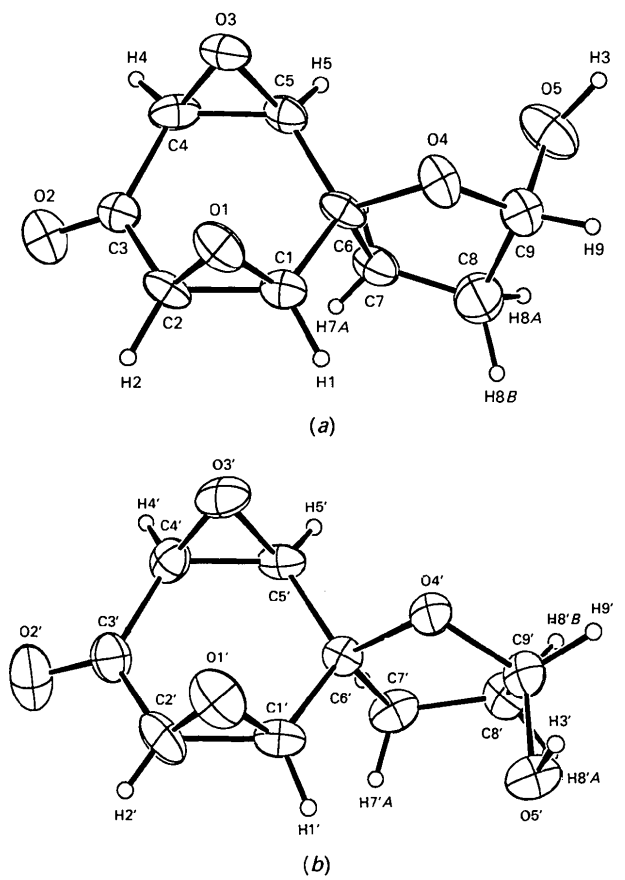


Fig. 1. (*a*) View of one of the two independent molecules of (2) showing the labeling scheme. (*b*) View of the second molecule of (2) showing the labeling scheme. Thermal ellipsoids are drawn at the 50% probability level and H atoms as small spheres of arbitrary size.

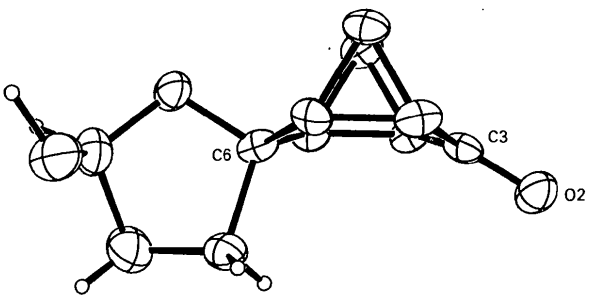


Fig. 2. An alternative view of (2) illustrating the boat conformation of the cyclohexanone ring.

Hydrogen bonding in this crystal structure results in clusters of four molecules. The two independent molecules are linked by a hydrogen bond between the alcohol groups and these two molecules are then linked to another pair by hydrogen bonds between the alcohol and the O atom of the lactol ring. The details of the hydrogen-bonding contacts are: O5—H3···O5′ 172°, O5···O5′ 2.817 (5), O5—H3 1.06, H3···O5′ 1.76 Å; O5′—H3′···O4′ 157°, O5′···O4′ 2.790 (4), O5′—H3′ 0.92, H3′···O4′ 1.92 Å.

Experimental

Crystal data

$C_9H_{10}O_5$
M_r = 198.18
Monoclinic
$P2_1/n$
a = 14.664 (6) Å
b = 6.319 (1) Å
c = 19.440 (7) Å
β = 107.86 (2)°
V = 1714 (1) Å^3
Z = 8
D_x = 1.536 Mg m^{-3}
Mo $K\alpha$ radiation
λ = 0.71073 Å
Cell parameters from 25 reflections
θ = 14-12°
μ = 0.1188 mm^{-1}
T = 223 K
Elongated flat plate
0.65 × 0.20 × 0.04 mm
Colorless

