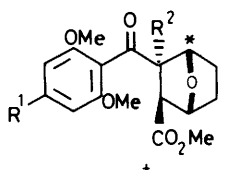
The Chemistry of Fungi. Part 80[1]. The *X*-Ray Crystallographic Structure of 8aβ-Bromo-5aα,5,6,7,8,8a-hexahydro-1,7α-dihydroxy-8α-methoxycarbonylxanthone Monohydrate, a Rearrangement Product of Methyl 2α-Bromo-2β-(2,6-dimethoxybenzoyl)-7-oxabicyclo[2.2.1]heptane-3β-carboxylate: A Novel Route to Xanthones: The Synthesis of Pinselin.

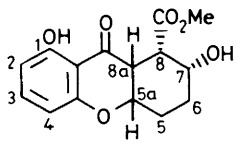
George Ferguson * **and Branko Kaitner**
Department of Chemistry, University of Guelph, Guelph, Ontario, Canada, N1G 2W1
Jeremy Gilmore, Victor O. T. Omuaru, and W. Basil Whalley *
The School of Pharmacy, University of London, 29—39 Brunswick Square, London WC1N 1AX

Treatment of methyl 2α-bromo-2β-(2,6-dimethoxybenzoyl)-7-oxabicyclo[2.2.1]heptane-3β-carboxylate (**1**; R^1 = H, R^2 = Br) with boron trichloride gives 8aβ-bromo-5aα-5,6,7,8,8a-hexahydro-1,7α-dihydroxy-8α-methoxycarbonylxanthone (**4**; R = H), as a monohydrate, the crystals of which are triclinic, space group $P\bar{1}$ with 8 molecules in a cell of dimensions *a* = 8.648(1), *b* = 17.597(3), *c* = 20.309(3) Å, α = 94.36(1), β = 91.39(1), γ = 93.41(1)°. The structure was solved by the heavy atom method and refined by full-matrix least-squares calculations with anisotropic thermal parameters; *R* = 0.050 for 2 939 reflexions with $I > 3\sigma(I)$. Dehydrobromination of (**4**; R = H) gave 5,6,7,8-tetrahydro-1,7α-dihydroxy-8α-methoxycarbonylxanthone (**5**) which was oxidised to 5,6,7,8-tetrahydro-1-hydroxy-8α-methoxycarbonyl-7-oxoxanthone (**6**). Bromination/dehydrobromination of (**6**) gave a monobromo-1,7-dihydroxy-8-methoxycarbonylxanthone. Application of this process to methyl 2α-bromo-2β-(2,6-dimethoxy-4-methylbenzoyl)-7-oxabicyclo[2.2.1]heptane-3β-carboxylate (**1**; R^1 = Me, R^2 = H) gave 1,7-dihydroxy-8-methoxycarbonyl-3-methylxanthone (pinselin) (**3**; R^1 = R^2 = Me) in high yield. This process provides a novel route to xanthones of type (**3**).

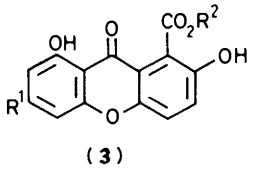
We have previously reported[2] that the action of boron trichloride upon certain diastereoisomers of the 7-oxabicyclo[2.2.1]heptane system, type (**1**; R^1 = R^2 = H) gives, *inter alia*, small quantities of materials to which the hexahydroxanthone structure, type (**2**) has been assigned. On the basis of the proposed mechanism,[2,3] for this reaction it appeared that if the nucleophilicity of the oxido-bridge carbon atom (* in **1**; R^1 = R^2 = H) could be increased, the yield of hexahydroxanthone might be improved, thus providing a potential route to xanthones of type (**3**), including the fungal metabolite, pinselin, (**3**; R^1 = R^2 = Me) which has hitherto been difficultly accessible by synthesis.[4] This objective has been realised.



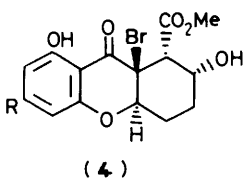
(**1**)†



(**2**)



(**3**)



(**4**)

† All the structures imply (±) compounds

Thus, the bromo ketone (**1**; R^1 = H, R^2 = Br)[2] appeared to be a suitable substrate for testing our hypothesis, and the action of boron trichloride upon (**1**; R^1 = H, R^2 = Br) produced, as the only identifiable product, in high yield, a substance having

