Synthetic Studies towards Paspalicine. Part 2.[1] An Alternative Approach to the Synthesis of the C/D Ring System

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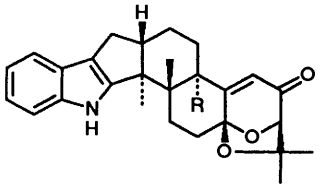
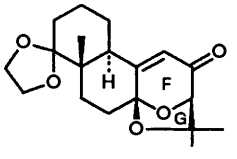
An alternative approach to the synthesis of the *trans*-hydrindane ring system containing an angular methyl group, which forms rings C and D of paspalicine, is described.

Construction of the molecular architecture of the indole-diterpene mould metabolites, paspalicine **1**[2] and paspalinine **2**[3] presents two particular challenges, namely, the formation of the unusual β-pyrone ketal function which comprises rings F and G, and the *trans*-hydrindane system with an angular methyl group, which comprises rings C and D.

Having completed the synthesis[1] of a model compound **3** which constitutes rings D–G of paspalicine with the correct functionality and stereochemistry, we turned our attention to the preparation of the C/D ring system, simultaneously making provision for the later incorporation of the indole ring and the β-pyrone ketal system.



Paspalicine **1** R = H
Paspalinine **2** R = OH



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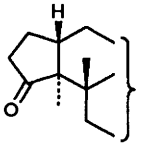

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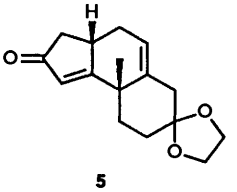

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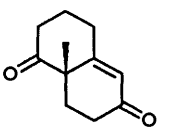
The difficulties inherent in the synthesis of the *trans* C/D ring system with the angular methyl group are amply illustrated in Smith's first[4] and second[5] generation syntheses of paspaline and in our own (unpublished) investigations,[6] all of which were planned to proceed *via* a ketone of form **4**. We, therefore, concluded that a different approach was required, and we accordingly decided to investigate the synthetic potential of an isomeric series of ketones and specifically, the cyclopentenone derivative **5** which should, in principle, be readily accessible from the Wieland–Miescher ketone **6**, *via* the method introduced by Poss and Belter.[7]

The monoketal **7** was alkylated by means of diethyl 3-iodopropynyl phosphonate–potassium hexamethyldisilazide–triethylborane,[8] which gave the ketophosphonate **8**, in which the introduced alkyl group is equatorial, in 90% yield. Hydration of **8** by Corey's method,[8] which avoids the use of acidic reaction conditions, gave the diketo phosphonate **9** (80% yield), cyclisation of which, by an intramolecular Wadsworth–Emmons reaction, gave the desired cyclopentenone derivative **5** in yields up to 55%. Under optimum conditions, therefore, the key cyclopentenone derivative **5** can be prepared in almost 40% yield from the ketal **7**. However, it must be emphasised that the Wadsworth–Emmons cyclisation has proved to be capricious, often giving yields lower than the 55% quoted.



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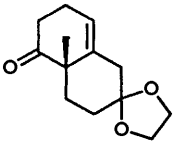

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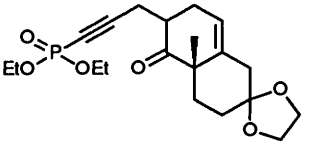

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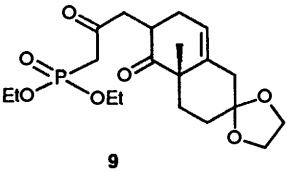

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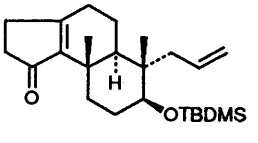
The stage was now set for the introduction of an appropriate group, preferably a methyl group, at the β-position of the enone function, by 1,4-addition of an organometallic species. However, in spite of hindrance from the adjacent methyl and hydrogen groups, and the hope that axial approach to position 9b might be favoured, we could not be confident of achieving alkylation in the desired stereochemical sense, in view of the experience of Smith and his collaborators[4] in the reductive alkylation of the ketone **10**, which, at best, still gave a preponderance of the undesired *cis*-fused product **11a** over the *trans*-isomer **11b**. In the event we were unable to examine the stereochemical course of the 1,4-additions of **5** in depth, because reaction with dimethyl zinc[5] failed, and reaction with diethylaluminium cyanide[5] gave an unacceptably low yield of the nitrile **12**, whose stereochemistry we did not determine.



