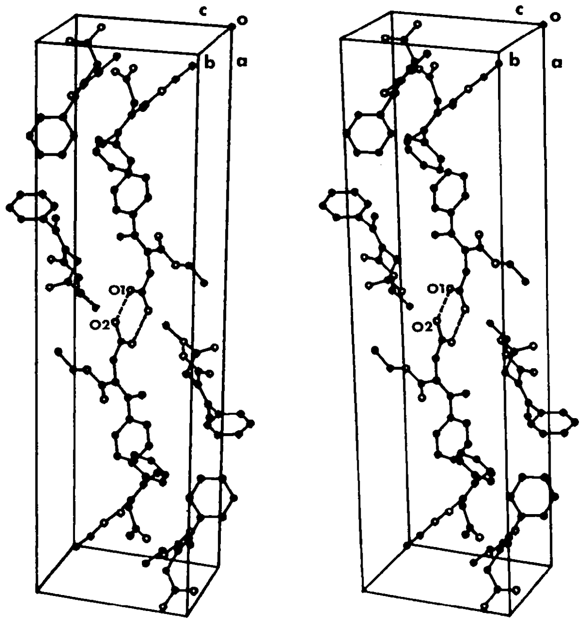

Fig. 2. Stereoscopic view of the unit cell showing the centrosymmetric hydrogen-bonded dimers.

Fig. 2 shows a stereoscopic view of the molecular packing. A hydrogen bond between the O(1) hydroxyl group and the O(2) carbonyl oxygen atoms of neighbouring molecules constitutes the major intermolecular attraction and packing force. The two molecules are linked by a pair of O(1)–H···O(2) hydrogen bonds across a crystallographic centre of inversion. The O(1)···O(2) and H(1)···O(2) distances are 2·690 (3) and 2·00 (3) Å, and the O(1)–H···O(2) angle is 171 (2)°.

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Structure of *p*-Anisoin, $C_{16}H_{16}O_4$

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Abstract. $M_r = 272{\cdot}3$, $P2_12_12_1$, $a = 12{\cdot}073$ (2), $b = 18{\cdot}917$ (2), $c = 5{\cdot}977$ (1) Å, $V = 1365{\cdot}1$ (4) Å^3, $Z = 4$, $D_x = 1{\cdot}325$ Mg m^{-3}, Cu $K\alpha$, $\lambda = 1{\cdot}5418$ Å, $\mu = 0{\cdot}74$ mm^{-1}, $F(000) = 576$, $T = 295$ K, final $R = 0{\cdot}042$ for 1242 non-zero reflections. The hydrogen bond between the carbonyl O and hydroxyl O atoms in *p*-anisoin is intramolecular [O···O 2·611 (3), H···O 2·01 (4) Å, O–H···O 113 (3), O=C–C–O 15·1 (4)°]. The molecular conformation is similar to that of benzoin, in which there is no intramolecular hydrogen bond. It has been shown that the type of hydrogen bond in solid benzoins depends on the molecular packing in the crystals.

Introduction. Previous work on benzoin (Haisa, Kashino & Morimoto, 1980) has shown that there is no intramolecular hydrogen bond between the carbonyl O and hydroxyl O atoms, in spite of an O···O distance of 2·585 (4) Å, but a bifurcated hydrogen bond exists between the intermolecular O atoms. Additionally, an IR spectrum (KBr disk) of *p*-anisoin (1) shows a sharp singlet in the OH stretching frequency band at 3450 cm^{-1}, while that of benzoin (2) shows a doublet at 3390 and 3350 cm^{-1} (Suryanarayana & Subrahmanyam, unpublished). This difference in the IR spectrum suggests a difference in the type of hydrogen bond in (1) and (2). However, there is no systematic

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study to draw a useful conclusion regarding the hydrogen-bond system of benzoins. The present work, which forms part of a study of the systematization of organic crystals (Haisa, 1978), has been undertaken in order to clarify the type of hydrogen bond in (1), and to elucidate the factors determining the type in benzoins in the solid state.