Data collection

Enraf-Nonius CAD-4 diffractometer
$\theta/2\theta$ scans
Absorption correction: none
5324 measured reflections
2379 independent reflections
1337 observed reflections [$I > 3.0\sigma(I)$]
$R_{int} = 0.11$
$\theta_{max} = 22.98°$
$h = 0 \rightarrow 16$
$k = -7 \rightarrow 7$
$l = -21 \rightarrow 21$
3 standard reflections
frequency: 180 min
intensity variation: 1.17%

Refinement

Refinement on F
$R = 0.060$
$wR = 0.074$
$S = 1.095$
1337 reflections
254 parameters
H atoms refined with $U = 1.3 \times U$ of bonded atom
$w = 4F_o^2/[\sigma^2(F_o^2) + 0.0121F_o^4]$
$(\Delta/\sigma)_{max} = 0.001$
$\Delta\rho_{max} = 0.3639$ e Å^{-3}
$\Delta\rho_{min} = -0.2917$ e Å^{-3}
Extinction correction: isotropic (Zachariasen, 1963)
Extinction coefficient: 0.77×10^{-6}
Atomic scattering factors from *International Tables for X-ray Crystallography* (1974, Vol. IV)

Data collection: *CAD*-4 (Enraf-Nonius, 1977). Cell refinement: *SET*4 (de Boer & Duisenberg, 1984). Data reduction: *MolEN PROCESS* (Fair, 1990). Program(s) used to solve structure: *SHELXS*86 (Sheldrick, 1985). Program(s) used to refine structure: *MolEN LSFM*. Molecular graphics: *ORTEP*II (Johnson, 1976). Software used to prepare material for publication: *MolEN BTABLE PTABLE CIFIN*.

Table 1. *Fractional atomic coordinates and equivalent isotropic displacement parameters* (Å^2)

$U_{eq} = (1/3)\Sigma_i\Sigma_j U_{ij}a_i^*a_j^*\mathbf{a}_i.\mathbf{a}_j$.

	x	y	z	U_{eq}
O1	0.9411 (2)	−0.1286 (5)	0.0839 (2)	0.027 (2)
O2	1.1718 (2)	0.0764 (5)	0.1009 (2)	0.036 (2)
O3	0.9339 (2)	0.2599 (5)	0.0195 (1)	0.028 (1)
O4	0.8296 (2)	0.2229 (5)	0.1386 (2)	0.031 (1)
O5	0.7939 (2)	0.5436 (6)	0.1825 (2)	0.047 (2)
C1	0.9601 (3)	−0.0146 (8)	0.1508 (2)	0.028 (2)
C2	1.0385 (3)	−0.0767 (7)	0.1229 (2)	0.024 (2)
C3	1.0869 (3)	0.0873 (7)	0.0932 (2)	0.024 (2)
C4	1.0323 (3)	0.2861 (8)	0.0627 (2)	0.030 (2)
C5	0.9535 (3)	0.3419 (7)	0.0911 (2)	0.025 (2)
C6	0.9313 (3)	0.2167 (7)	0.1484 (2)	0.022 (2)
C7	0.9785 (3)	0.3213 (8)	0.2226 (2)	0.032 (2)
C8	0.9040 (4)	0.306 (1)	0.2591 (3)	0.048 (3)
C9	0.8118 (3)	0.3277 (9)	0.1972 (3)	0.039 (2)
O1′	0.6250 (2)	0.3333 (5)	−0.0988 (2)	0.034 (2)
O2′	0.7773 (2)	0.5187 (6)	−0.1948 (2)	0.056 (2)
O3′	0.5532 (2)	0.6886 (5)	−0.1832 (2)	0.030 (2)
O4′	0.5521 (2)	0.6973 (5)	−0.0313 (1)	0.024 (1)
O5′	0.6062 (2)	0.5664 (5)	0.0865 (2)	0.030 (2)
C1′	0.6794 (3)	0.4804 (8)	−0.0478 (2)	0.029 (2)
C2′	0.7162 (3)	0.4002 (8)	−0.1040 (3)	0.036 (2)
C3′	0.7179 (3)	0.5387 (8)	−0.1647 (2)	0.033 (2)
C4′	0.6518 (3)	0.7253 (8)	−0.1804 (2)	0.030 (2)
C5′	0.6149 (3)	0.8038 (7)	−0.1237 (2)	0.022 (2)
C6′	0.6399 (3)	0.7030 (7)	−0.0504 (2)	0.021 (2)
C7′	0.7090 (3)	0.8429 (8)	0.0086 (2)	0.030 (2)
C8′	0.6522 (3)	0.9112 (8)	0.0568 (2)	0.030 (2)
C9′	0.5729 (3)	0.7470 (7)	0.0435 (2)	0.027 (2)