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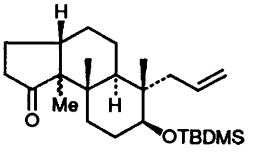
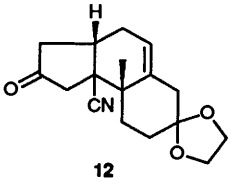


11a β-Me
11b α-Me



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These 1,4-additions, however, were peripheral to our major endeavour, which was to investigate the possibility of a site-directed cyclopropanation by the hydroxy group in the related allyl alcohol, by the method introduced by Corey and Virgil.[8] This necessarily relies on the stereoselective reduction of the carbonyl group to the α-allyl alcohol **13**, which on cyclopropanation should give stereospecifically the hydroxycyclopropane derivative **14**. Oxidation to the α-keto-cyclopropane **15**, followed by reductive fission of the cyclo-

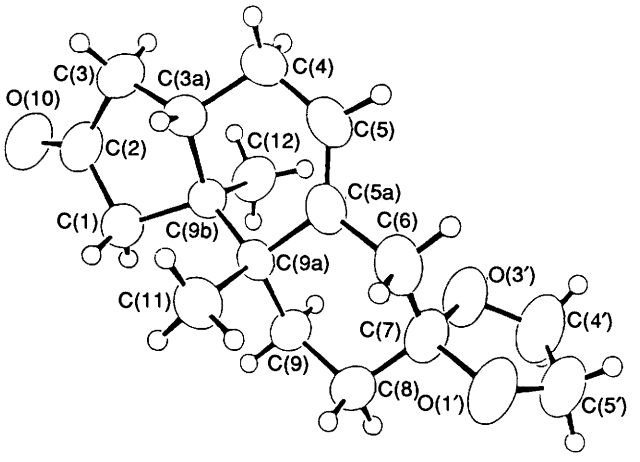


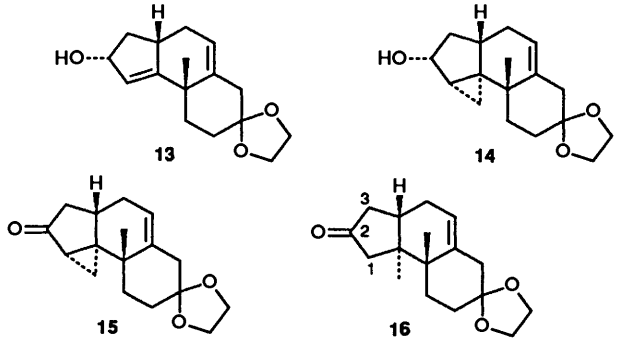
Fig. 1 ORTEP diagram of the crystal and molecular structure of compound **16**

Table 1 Selected bond lengths (pm) for **16** with esds in parentheses

C(2)–C1)	151.2(6)	C(9b)–C(1)	154.1(6)
C(3)–C(2)	150.6(7)	O(10)–C(2)	121.2(4)
C(3a)–C(3)	152.2(6)	C(4)–C(3a)	152.2(6)
C(9b)–C(3a)	154.6(5)	C(5)–C(4)	149.0(6)
C(5a)–C(5)	132.7(5)	C(6)–C(5a)	150.8(6)
C(9a)–C(5a)	153.4(6)	C(7)–C(6)	150.7(7)
C(8)–C(7)	150.3(7)	O(1')–C(7)	142.9(4)
O(3')–C(7)	142.4(4)	C(9)–C(8)	152.8(6)
C(9a)–C(9)	155.0(6)	C(9b)–C(9a)	155.2(5)
C(11)–C(9a)	155.4(5)	C(12)–C(9b)	154.7(5)
C(5')–O(1')	137.4(5)	C(4')–O(3')	134.9(5)
C(5')–C(4')	143.7(6)		

All hydrogen atoms are in idealised positions with C–H = 96 pm.