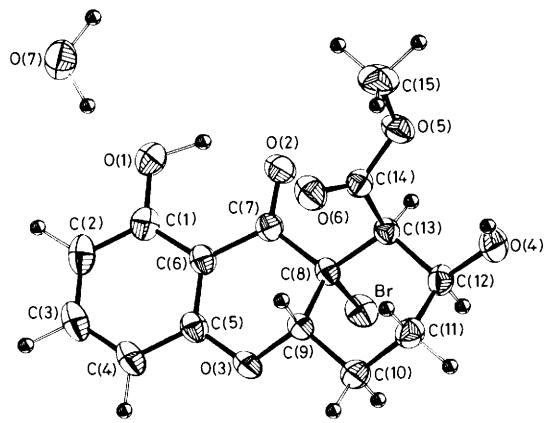


Figure 1. A view of (**4**; R = H) with the crystallographic numbering scheme.

the correct spectral characteristics for structure (**4**; R = H). The elemental analysis, however, was consistently in accord with the molecular formula, $C_{15}H_{15}BrO_6 \cdot H_2O$ and the apparent water of crystallisation was not removable by any normal processes. It thus seemed prudent to establish the validity of our conclusions by an alternative method. Hence (**4**; R = H) was examined by *X*-ray crystallography which confirmed the structure (and relative stereochemistry), and the presence of water of crystallisation in the crystal lattice.

Figure 1 shows a view of (**4**; R = H) with the crystallographic numbering scheme. The crystals are centrosymmetric and the molecule shown in Figure 1 and its enantiomer are present equally in the crystal lattice. Aromatic ring A is planar, ring B has a C(9) envelope conformation [C(9) is 0.64 Å off the O(3),C(5)–C(8) plane], and ring C has a regular chair conformation slightly deformed (ring torsion angles −59.5 to

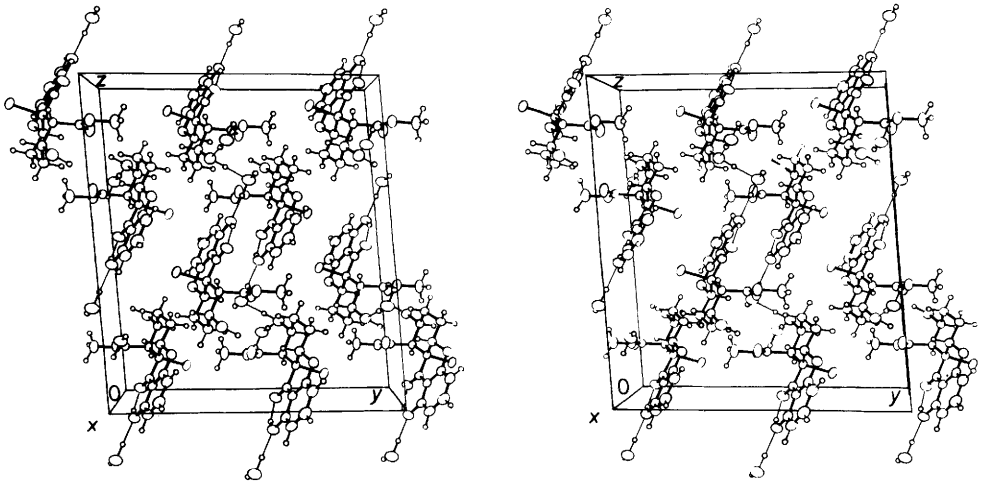


Figure 2. A stereoview of the unit cell contents of (**4**; R = H)·H_2O. Hydrogen bonds are shown by thin lines.

Table 1. Selected dimensions for (**4**; R = H)·H_2O

(a) Bond lengths (e.s.d.'s are 0.003—0.005 Å)

	Type	Minimum	Maximum	No. of bonds	mean
	Br–C	1.986			1.986
	$C(sp^2)$=O	1.197	1.220	2	1.209
	$C(sp^2)$–O(C)	1.330	1.366	2	1.348
	$C(sp^2)$–O(H)	1.352		1	1.352
	$C(sp^3)$–O(C)	1.437	1.444	2	1.441
	$C(sp^3)$–O(H)	1.424		1	1.424
(aromatic)	$C(sp^2)$–$C(sp^2)$	1.376	1.419	6	1.394
	$C(sp^2)$–$C(sp^2)$	1.458		1	1.458
	$C(sp^2)$–$C(sp^3)$	1.522	1.526	2	1.524
	$C(sp^3)$–$C(sp^3)$	1.512	1.558	2	1.534

(b) Hydrogen bond distances:

	d(O ··· O)	d(H ··· O)
O(1)–H ··· O(2)	2.604	1.69
O(4)–H ··· $O(7)^{I}$	2.774	1.69
O(7)–H(71) ··· $O(4)^{II}$	2.786	1.71
O(7)–H(72) ··· $O(1)^{III}$	2.876	1.80

The superscripts refer to the following transformations.