Experimental. Crystals obtained from an ethanol solution by slow evaporation, colorless prisms elongated along **c**. D_m not determined. Systematic absences $h00$ for h odd, $0k0$ for k odd, $00l$ for l odd, indicating space group $P2_12_12_1$; crystal 0·10 × 0·10 × 0·42 mm; Rigaku AFC-5 four-circle diffractometer; lattice parameters determined from 20 reflections by least squares; intensities measured up to $2\theta = 125°$; ω–2θ scan method, scan speed 4° min^{-1} in 2ω, scan range $1{\cdot}2° + 0{\cdot}15° \tan\theta$; Ni-filtered Cu $K\alpha$ at 40 kV and 200 mA; background measured for 4 s on either side of peak; three reference reflections showed no intensity deterioration; intensities corrected for Lorentz and polarization factors, but not for absorption; 1287 independent reflections (ranging over $h = 0$ to 13, $k = 0$ to 21, $l = 0$ to 6) used for refinement; 1242 non-zero reflections; structure solved by *MULTAN*78, and refined by block-diagonal least squares; $\sum w(|F_o| - |F_c|)^2$ minimized, with $w = 1{\cdot}0/[\sigma(F_o)^2 + 0{\cdot}0109|F_o| + 0{\cdot}002|F_o|^2]$ for $|F_o| > 0$, $w = 0{\cdot}5635$ for $|F_o| = 0$; locations of H atoms determined from a difference Fourier synthesis and refined by least squares; non-H atoms anisotropic, H atoms isotropic; $R = 0{\cdot}046$ for 1287 reflections, $wR = 0{\cdot}047$, $S = 1{\cdot}02$, $(\Delta/\sigma)_{\max}$ in final refinement cycle 0·2 for non-H atoms and 1·2 for H atoms; max. and min. $\Delta\rho$ in final difference Fourier map $\pm 0{\cdot}14$ e Å^{-3}; atomic scattering factors taken from *International Tables for X-ray Crystallography* (1974); no correction for secondary extinction; computations carried out at the Crystallographic Research Center, Institute for Protein Research, Osaka University, and at the Okayama University Computer Center; programs used were *MULTAN*78 (Main, Hull, Lessinger, Germain, Declercq & Woolfson, 1978), *HBLS*-V (Ashida, 1973), *MOLCON* (Fujii, 1979) and *ORTEP* (Johnson, 1965).

Discussion. The final atomic parameters are listed in Table 1.* The thermal ellipsoids and numbering are shown in Fig. 1. Bond lengths and angles are listed in Table 2. The molecular conformation is compared with that of (2) in Table 3.

Table 1. *Final atomic parameters (positional* ×10^4) *with e.s.d.'s in parentheses*

$$B_{eq} = \tfrac{4}{3}\textstyle\sum_i \beta_{ii}/a_i^{*2}.$$

	x	y	z	B_{eq}(Å^2)
O(1)	5470 (2)	4606 (1)	4546 (4)	4·8 (1)
O(2)	4590 (2)	4169 (1)	8289 (4)	4·2 (1)
O(3)	8407 (2)	7371 (1)	5169 (5)	5·0 (1)
O(4)	1439 (2)	6790 (1)	9721 (4)	4·4 (1)
C(1)	6333 (2)	5640 (1)	5869 (5)	3·3 (1)
C(2)	6940 (2)	5721 (1)	3920 (5)	3·4 (1)
C(3)	7653 (2)	6290 (2)	3592 (5)	3·9 (1)
C(4)	7756 (2)	6788 (1)	5287 (5)	3·7 (1)
C(5)	7154 (3)	6718 (2)	7256 (5)	4·2 (1)
C(6)	6460 (3)	6146 (2)	7546 (5)	3·8 (1)
C(7)	4049 (2)	5400 (1)	8612 (5)	3·2 (1)
C(8)	3263 (2)	5493 (1)	6958 (5)	3·4 (1)
C(9)	2368 (2)	5956 (1)	7250 (5)	3·4 (1)
C(10)	2279 (2)	6321 (1)	9244 (5)	3·2 (1)
C(11)	3054 (3)	6235 (2)	10933 (5)	3·7 (1)
C(12)	3939 (2)	5775 (2)	10606 (5)	3·5 (1)
C(13)	5603 (2)	5016 (1)	6091 (5)	3·3 (1)
C(14)	4991 (2)	4871 (1)	8292 (5)	3·4 (1)
C(15)	9075 (3)	7467 (2)	3226 (8)	5·3 (2)
C(16)	706 (3)	6976 (2)	7929 (7)	5·0 (2)

Table 2. *Bond lengths* (Å) *and bond angles* (°)