propane ring α to the carbonyl group should then give the desired cyclopentanone derivative **16**. In the event, conversion of the cyclopentenone **5** into the crucial ketone **16** proceeded without incident. Reduction of **5** by means of lithium 1,2-dimethylpropylborohydride gave an almost quantitative yield of the α-allylic alcohol **13**, which on cyclopropanation with butyl-lithium and the Simmons–Smith reagent gave in 61% yield the hydroxycyclopropane **14**. Oxidation by Swern's method then gave the related ketone **15**. Although the complete stereochemistry of this intermediate was not unequivocally deduced we suspected that the cyclopropyl methylene group was *trans* with respect to the adjacent methyl group, since we could detect no nuclear Overhauser enhancement of either of the signals arising from the cyclopropyl methylene group when the C-12b methyl protons were irradiated. Finally, cleavage of the cyclopropyl ring in **15** by means of lithium in liquid



ammonia gave the desired ketone **16**, which, we were gratified to find, gave crystals suitable for X-ray crystal structure

Table 2 Selected bond angles (°) for **16** with esds in parentheses

C(9b)–C(1)–C(2)	104.0(3)	C(3)–C(2)–C(1)	108.9(3)
O(10)–C(2)–C(1)	125.4(4)	O(10)–C(2)–C(3)	125.7(4)
C(3a)–C(3)–C(2)	104.3(3)	C(4)–C(3a)–C(3)	118.0(3)
C(9b)–C(3a)–C(3)	105.2(3)	C(9b)–C(3a)–C(4)	111.0(3)
C(5)–C(4)–C(3a)	109.8(3)	C(5a)–C(5)–C(4)	125.9(4)
C(6)–C(5a)–C(5)	120.8(4)	C(9a)–C(5a)–C(5)	123.5(4)
C(9a)–C(5a)–C(6)	115.6(3)	C(7)–C(6)–C(5a)	113.8(3)
C(8)–C(7)–C(6)	111.8(3)	O(1')–C(7)–C(6)	108.7(4)
O(1')–C(7)–C(8)	110.6(4)	O(3')–C(7)–C(6)	109.6(4)
O(3')–C(7)–C(8)	110.1(4)	O(3')–C(7)–O(1')	105.9(3)
C(9)–C(8)–C(7)	110.0(3)	C(9a)–C(9)–C(8)	114.2(3)
C(9)–C(9a)–C(5a)	109.4(3)	C(9b)–C(9a)–C(5a)	108.4(3)
C(9b)–C(9a)–C(9)	111.0(3)	C(11)–C(9a)–C(5a)	108.3(3)
C(11)–C(9a)–C(9)	108.0(3)	C(11)–C(9a)–C(9b)	111.7(3)
C(3a)–C(9b)–C(1)	100.5(3)	C(9a)–C(9b)–C(1)	117.5(3)
C(9a)–C(9b)–C(3a)	109.7(3)	C(12)–C(9b)–C(1)	107.1(3)
C(12)–C(9b)–C(3a)	110.2(3)	C(12)–C(9b)–C(9a)	111.2(3)
C(5')–O(1')–C(7)	109.5(4)	C(4')–O(3')–C(7)	108.6(4)
C(5')–C(4')–O(3')	109.7(4)	C(4')–C(5')–O(1')	106.2(4)

All hydrogen atoms are in idealised positions so that, where appropriate, H–C–H = 109.5°.

Table 3 Non-hydrogen atom coordinates for **16** with estimated standard deviations (esds) in parentheses

	x	*y*	*z*
C(1)	2 020(4)	8 723(3)	4 668(1)
C(2)	2 902(4)	10 243(3)	4 583(1)
C(3)	3 826(5)	10 245(3)	4 061(1)
C(3a)	3 584(4)	8 652(3)	3 862(1)
C(4)	3 415(5)	8 380(4)	3 260(1)
C(5)	2 713(5)	6 831(4)	3 139(1)
C(5a)	1 963(4)	5 905(3)	3 478(1)
C(6)	1 458(5)	4 321(3)	3 320(1)
C(7)	−598(5)	3 810(3)	3 459(1)
C(8)	−833(5)	4 081(3)	4 040(1)
C(9)	−495(4)	5 724(3)	4 173(1)
C(9a)	1 607(4)	6 334(3)	4 052(1)
C(9b)	1 679(4)	8 051(3)	4 100(1)
O(10)	2 875(3)	11 286(3)	4 888(1)
C(11)	3 298(5)	5 586(3)	4 447(1)
C(12)	−290(4)	8 766(3)	3 811(1)
O(1')	−827(4)	2 267(2)	3 334(1)
O(3')	−2 184(4)	4 548(2)	3 125(1)
C(4')	−3 367(6)	3 517(4)	2 850(2)
C(5')	−2 512(7)	2 066(4)	2 962(2)