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

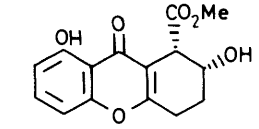
Table 2. Final position parameters (Br × 10^5, other × 10^4 with estimated standard deviation in parentheses

	x/a	y/b	z/c
Br	11 009(4)	24 059(2)	8 682(2)
O(1)	3 711(3)	434(1)	−640(1)
O(2)	1 448(3)	627(2)	167(1)
O(3)	4 401(2)	1 999(1)	1 411(1)
O(4)	−1 293(3)	975(2)	2 416(1)
O(5)	−665(3)	−270(1)	1 392(1)
O(6)	1 888(3)	−90(1)	1 590(2)
O(7)	858(3)	5 322(2)	1 922(1)
C(1)	4 606(4)	888(2)	−198(2)
C(2)	6 138(4)	1 057(2)	−339(2)
C(3)	7 047(4)	1 528(2)	105(2)
C(4)	6 481(4)	1 844(2)	696(2)
C(5)	4 940(4)	1 672(2)	836(2)
C(6)	3 975(3)	1 195(2)	396(1)
C(7)	2 345(4)	1 034(2)	530(1)
C(8)	1 782(3)	1 427(2)	1 166(1)
C(9)	3 120(3)	1 573(2)	1 673(1)
C(10)	2 662(4)	1 988(2)	2 311(2)
C(11)	1 344(4)	1 505(2)	2 602(2)
C(12)	−51(4)	1 385(2)	2 125(2)
C(13)	353(3)	998(2)	1 441(1)
C(14)	654(3)	157(2)	1 485(1)
C(15)	−547(5)	−1 080(2)	1 437(2)

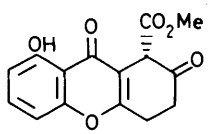
48.4°) by the presence of the axial bromine and carboxymethyl substituents. Bond lengths (Table 1) are in accord with expected values. In the crystal lattice (Figure 2) the water molecule takes part in three O–H ··· O hydrogen bonds (two as donor, one as acceptor) and is thus firmly anchored in the lattice (Table 2). There is one additional intramolecular O–H ··· O hydrogen bond between hydroxy O(1)–H and adjacent carboxyl oxygen O(2) (O ··· O 2.604 Å). The stereochemistry (and structure) of (**4**; R = H) is thus in agreement with previous conclusions,[2] and provides collateral evidence for the structures of the relevant precursors,[2] especially the bromo ketone (**1**; R^1 = H, R^2 = Br).

In accord with its structure, (**4**; R = H) eliminated hydrogen bromide readily to yield the tetrahydroxanthone (**5**), which was oxidised to the ketone (**6**). Aromatisation of (**6**) to the xanthone, type (**3**), did not occur easily, and bromination/dehydrobromination gave a mono-bromoxanthone, of type (**3**). We thus turned our attention to the synthesis of pinselin[4] (**3**; R^1 = R^2 = Me), and hence of pinselic acid (**3**; R^1 = Me, R^2 = H).

Prepared from 3,5-dimethoxytoluene and 7-oxabicyclo-[2.2.1]heptane-2β,3β-dicarboxylic anhydride, as for the analogue (**1**; R^1 = R^2 = H), the resultant ester (**1**; R^1 = Me, R^2 = H) was brominated using phenyltrimethyl-ammonium perbromide, and the reaction mixture quenched with (*a*) aqueous base to yield 2α-bromo-2β-(2,6-dimethoxy-4-methylbenzoyl)-3β-methoxycarbonyl-7-oxabicyclo[2.2.1]heptane (**1**; R^1 = Me, R^2 = Br), or (*b*) with water to give a mixture of (**1**; R^1 = Me, R^2 = Br) and the epimeric 2β-bromo ketone (**7**). Treatment of (**1**; R^1 = Me, R^2 = Br) with boron trichloride gave 8aβ-bromo-5aα,5,6,7,8,8a-hexahydro-1,7α-dihydroxy-8α-methoxycarbonyl-3-methylxanthone (**4**; R = Me). Bromination of the corresponding ketone (**8**; R = H) with copper(II)



(5)†



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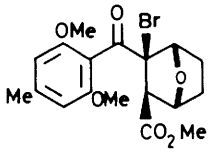

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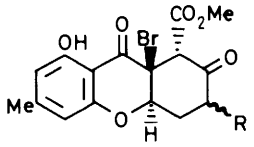

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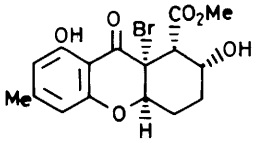

(9)

† All the structures imply (±) compounds.