O(1)–C(13)	1·217 (4)	C(4)–C(5)	1·390 (4)
O(2)–C(14)	1·413 (4)	C(5)–C(6)	1·379 (4)
O(3)–C(4)	1·356 (4)	C(7)–C(8)	1·382 (4)
O(3)–C(15)	1·426 (6)	C(7)–C(12)	1·393 (4)
O(4)–C(10)	1·377 (4)	C(7)–C(14)	1·527 (4)
O(4)–C(16)	1·433 (4)	C(8)–C(9)	1·402 (4)
C(1)–C(2)	1·385 (4)	C(9)–C(10)	1·382 (4)
C(1)–C(6)	1·394 (4)	C(10)–C(11)	1·386 (4)
C(1)–C(13)	1·479 (4)	C(11)–C(12)	1·392 (4)
C(2)–C(3)	1·392 (4)	C(13)–C(14)	1·534 (4)
C(3)–C(4)	1·389 (4)		

C(4)–O(3)–C(15)	118·3 (3)	C(12)–C(7)–C(14)	120·8 (3)
C(10)–O(4)–C(16)	117·3 (3)	C(7)–C(8)–C(9)	121·3 (3)
C(2)–C(1)–C(6)	118·1 (3)	C(8)–C(9)–C(10)	118·7 (3)
C(2)–C(1)–C(13)	118·6 (3)	O(4)–C(10)–C(9)	123·9 (3)
C(6)–C(1)–C(13)	123·3 (3)	O(4)–C(10)–C(11)	115·0 (3)
C(1)–C(2)–C(3)	122·1 (3)	C(9)–C(10)–C(11)	121·1 (3)
C(2)–C(3)–C(4)	118·5 (3)	C(10)–C(11)–C(12)	119·3 (3)
O(3)–C(4)–C(3)	124·4 (3)	C(7)–C(12)–C(11)	120·8 (3)
O(3)–C(4)–C(5)	115·1 (3)	O(1)–C(13)–C(1)	121·3 (3)
C(3)–C(4)–C(5)	120·4 (3)	O(1)–C(13)–C(14)	118·3 (3)
C(4)–C(5)–C(6)	119·9 (3)	C(1)–C(13)–C(14)	120·5 (3)
C(1)–C(6)–C(5)	121·0 (3)	O(2)–C(14)–C(7)	111·2 (2)
C(8)–C(7)–C(12)	118·8 (3)	O(2)–C(14)–C(13)	109·4 (2)
C(8)–C(7)–C(14)	120·4 (3)	C(7)–C(14)–C(13)	110·4 (2)

Table 3. *Comparison of the molecular conformations of p-anisoin and benzoin*

	p-Anisoin	Benzoin
O(1)···O(2)	2·611 (3) Å (intramolecular hydrogen bond)	2·585 (4) Å (no intramolecular hydrogen bond)
O(1)–C(13)–C(14)–O(2)	15·1 (4)°	26·0 (4)°
C(2)–C(1)–C(13)–O(1)	−5·2 (4)	−12·5 (4)
C(1)–C(13)–C(14)–C(7)	72·4 (3)	84·9 (3)
C(8)–C(7)–C(14)–C(13)	53·4 (4)	68·9 (3)
C(8)–C(7)–C(14)–O(2)	−68·2 (4)	−48·1 (4)
C(15)–O(3)–C(4)–C(3)	−3·2 (5)	—
C(16)–O(4)–C(10)–C(9)	−8·6 (4)	—
Dihedral angle between terminal phenyl rings	98·1 (1)	115·5 (1)

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* Lists of structure factors, anisotropic thermal parameters, coordinates and isotropic thermal parameters of the H atoms and bond lengths and angles involving H atoms have been deposited with the British Library Lending Division as Supplementary Publication No. SUP 42106 (10 pp.). Copies may be obtained through The Executive Secretary, International Union of Crystallography, 5 Abbey Square, Chester CH1 2HU, England.

The bond lengths and angles in (1) are in agreement with those of (2) within the experimental errors, except for C(1)—C(13) 1·479 (4) Å.