analysis. This amply confirmed the structure and stereochemistry of this ketone. A drawing of the structure of the molecule is shown in Fig. 1, selected interatomic distances and bond angles are given in Tables 1 and 2, and non-hydrogen atom coordinates in Table 3. The overall yield of **16** from the cyclopentenone derivative **5** is 25%, which could conceivably be increased, since we have not had an opportunity to attempt to optimise the yields beyond the first stage.

As an intermediate in paspalicine synthesis the ketone **15** has considerable potential. Thus, trapping of the enolate anion, obtained in the lithium–ammonia reduction of **15**, by appropriate reagents, should allow regiospecific access to α-substituted derivatives of **16**. The indole ring could then be attached *via* Wender's method.[9] Alternatively, ketone transposition should afford the 1-oxo isomer of **16**, which is an intermediate in Smith's synthesis[10] of paspalicine.*

* Initial attempts to trap the enolate anion generated in the reduction of the cyclopropyl ketone **15** have not proved very promising, and we have not, as yet, had an opportunity to examine the behaviour of the ketone **16** itself. However, Prof. B. Trost has made the interesting observation that *kinetic* enolization of **16** may well give the 1,2-enolate

Experimental

M.p.s were determined on a Reichert hot-stage apparatus and are uncorrected. IR spectra were recorded on either a Perkin-Elmer 1420 or a Philips PU9706 spectrophotometer. NMR spectra were recorded on either a GE QE 300 (^{1}H 300 MHz and ^{13}C 75 MHz) or a Bruker AM400 spectrometer (^{1}H 400 MHz and ^{13}C 100 MHz). Solutions in deuteriochloroform, with tetramethylsilane as internal standard, were used unless otherwise stated. Mass spectra were recorded on either a VG Autospec or a Kratos MS25 instrument; accurate mass measurements were carried out using an A.E.I./Kratos MS902/50 instrument.

All reactions in non-aqueous solution were carried out under nitrogen or argon unless otherwise stated. All reactions involving lithium metal were carried out under an atmosphere of argon.

Single Crystal X-ray Diffraction Analysis of Compound **16**.—All crystallographic measurements were carried out at 290 K on a Stoe STAD14 diffractometer using graphite monochromated copper K_α X-radiation (λ = 154.084 pm). Data were collected in the range $3.0° < 2\theta < 120.0°$ using ω–θ scans with no significant variation observed in the intensities of three standard reflections. The data-set was corrected for Lorentz and polarisation factors but not for absorption.

The structure was solved by direct methods using SHELXS [11] and was refined by full-matrix least-squares using SHELX76.[12] All non-hydrogen atoms were refined with anisotropic thermal parameters. All hydrogen atoms were included in calculated positions (C–H = 96 pm) and were refined with an overall isotropic thermal parameter. The weighting scheme $w = [\sigma^2(F_0 + 0.0024(F_0)^2]^{-1}$ was used.

Crystal data. $C_{17}H_{24}O_3$, M = 276.38, monoclinic, space group $P2_1/n$, a = 657.35(3), b = 900.75(3), c = 2508.17(13) pm, β = 96.679(4)°, U = 1.4750(1) nm^3, Z = 4, D_x = 1.24 Mg m^{-3}, μ = 6.30 cm^{-1}, $F(000)$ = 600.

Data collection. Scan speeds 1.5–8.0° min^{-1}, ω scan widths 1.05° + α-doublet splitting, $4.0 < 2\theta < 120°$, 2375 Data collected, 1646 with $I > 1.0\,\sigma(I)$ considered observed.

Structure refinement. Number of parameters = 188, R = 0.0580, R_w = 0.0622.