bromide gave 6,8aβ-dibromo-5aα,5,6,7,8,8a-hexahydro-1-hydroxy-8α-methoxycarbonyl-3-methyl-7-oxoxanthone (**8**; R = Br) which was converted by triethylamine into 1,7-dihydroxy-8-methoxycarbonyl-3-methylxanthone, having the requisite[4] spectral properties, m.p. and elemental analysis for pinselin (**3**; $R^1 = R^2$ = Me). The 2β-bromo ketone (**7**) was similarly converted into pinselin by way of 8aα-bromo-5aα,5,6,7,8,8a-hexahydro-1,7α-dihydroxy-8α-methoxycarbonyl-3-methylxanthone (**9**), the corresponding 7-ketone and the unstable dibromo derivative.

This process thus offers a short, high-yielding synthesis for xanthones of type (**3**).

Experimental

Light petroleum refers to the fraction of b.p. 60—80 °C: n.m.r. spectra were determined at 60 MHz.

8aβ-Bromo-5aα,5,6,7,8,8a-hexahydro-1,7α-dihydroxy-8α-methoxycarbonylxanthone (**4**; R = H).—A solution of methyl 2α-bromo-2β-(2,6-dimethoxybenzoyl)-7-oxabicyclo[2.2.1]-heptane-3β-carboxylate[2] (1 g) in dichloromethane (20 ml) was treated at −70 °C with a solution of boron trichloride (1.5 g) in dichloromethane (15 ml). After 7 h at this temperature the product was isolated with ether to yield *8aβ-bromo-5aα,5,6,7,8a-hexahydro-1,7α-dihydroxy-8α-methoxycarbonylxanthone* (0.8 g) which formed yellow cubes, m.p. 122 °C from chloroform–light petroleum (Found: C, 46.4; H, 4.1%; M^+, 370/372. $C_{15}H_{15}BrO_6 \cdot H_2O$ requires C, 46.3: H, 4.3%; *M* 370/372), having τ 2.45—2.75 (1 H, m, ArH), 3.35—3.60 (2 H, m, ArH), 5.95—6.20 (1 H, m, 5a-H), 6.28 (3 H, s, CO_2CH_3), 8.1 (1 H, s, exchangeable with D_2O), 7.60—8.50 (4 H, m, CH_2CH_2), and −3.95 (1 H, s, ArOH).

Methylation of this hexahydroxanthone (0.4 g) in boiling acetone (20 ml) containing an excess of methyl iodide and potassium carbonate (1 g) during 6 h, gave 5,6,7,8-*tetrahydro-7α-hydroxy-1-methoxy-8α-methoxycarbonylxanthone* (0.35) as prisms, m.p. 202 °C from chloroform–light petroleum (Found: C, 62.7; H, 5.0. $C_{16}H_{16}O_6$ requires C, 63.2; H, 5.3%). The n.m.r. spectrum had signals *inter alia* at τ 2.45—3.34 (3 H, m, ArH), 6.12 (3 H, s, ArOMe), and 6.35 (3 H, s, CO_2Me).

Prepared from 8aβ-bromo-5aα,5,6,7,8,8a-hexahydro-1,7α-dihydroxy-8α-methoxycarbonylxanthone (0.4 g) by the pyridine–acetic anhydride method, at room temperature during 24 h, *1,7α-diacetoxy-5,6,7,8-tetrahydro-8α-methoxycarbonylxanthone* formed prisms, m.p. 152 °C from ethyl acetate–light petroleum (Found: C, 60.5; H, 4.9. $C_{19}H_{18}O_8$ requires C, 60.9; H, 4.9%).

The corresponding *di-O-benzoate* formed stout prisms, m.p. 172 °C from ethyl acetate–light petroleum (Found C, 69.1, H, 4.5. $C_{29}H_{22}O_8$ requires C, 69.0; H, 4.5%).

5,6,7,8-Tetrahydro-1,7α-dihydroxy-8α-methoxycarbonylxanthone (**5**).—A solution of 8aβ-bromo-5aα,5,6,7,8,8a-hexahydro-1,7α-dihydroxy-8α-methoxycarbonylxanthone (0.4 g) in pyridine was maintained at 80 °C during 6 h to yield the title *xanthone* (0.3 g) as pale yellow plates, m.p. 197—198 °C (Found: C, 61.1; H, 5.2. $C_{15}H_{14}O_6$ requires C, 62.1; H, 4.8%). The n.m.r. spectrum exhibited signals at τ −3.15 (1 H, s, ArOH), 7.75 (1 H, s, 7-H), 2.4—2.7 (1 H, m, ArH), 3.15—3.46 (2 H, m, ArH), 5.8—6.05 (2 H, m, 7-, 8-H) 6.2 (3 H, s, CO_2Me), 7.1—7.3 (2 H, m, CH_2), and 7.75—8.05 (2 H, m, CH_2).