In (1) carbonyl O(1) and hydroxyl O(2) are linked by an intramolecular hydrogen bond, while in (2) the O atoms participate in intermolecular hydrogen bonds (Haisa *et al.*, 1980). However, their molecular conformations are similar to each other, differences in the corresponding torsion angles being within 20° (Table 3). In (1) the torsion angle O(1)—C(13)—C(14)—O(2) is so small [15·1 (4)°] as to facilitate the formation of the intramolecular hydrogen bond. The corresponding angle in (2) is also small [26·0 (4)°]; this is determined by the bifurcated intermolecular hydrogen bonds. The present result shows that when the torsion angle around C(13)—C(14) is once fixed at a small value by either intramolecular or intermolecular effects, then the torsion angles around C(1)—C(13) and C(7)—C(14), and thus the overall molecular conformations of benzoins, are mainly determined by intramolecular steric requirements.

In *o*-anisoin (3) (Plana, Miravitlles, Solans & Galí, 1977), the torsion angle around C(1)—C(13) is increased by the effect of *ortho* substitution [C(2)—C(1)—C(13)—O(1) 34·4 (8)°].

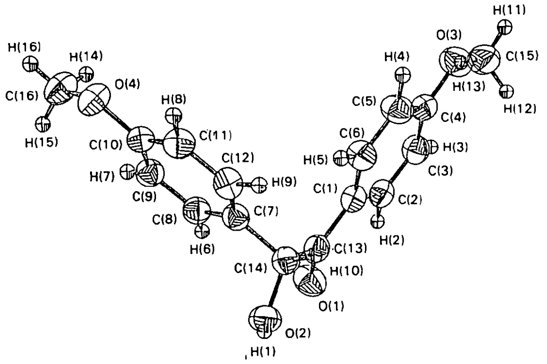

Fig. 1. View of the molecule with numbering of the atoms. Ellipsoids of 50% probability are used for the non-H atoms; the H atoms are represented as spheres equivalent to $B = 1\cdot0$ Å^2.

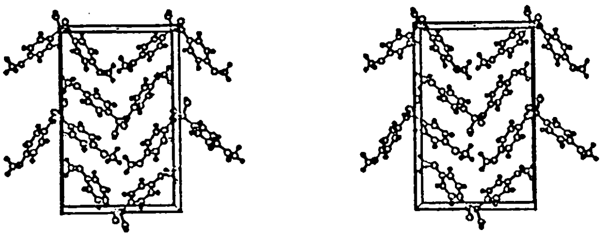

Fig. 2. Stereoscopic view of the molecular packing in the cell. The *a* axis points from left to right, the *b* axis upwards, and the *c* axis into the plane of the paper.

Table 4. *Correspondence of the crystallographic axes of p-anisoin* (1) *and benzoin* (2) *to those of o-anisoin* (3)

(3)	(1)	(2)
Pcab, $Z = 8$	$P2_12_12_1$, $Z = 4$	$P2_1/a$, $Z = 4$
$a = 22\cdot914$ (8) Å	$b = 18\cdot917$ (2) Å	$a = 18\cdot76$ (2) Å
$b/2 = 14\cdot937$ (7)/2	$c = 5\cdot977$ (1)	$b = 5\cdot765$ (5)
$c = 8\cdot110$ (2)	$a = 12\cdot073$ (2)	$c = 10\cdot44$ (2)
		$\beta = 107\cdot1$ (2)°

The arrangement of the molecules in the crystal is shown in Fig. 2. Molecules related by a 2_1 axis along **c** are held together by van der Waals interactions to form a sheet parallel to (010). The sheets related by a 2_1 axis along **b** are stacked to complete the whole structure. All the intermolecular contacts are normal van der Waals interactions.

The intermolecular hydrogen bond as found in (2) is not allowed in (1) because of the packing requirement. If the same crystal structure of $P2_1/a$ for (2) were assumed for (1), the molecules related by the 2_1 axis should be linked by the intermolecular hydrogen bonds, and the symmetry operation between the sheets should change to $\bar{1}$. This change would result in an unexpectedly long interplanar distance between the phenyl rings related by $\bar{1}$ because of the existence of the *p*-methoxy groups [note phenyl rings A^{i} and A^{iii} in (2) (Haisa *et al.*, 1980; and Fig. 1 therein)]. Hence, the intramolecular hydrogen bond is formed instead.