Diethyl 3-(6,6-*Ethylenedioxy*-8a-*methyl*-1-*oxo*-1,2,3,5,6,7,8,8a-*octahydro*-2-*naphthyl*)*propyn*-1-*ylphosphonate* (**8**).—A solution of the monoketal **7**[13] (4.12 g, 18.6 mmol) in tetrahydrofuran (25 cm^3) was added dropwise to a solution of potassium hexamethyldisilazide in toluene (0.5 mol dm^{-3}; 45 cm^3, 22.5 mmol) at −78 °C. The solution was stirred at −78 °C for 30 min, after which a solution of triethylborane in tetrahydrofuran (1.0 mol dm^{-3}; 22.3 cm^3, 22.3 mmol) was added dropwise. The resulting green solution was allowed to warm to −30 °C over 30 min, after which a solution of diethyl 3-iodoprop-1-ynylphosphonate [7] (5.6 g, 18.6 mmol) in tetrahydrofuran (25 cm^3) was added dropwise. The resulting suspension after being allowed to warm to room temperature was stirred for 2 h. The reaction mixture was then quenched with saturated ammonium chloride solution (50 cm^3) and extracted with ethyl acetate (3 × 50 cm^3). The combined extracts were dried ($MgSO_4$) and concentrated under reduced pressure. The residue was separated by column chromatography on silica gel using ethyl acetate–light petroleum (3:2) and then ethyl acetate as eluent. The *title compound* **8** (6.58 g, 90%) was obtained as a pale yellow oil, consisting of a 7:3 mixture of epimers (Found: C, 60.55; H, 7.35. $C_{20}H_{29}O_6P$ requires C, 60.60; H, 7.35%); ν_{max}/cm^{-1} 2200, 1710, 1260 and 1020; δ_H(300 MHz) for major epimer: 1.28 (3 H, s), 1.31 (6 H, t, J 7), 1.5–1.9 (4 H, m), 2.10 (1 H, m), 2.19 (1 H, m), 2.35 (1 H, ddd, J 17.7, 8.7, 4.4), 2.53 (1 H, m), 2.72 (2 H, m), 3.08 (1 H, m), 3.91 (4 H, m), 4.09 (4 H, m), 5.45 (1 H, m); for minor epimer: 1.27 (3 H, s), 1.37 (6 H, t, J 7), 1.5–1.9 (4 H, m), 2.1–2.3 (2 H, m), 2.41 (1 H, ddd, J 13.0, 8.5, 4.3), 2.56 (1 H, m), 2.67 (1 H, dt, J 16.4, 6.6), 2.82 (1 H, m), 2.94 (1 H, m), 3.96 (4 H, m), 4.14 (4 H, m) and 5.64 (1 H, dd, J 1.7, 5.0); m/z (%) 397 (2.3), 396 (M^+, 7.5), 221 (14.9), 176 (10.3), 100 (10.7) and 99 (100).

Diethyl 3-(6,6-*Ethylenedioxy*-8a-*methyl*-1-*oxo*-1,2,3,5,6,7,8,-8a-*octahydro*-2-*naphthyl*)-2-*oxopropylphosphonate* **9**.—A solution of the alkynylphosphonate **8** (2.47 g, 6.24 mmol), mercury(II) chloride (1.69 g, 6.23 mmol), pyridine (0.75 cm^3, 9.27 mmol), water (25 cm^3) and tetrahydrofuran (25 cm^3) was stirred at room temperature for 66 h after which it was extracted with chloroform (3 × 30 cm^3). The combined extracts were washed with water (2 × 20 cm^3), dried ($MgSO_4$) and concentrated under reduced pressure. Column chromatography of the residue on silica gel using ethyl acetate as eluent gave crude β-keto phosphonate **9** (2.04 g, 80%) as an orange oil; δ_H(300 MHz) 1.2–1.4 (9 H, m), 1.5–2.65 (10 H, m), 3.0–3.5 (3 H, m), 3.95 (4 H, m), 4.1–4.25 (4 H, m) and 5.40–5.55 (1 H, m).