5,6,7,8-Tetrahydro-1-hydroxy-8α-methoxycarbonyl-7-oxoxanthone (**6**).—(*a*) Oxidation of a solution of 5,6,7,8-tetrahydro-1,7α-dihydroxy-8α-methoxycarbonylxanthone (0.8 g) in acetone (130 ml) at 0 °C with standard Jones's reagent (1.5 ml) was complete in 10 min to yield *5,6,7,8-tetrahydro-1-hydroxy-8α-methoxycarbonyl-7-oxoxanthone* (0.65 g) as yellow needles, m.p. 160 °C, from chloroform–light petroleum (Found: C, 62.6; H, 4.9. $C_{15}H_{12}O_6$ requires C, 62.5; H, 4.2%). The n.m.r. spectrum showed signals *inter alia* at τ 2.4—2.75 (1 H, m, ArH), 3.2—3.45 (2 H, d, ArH), and 6.9—7.5 (4 H, m, CH_2CH_2).

(*b*) Oxidation of 8aβ-bromo-5a,5,6,7,8,8a-hexahydro-1,7α-dihydroxy-8-methoxycarbonylxanthone (1 g) as in (*a*), gave the corresponding *7-ketone* (0.9 g) as yellow cubes, m.p. 135 °C from chloroform–light petroleum (Found: C, 48.5; H, 3.7. $C_{15}H_{13}BrO_6$ requires C, 48.8; H, 3.5%). Dehydrobromination of this ketone (1 g) with warm pyridine gave 5,6,7,8-tetrahydro-1-hydroxy-8-methoxycarbonyl-7-oxoxanthone (0.8 g) identical (m.p., mixed m.p., i.r. and n.m.r.) with the specimen obtained by route (*a*).

Monobromo-1,7-dihydroxy-8-methoxycarbonylxanthone.—A solution of the previous ketone (3 g) in tetrahydrofuran was stirred and treated with phenyltrimethylammonium perbromide (4 g) at 6 °C, during 5 h. Isolated in the normal manner, the product was partially purified from chloroform to yield a monobromo-1,7-dihydroxy-8-methoxycarbonylxanthone (2.5 g) as a yellow, microcrystalline solid, m.p. 280—282 °C, exhibiting an intense green ferric reaction. This impure product was converted into the 1,7-di-*O*-acetate, which exhibited n.m.r. signals at τ 2.2—3.2 (4 H, m, ArH), 6.11 (3 H, s, CO_2Me), 7.78, (3 H, s, OCOMe), and 7.82 (3 H, s, OCOMe). Hydrolysis gave the *monobromo-1,7-dihydroxy-8-methoxycarbonylxanthone* as micro-crystalline needles, m.p. 280 °C (Found: C, 49.0; H, 2.7. $C_{15}H_9BrO_6$ requires C, 49.3; H, 2.5%).

2β-(2,6-Dimethoxy-4-methylbenzoyl)-3β-methoxycarbonyl-7-oxabicyclo[2.2.1]heptane (**1**; R^1 = Me, R^2 = H).—Prepared from 3,5-dimethoxytoluene (2 g) and 7-oxabicyclo[2.2.1]-heptane-2β,3β-dicarboxylic anhydride (2 g) as previously[2], *2β-(2,6-dimethoxy-4-methylbenzoyl)-3β-methoxycarbonyl-7-oxabicyclo[2.2.1]heptane-3β-carboxylic acid* (2.0 g) formed needles, m.p. 180 °C from methanol (Found: C, 63.5, H, 6.3. $C_{17}H_{20}O_6$ requires C, 63.7, H, 6.3%).

Esterification of this acid with diazomethane gave (quantitatively) 2β-(2,3-*dimethoxy*-4-*methylbenzoyl*)-3β-*methoxycarbon-*

yl-7-oxabicyclo[2.2.1]*heptane* as elongated prisms, m.p. 151 °C from methanol (Found: C, 65.0; H, 6.7. $C_{18}H_{22}O_6$ requires C, 64.6; H, 6.6%). The n.m.r. spectrum exhibited signals *inter alia* at τ 3.70 (2 H, s, ArH), 4.99 and 5.32 (2 H, d, m, bridgehead H), 6.30 (6 H, s, 2 OMe), 6.42 (3 H, s, CO_2Me), 7.73 (3 H, s, ArMe), and 8.10—8.67 (4 H, m, CH_2CH_2).