Lists of structure factors, anisotropic displacement parameters, H-atom coordinates and complete geometry have been deposited with the British Library Document Supply Centre as Supplementary Publication No. SUP 71582 (14 pp.). Copies may be obtained through The Technical Editor, International Union of Crystallography, 5 Abbey Square, Chester CH1 2HU, England. [CIF reference: CR1079]

References

Boer, J. L. de & Duisenberg, A. J. M. (1984). *Acta Cryst.* A**40**, C-410.
Duax, W. L., Weeks, C. M. & Rohrer, D. C. (1976). *Topics in Stereochemistry*, Vol. 9, edited by E. L. Eliel & N. L. Allinger, pp. 271-283.
Enraf-Nonius (1977). *CAD-4 Operations Manual*. Enraf-Nonius, Delft, The Netherlands.
Fair, C. K. (1990). *MolEN. An Interactive Intelligent System for Crystal Structure Analysis*. Enraf-Nonius, Delft, The Netherlands.
Felhaber, H. W., Kogler, H., Mukhopadhyay, T., Vijayakumar, E. K. S. & Ganguli, B. N. (1988). *J. Am. Chem. Soc.* **101**, 8242-8244.
Felhaber, H. W., Kogler, H., Mukhopadhyay, T., Vijayakumar, E. K. S., Roy, K., Rupp, R. H. & Ganguli, B. N. (1988). *J. Antibiot.* **41**, 1785-1794.
Johnson, C. K. (1976). *ORTEP*II. Report ORNL-5138. Oak Ridge National Laboratory, Tennessee, USA.
McKillop, A., McLaren, L., Taylor, R. J. K., Watson, R. J. & Lewis, N. (1992). *Synlett*, pp. 201-203.
McKillop, A., Taylor, R. J. K., Watson, R. J. & Lewis, N. (1992*a*). *J. Chem. Soc. Chem. Commun.* pp. 1589-1591.
McKillop, A., Taylor, R. J. K., Watson, R. J. & Lewis, N. (1992*b*). *Synlett*, pp. 1005-1006.
Rama Rao, A. V., Gurjar, M. K. & Sharma, P. A. (1991). *Tetrahedron Lett.* **32**, 6613-6616.
Roy, K., Mukhopadhyay, T., Reddy, G. C. S., Desikan, K. R., Rupp, R. H. & Ganguli, B. N. (1988). *J. Antibiot.* **41**, 1780-1784.
Sheldrick, G. M. (1985). *SHELXS*86. *Program for the Solution of Crystal Structures*. Univ. of Göttingen, Germany.
Zachariasen, W. H. (1963). *Acta Cryst*, **16**, 1139-1144.

Acta Cryst. (1994). C**50**, 276–278

Dimethyl 9-[(*S*)-(−)-*N*-Acetylalanyloxy]-methyl-9,10-dihydro-9,10-etheno-anthracene-11,12-dicarboxylate

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(*Received* 2 *June* 1993; *accepted* 19 *August* 1993)

Abstract

The molecule of $C_{26}H_{25}NO_7$ has normal dimensions, with the carboxymethyl group that is remote from the 9-substituent conjugated with the C11=C12 double bond and the adjacent carboxymethyl group out of conjugation. Molecules are linked by N—H···O hydrogen bonds.