7,7-*Ethylenedioxy*-9a-*methyl*-3a,4,7,8,9,9a-*hexahydro*-3H,6H-*benz*[e]*inden*-2-*one* **5**.—A mixture of the β-keto phosphonate **9** (576 mg, 1.39 mmol), caesium carbonate (900 mg, 2.76 mmol) and tetrahydrofuran (40 cm^3) was stirred at room temperature for 66 h. The resulting brown suspension was partitioned between ethyl acetate (3 × 50 cm^3) and water (50 cm^3). The aqueous phase was further extracted with chloroform (2 × 30 cm^3). The combined organic phases were dried ($MgSO_4$) and concentrated under reduced pressure and the crude product was subjected to column chromatography on silica gel using ethyl acetate–light petroleum (2:3) as eluent to give the *cyclopentenone* **5** (200 mg, 55%) as colourless plates, m.p. 131–133 °C, from ether–ethyl acetate (Found: C, 74.05; H, 7.8. $C_{16}H_{20}O_3$ requires C, 73.80; H, 7.75%); ν_{max}/cm^{-1} 1715, 1695, 1615, 1253 and 1100; δ_H(300 MHz) 1.37 (3 H, s), 1.75–2.12 (6 H, m), 2.25 (1 H, dd, J 2.7, 13.8), 2.50–2.75 (3 H, m), 3.12 (1 H, m), 3.95 (4 H, m), 5.47 (1 H, m) and 5.90 (1 H, d, J 1); δ_C(75 MHz) 24.64, 30.49, 33.29, 33.88, 35.23, 38.66, 40.70, 41.84, 64.13, 64.17, 108.47, 121.28, 124.47, 137.25, 189.66 and 208.84; m/z (%) 261 (3.9), 260 (M^+, 13.8), 100 (18.4), 99 (100), 91 (11.8) and 55 (26.5).

9b-*Cyano*-7,7-*ethylenedioxy*-9a-*methyl*-3a,4,6,7,8,9,9a,9b-*octahydro*-1H,3H-*benz*[e]*inden*-2-*one* **12**.—A solution of diethylaluminium cyanide in toluene (1.0 mol dm^{-3}; 1 cm^3, 1 mmol) was added dropwise to a solution of the cyclopentenone **5** (50 mg, 0.19 mmol) in toluene (1 cm^3) at 0 °C. The reaction mixture was stirred at 0 °C for 30 min, and then at room temperature for

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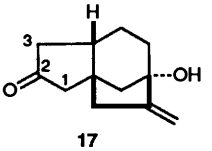
anion which, with appropriate manipulation, would allow us to attach the indole ring in the desired sense.

A not too dissimilar case is provided by the ketone **17** which, on kinetic enolization ($LiNPr^i_2$, −20 °C, THF, HMPA), unexpectedly gave the 1,2-enolate anion regioselectively (G. Stork, W. Clark Still and J. Singh, *Tetrahedron Lett.*, 1979, 5077. We warmly thank Prof. B. Trost for drawing our attention to this reference and for the interest he has shown in our work).



17

This could be isolated as the trimethylsilyl ether from which, *via* regeneration of the lithium enolate, followed by carbonation, a mixture of epimeric 1-carboxylic acids was obtained. Under conditions in which the alternative enolates underwent rapid interconversion (Me_2CO_3, NaH, C_6H_6, HMPA) the major product of methoxycarbonylation was the 3-carboxylic ester. It remains to be seen whether the ketone **16** shows similar reactivity.

a further 60 min. The mixture was quenched with saturated aqueous ammonium chloride (30 cm^3) and extracted with ethyl acetate (3 × 20 cm^3). The combined extracts were dried ($MgSO_4$) and concentrated under reduced pressure and the residue was subjected to column chromatography on silica gel using ethyl acetate–light petroleum (2:3) as eluent to give the *title compound* **12** (13 mg, 24%) as colourless prisms, m.p. 180–182 °C from ether, (Found: C, 71.2; H, 7.55; N, 4.90. $C_{17}H_{21}NO_3$ requires C, 71.05; H, 7.35; N, 4.85%); ν_{max}/cm^{-1} 1751; δ_H(300 MHz) 1.20 (3 H, s), 1.50–1.65 (2 H, m), 1.825 (2 H, m), 2.3–2.7 (9 H, m), 3.95 (4 H, m) and 5.53 (1 H, m); *m/z* (%) 287 (M^+, 4.2), 258 (6.7), 272 (2.6), 100 (32.1) and 99 (100).