Bromination of a solution of this ester (3 g) in tetrahydrofuran (150 ml) with phenyltrimethylammonium perbromide (4.5 g) during 5 h at 0 °C, followed by quenching with 10% aqueous sodium dithionite (50 ml) and 10% aqueous sodium hydrogen carbonate (50 ml) and extraction with chloroform gave 2α-*bromo*-2β-(2,6-*dimethoxy*-4-*methylbenzoyl*)-3α-*methoxycarbonyl*-7-*oxabicyclo*[2.2.1]*heptane* (1.9 g) as prisms, m.p. 151 °C from chloroform–methanol (Found: C, 52.3; H, 5.1. $C_{18}H_{21}BrO_6$ requires C, 52.3; H, 5.1%). The n.m.r. spectrum exhibited signals at τ 3.62 (2 H, s, ArH), 4.70—5.00 (2 H, m), 4.21 (6 H, s, 2 OMe), 4.28 (3 H, s, ArMe), 6.99 (1 H, s), 7.3—7.5 (1 H m), 7.66 (3 H, s, OCOMe), and 7.9—8.4 (3 H, m).

Repetition of this bromination but pouring into water (100 ml) after 5 h, at 0 °C and extraction with ethyl acetate gave a crude product which was partially purified by chromatography on silica from ethyl acetate–light petroleum (1 : 3). Fractional crystallisation from chloroform–methanol of this partially purified eluate gave (*a*) 2α-bromo-2β-(2,6-dimethoxy-4-methylbenzoyl)-3β-methoxycarbonyl-7-oxabicyclo[2.2.1]heptane (**1**; R^1 = Me, R^2 = Br) (1.2 g) and (*b*) 2β-*bromo*-2α-(2,6-*dimethoxy*-4-*methylbenzoyl*)-3β-*methoxycarbonyl*-7-*oxabicyclo*[2.2.1]*heptane* (0.7 g) as prisms, m.p. 164—165 °C from chloroform–methanol (Found: C, 52.2; H, 5.0; Br, 19.5. $C_{18}H_{21}BrO_6$ requires C, 52.3; H, 5.1, Br, 19.3%). The n.m.r. spectrum exhibited signals at τ 3.60 (2 H, s, ArH), 5.02 (2 H, m), 6.06 (1 H, s), 6.20 (6 H, s, 2 × OMe), 6.30 (3 H, s, ArMe), 7.63 (3 H, s, OCOMe), and 8.1—8.4 (3H, m).

The Synthesis of Pinselin.—(*a*) A solution of 2α-bromo-2β-(2,6-dimethoxy-4-methylbenzoyl)-3β-methoxycarbonyl-7-oxabicyclo[2.2.1]heptane (1 g) was treated with boron trichloride as previously described to yield 8*aβ*-*bromo*-5*aα*,5,6,7,8,8*a*-*hexahydro*-1,7α-*dihydroxy*-8α-*methoxycarbonyl*-3-*methylxanthone* (0.8 g) as yellow prisms, m.p. 121 °C from chloroform–methanol (Found: C, 47.3; H, 4.8. $C_{16}H_{17}O{\cdot}H_2O$ requires C, 47.7; H, 4.8%). The n.m.r. spectrum exhibited signals at τ −1.05 (1 H, s, OH), 3.60 (1 H, s, ArH), 3.67 (1 H, s, ArH), 5.0—5.7 (2 H, m), 6.0—6.2 (1 H, m), 6.25 (3 H, s, ArMe), 7.3—8.3 (4 H, m), 7.33 (1 H, m), and 7.70 (3 H, s, OCOMe).

Oxidation of this xanthone with Jones' reagent furnished (almost quantitatively) 8*aβ*-*bromo*-5*a*,5,6,7,8,8*a*-*hexahydro*-1-*hydroxy*-8α-*methoxycarbonyl*-7-*oxo*-3-*methylxanthone* as golden yellow prisms, m.p. 130—131 °C from chloroform–methanol (Found: C, 49.4; H, 3.9. $C_{16}H_{15}BrO_6$ requires C, 50.1; H, 3.9%). The n.m.r. spectrum exhibited signals at τ −0.94 (1 H, s, OH), 3.64 (1 H, s, ArH), 3.70 (1 H, s, ArH), 5.01 (1 H, m), 6.50 (1 H, s), 6.36 (3 H, s, ArMe), 7.3—7.7 (4 H, m), and 7.77 (3 H, s, OCOMe).