Crystals of (3) belong to the minimal supergroup *Pcab* of both $P2_12_12_1$ of (1) and $P2_1/a$ of (2). There is neither an intermolecular nor an intramolecular hydrogen bond in (3). Molecular arrangements close to the actual structures of (1) or (2) can be obtained from the structure of (3) by removing $\bar{1}$ or 2_1 along **a** (or **c**), and then by adjusting the molecular packing by means of translations and rotations of the molecules with respect to the crystallographic axes. The correspondence of the axes among these crystals is shown in Table 4. Such a correspondence of the structures indicates that the crystal structures of benzoins are mainly dominated by the molecular packing, not by the hydrogen bonding. The structure as found in (2) is not inherently one involving the intermolecular hydrogen bond though it is nevertheless in conformity with the formation of the hydrogen bond. In fact, the type of hydrogen bond in (1) is intramolecular and in (2) intermolecular; in (3) there is no hydrogen bond.

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Structure of 3-*O*-Demethylcolchicine Acetone Solvate, $C_{21}H_{23}NO_6.C_3H_6O$

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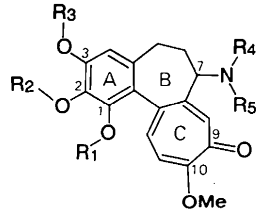
Abstract. $M_r = 443{\cdot}5$, orthorhombic, $P2_12_12_1$, $a = 8{\cdot}030\,(1)$, $b = 9{\cdot}700\,(1)$, $c = 30{\cdot}710\,(3)$ Å, $V = 2392{\cdot}0$ Å^3, $Z = 4$, $D_m = 1{\cdot}22\,(1)$, $D_x = 1{\cdot}231$ g cm^{-3}, $\lambda(\mathrm{Cu}\,K\alpha) = 1{\cdot}5418$ Å, $\mu = 7{\cdot}58$ cm^{-1}, $F(000) = 944$, $T = 293$ K, $wR = 0{\cdot}052$ for 2788 reflections. This biologically relatively active colchinoid compound crystallizes as an acetone solvate. The intensity data were not of very high quality and the structure was refined first with data processed by standard methods and then with Bayesian techniques which produced an improvement in the precision of the results. The molecular conformation bears considerable resemblance to those of previously reported active colchinoids.

Introduction. Colchicine and its analogs are thought to inhibit biological processes by blocking the polymerization of tubulin. While chemical manipulation of colchicine has indicated that aromatic substitution, proper chirality of the acetimido function and a carbonyl group at C(9) are necessary for effective tubulin binding (Capraro & Brossi, 1983), definite conclusions as to the role of these functionalities are lacking. The present structure is that of a chemically modified colchinoid compound which still possesses a biological activity not greatly diminished from that of colchicine itself (Capraro & Brossi, 1983). This investigation represents the second paper in an investigation of colchinoid compounds at the extremes of biological activity (the first was Silverton, Sharma & Brossi, 1985).

The general formula of the colchinoids is given as (I) and 3-*O*-demethylcolchicine has $R1$=$R2$=methyl, $R3$=$R4$=H, $R5$=acetyl.



(I)

Experimental. 3-*O*-Demethylcolchicine (crystallized from acetone): m.p. (uncorrected, acetone solvate), Fisher–Johns apparatus, 554 K optical rotation, Perkin–Elmer 241 polarimeter $[\alpha]_D^{20\,^\circ\mathrm{C}} = -157^\circ$ ($c = 0{\cdot}4$ g dm^{-3}, $CHCl_3$). Literature (Rosner, Capraro, Jacobson, Brossi, Iorio, Williams, Sik & Chignell, 1981): m.p. 543 K, $[\alpha]_D^{20\,^\circ\mathrm{C}} = -151^\circ$ ($CHCl_3$). $C_{21}H_{23}NO_6.CH_3COCH_3$; C, H, N calculated: 64·99, 6·59, 3·150; found (Microanalytical Section, Laboratory of Chemistry, NIADDK, NIH): 64·79, 6·70, 3·01%.

X-ray experimental data: Enraf–Nonius CAD-4 diffractometer; colorless prismatic crystals, 0·3 × 0·1 × 0·1 mm; $\sin\theta/\lambda(\max.) = 0{\cdot}6235$ Å^{-1}; 2788 reflections measured (max. time 90 s, $h\,0\rightarrow10$, $k\,0\rightarrow12$, $l\,0\rightarrow38$), 1092 reflections with $I \le \sigma(I)$. 20 reflections ($20 \le \theta \le 30^\circ$) used for measuring lattice parameters. No absorption correction.

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