A solution of this ketone (0.33 g) in chloroform (20 ml) and ethyl acetate (20 ml) containing copper(II) bromide (0.45 g) was refluxed during 20 min. The product was purified from ethyl acetate–light petroleum to yield 6,8*a*-*dibromo*-5*a*,5,6,7,8,8*a*-*hexahydro*-1-*hydroxy*-8-*methoxycarbonyl*-3-*methyl*-7-*oxoxanthone* (0.3 g) as yellow prisms, m.p. 153—155 °C (decomp.) (Found: C, 41.3; H, 3.0%; M^+, 460, 462, 464. $C_{16}H_{14}Br_3O_6$ requires C, 41.6; H, 3.1%; *M*, 460, 462, 464). The n.m.r. spectrum showed signals at τ −1.09 (1 H, s, OH), 3.50 (1 H, s, ArH), 3.60 (1 H, s, ArH), 4.69 (1 H, dd, *J* 10 Hz, 5 Hz), 5.3—5.6 (2 H, m), 4.24 (3 H, s, ArMe), 6.6—7.3 (2 H, m), and 7.67 (3 H, s, OCOMe).

A solution of this dibromo compound (0.25 g) in chloroform (10 ml) containing triethylamine (5 ml) was kept for 5 mins, when the solvents were removed under reduced pressure. The product was extracted from the acidified residue (5% hydrochloric acid 10 ml) with chloroform to yield 1,7-dihydroxy-8-methoxycarbonyl-3-methylxanthone (pinselin) (0.14 g) which formed yellow needles, m.p. 223—224 °C from methanol, with an intense green ferric reaction in alcohol. Sublimation (0.03 mmHg) gave yellow plates, m.p. 221 °C (Found: C, 63.7; H, 4.0. $C_{16}H_{12}O_6$ requires C, 64.0; H, 4.0%). The n.m.r. spectrum (in $CDCl_3$–CD_3OD) showed signals at τ 2.60 (2 H, s), 3.27 (1 H, m), 3.42 (1 H, s), 5.97 (3 H, s, ArMe), and 7.60 (3 H, s, OCOMe) (lit.,[4] m.p. 226—227 °C).

(*b*) Treatment of 2β-bromo-2α-(2,6-dimethoxy-4-methylbenzoyl)-3β-methoxycarbonyl-7-oxabicyclo[2.2.1]heptane (1 g) with boron trichloride as previously gave 8*aα*-*bromo*-5,5*a*,6,7,8,8*a*-*hexahydro*-1,7α-*dihydroxy*-8α-*methoxycarbonyl*-3-*methylxanthone* (0.6 g) as yellow prisms, m.p. 187—198 °C from ethyl acetate–light petroleum (Found: C, 49.6; H, 4.4; Br, 20.0. $C_{16}H_{17}BrO_6$ requires C, 49.9; H, 4.6; Br, 20.7%). The n.m.r. spectrum shows signals at τ −1.14 (1 H, s, OH), 3.61 (1 H, s), 3.66 (1 H, s), 4.3—4.8 (1 H, m), 5.64 (1 H, d, *J* 5 Hz), 5.85—6.33 (1 H, m), 6.17 (3 H, s, ArMe), 6.66 (1 H, s), 7.70 (3 H, s, OCOMe), and 7.6—8.3 (4 H, m).

Oxidation of this hydroxyhexahydroxanthone (0.25 g) with Jones' reagent in the normal manner gave 8*aα*-*bromo*-5*aα*,5,6,7,8,8*aα*-*hexahydro*-1-*hydroxy*-8α-*methoxycarbonyl*-3-*methyl*-7-*oxoxanthone* (0.14 g) as orange prisms, m.p. 130—135 °C (decomp.) from ethyl acetate–light petroleum (Found: C, 49.5; H, 4.0. $C_{16}H_{15}BrO_6$ requires C, 50.1; H, 3.9%). The n.m.r. spectrum exhibited signals at τ −1.44 (1 H, s, OH), 3.59 (1 H, s, ArH), 3.68 (1 H, s, ArH), 4.74 (1 H, m), 6.09 (3 H, s, ArMe), 6.19 (1 H, s), 7.1—7.8 (4 H, m), and 7.70 (3 H, s, OCOMe).

A solution of this hexahydroxanthone (0.1 g) in ethyl acetate (5 ml) and chloroform (5 ml) was treated with copper(II) bromide (0.2 g) as described for the isomer to yield (without purification of the unstable dibromo intermediate) pinselin (4.5 mg) the physical properties of which were identical with those of the compound (*a*).

X-*Ray Crystallography of* (**4**; R = H)·H_2O.—Preliminary photographic work was carried out on a part of a flat, yellow prism elongated along the *a* axis; oscillation, Weissenberg, and precession photographs, taken with Cu-K_α radiation established preliminary unit-cell data. Accurate cell constants were determined by the automatic centreing of 12 strong reflections for which θ(Mo-K_α) was between 10 and 20°.

Crystal Data.—$C_{15}H_{17}BrO_7$, *M* = 389.2. Triclinic, *a* = 8.648(1), *b* = 17.597(3), *c* = 20.309(3) Å, α = 94.36(1), β = 91.39(1), γ = 93.41(1)°, *V* = 3074.9 Å^3, *Z* = 8, D_c = 1.68 g cm^{-3}, *F*(000) = 1584. Mo-K_α radiation, λ = 0.710 69 Å, μ(Mo-K_α) = 26.2 cm^{-1}. Space group $F\bar{1}$ (C_i^1, No. 2) from systematic absences *hkl* absent when *h* + *k*, *h* + *l*, and *k* + *l* are odd.

We were led to choose an *F* lattice system, with angles not much removed from 90°, from our photographic studies. The corresponding reduced cell is *a* = 9.570(2), *b* = 10.940(2), *c* = 8.648(1) Å, α = 111.88(1), β = 113.40(1), γ = 85.30(1)°, and is obtained from the *F* lattice dimensions by use of the matrix [−0.5, −0.5,0; −0.5,0, −0.5; 1,0,0].

Data were collected in our usual way.[5] Of the 3 503 unique reflections measured, the 2 939 with $I > 3\sigma(I)$ were labelled, observed and used in the final refinement of the structure parameters. The data were corrected for Lorentz and polarization factors but not for absorption.

Structure Analysis.—The position of the bromine atom was deduced from a Patterson synthesis, the remaining non-hydrogen atoms were located from a heavy-atom phased Fourier summation. The structure was refined using the

SHELX[6] program by full-matrix least-squares calculations, with all atoms allowed individual isotropic vibration parameters, to give $R = 0.116$. At this point a difference synthesis revealed the presence of a peak (8.4 e Å^{-3}) in the map which could be interpreted as a water molecule. Maxima (*ca.* 0.6 e Å^{-3}) were observed in positions expected for the hydrogen atoms in (**4**; R^1 = H). These were allowed for (geometrically, C–H 1.08 Å) and included but not refined in subsequent refinement cycles. Refinement continued with all the non-hydrogen atoms allowed anisotropic motion; an overall isotropic value was refined for the H atoms. A difference synthesis when R was 0.051 revealed two maxima around the water molecule consistent with the H_2O protons. Before the last round of calculations the protons involved in hydrogen bonding were positioned from difference maps. The protons involved in intermolecular hydrogen bonding had O–H • • • O angles close to 180° and they were placed on the line of centres; the co-ordinates of the proton involved in the intramolecular hydrogen bond were determined from the difference map. Refinement converged with $R = 0.050$, $R_w = 0.052$ and a final difference synthesis was devoid of any peaks of chemical significance. In the final refinement cycles, weights based on counting statistics were employed and the scattering factors were taken from references 7, 8, and 9.

* For details of the Supplementary publications Scheme, see Instructions for Authors (1985), *J. Chem. Soc., Perkin Trans. 1*, 1985, Issue 1.

Table 1 contains selected molecular dimensions, and Table 2 has co-ordinates of the non-hydrogen atoms. The calculated H atom positions, thermal parameters and a table of molecular dimensions have been deposited as Supplementary Publication [Sup. No. 56218 (4 pp.)].* The structure factors are available on request from the editorial office.

References

1 Part 79, N. H. Rama, E. Turner, and W. B. Whalley, *J. Chem. Research (S)*, 1981, 149.
2 A. D. Borthwick, D. J. Curry, A. Poynton, W. B. Whalley and (in part) J. W. Hooper, *J. Chem. Soc., Perkin Trans. 1*, 1980, 2435.
3 M. Ahbab, A. D. Borthwick, J. W. Hooper, J. S. Millership, W. B. Whalley, G. Ferguson, and F. C. Marsh, *J. Chem. Soc., Perkin Trans. 2*, 1976, 1369.
4 C. E. Moppett, *Chem. Commun.*, 1971, 423; K. K. Law, T-L. Chan, and S. W. Tam, *J. Org. Chem.*, 1979, **44**, 4452.
5 G. Ferguson, D. F. Rendle, J. M. Midgley, and W. B. Whalley, *J. Chem. Soc., Perkin Trans. 2*, 1978, 267.
6 G. M. Sheldrick, 1976. SHELX Computer Program, University Chemical Laboratory, Cambridge.
7 D. T. Cromer and J. B. Mann, *Acta Cryst., Sect A*, 1968, **24**, 321.
8 R. F. Stewart, E. R. Davidson, and W. T. Simpson, *J. Chem. Phys.*, 1965, **42**, 3175.
9 D. T. Cromer and D. Liberman, *J. Chem. Phys.*, 1970, **53**, 1891.

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