7,7-*Ethylenedioxy*-9a-*methyl*-2,3,3a,4,6,7,8,9-*octahydro*-9a*H*-*benz*[e]*inden*-2-*ol* **13**.—A solution of the cyclopentenone **5** (150 mg, 0.58 mmol) in tetrahydrofuran (4 cm^3) was added dropwise to a solution of lithium 1,2-dimethylpropylborohydride in tetrahydrofuran (1.0 mol dm^{-3}; 0.75 cm^3, 0.75 mmol) at −40 °C. The solution was then stirred for 4 h while warming to room temperature. Water (0.5 cm^3), ethanol (0.5 cm^3), dilute sodium hydroxide (0.5 cm^3) and hydrogen peroxide solution (10%; 0.5 cm^3) were added to the solution and the mixture was stirred at room temperature for 30 min; it was then partitioned between water (10 cm^3) and chloroform (3 × 20 cm^3). The combined organic phases were dried ($MgSO_4$) and concentrated under reduced pressure and the crude product was purified by column chromatography on silica gel using ethyl acetate–light petroleum (2:3) and then ethyl acetate as eluent.

Cyclopentenol **13** (150 mg, 99%) was obtained as a pale yellow oil (Found: C, 73.5; H, 8.6. $C_{16}H_{22}O_3$ requires C, 73.25; H, 8.45%); ν_{max}/cm^{-1} 3600–3200, 1650, 1365, 1145, 1120 and 1095; δ_H(300 MHz) 1.22 (3 H, s), 1.35–1.50 (2 H, m), 1.72–2.0 (5 H, m), 2.19 (1 H, dd, *J* 2.6, 13.8), 2.42 (1 H, m), 2.58 (2 H, m), 2.74 (1 H, m), 3.95 (4 H, m), 4.81 (1 H, m), 5.39 (1 H, m) and 5.44 (1 H, m); δ_C(75 MHz), 25.32, 30.96, 34.13, 36.04, 37.21, 38.47, 40.72, 41.11, 64.29, 64.41, 77.43, 109.25, 121.80, 122.19, 138.47 and 158.02; *m/z* (%) 262 (M^+, 12.2), 245 (6.8), 244 (5.8), 129 (12.6), 128 (11.8) and 99 (100).

7,7-*Ethylenedioxy*-9a-*methyl*-1,1a,2,3,3a,4,6,7,8,9-*decahydro*-9a*H*-*cyclopropa*[c]*benz*[e]*inden*-2-*ol* **14**.—Zinc dust (708 mg, 11.9 mmol) was added in one portion to a hot, vigorously stirred solution of cooper(II) acetate monohydrate (46 mg, 0.23 mmol) in glacial acetic acid (1 cm^3). After 2 min the couple was washed successively with glacial acetic acid (2 cm^3) and ether (3 × 2 cm^3). To the couple was then added ether (2 cm^3) followed by dropwise addition of diiodomethane (0.7 cm^3, 8.69 mmol). Heat of reaction caused the mixture to reflux for *ca.* 20 min. A solution of butyllithium in hexanes (1.6 mol dm^{-3}; 0.36 cm^3, 0.58 mmol) was added dropwise to a solution of the alcohol **13** (150 mg, 0.58 mmol) in ether (4 cm^3) at −20 °C. The resulting pale yellow solution was then added dropwise (syringe) to the solution of the Simmons–Smith reagent prepared above. The reaction mixture was stirred at room temperature for 3 h, quenched with saturated aqueous sodium hydrogen carbonate (5 cm^3) and extracted with chloroform (4 × 20 cm^3). The combined extracts were dried ($MgSO_4$) and concentrated under reduced pressure. The product was purified by column chromatography on silica gel using ethyl acetate–light petroleum (3:2) as eluent. The *hydroxycyclopropane* **14** (96 mg, 61%) was obtained as a pale yellow oil (Found: C, 73.9; H, 8.7. $C_{17}H_{24}O_3$ requires C, 73.90; H, 8.75%); ν_{max}/cm^{-1} 3500–3200, 1420, 1355 and 1190; δ_H(300 MHz) 0.62 (2 H, m), 0.86 (2 H, m), 1.18 (3 H, s), 1.35–2.08 (8 H, m), 2.16–2.33 (2 H, m), 2.52 (1 H, ddd, *J* 2.6, 5.6, 14.1), 3.95 (4 H, m), 4.50 (1 H, dt, *J* 4.1, 7.6) and 5.45 (1 H, m); δ_C(75 MHz) 4.56, 21.60, 24.21, 29.21, 30.63, 32.81, 34.02, 34.53, 35.72, 38.80, 41.90, 64.25, 64.42, 74.66, 109.21, 123.22 and 140.69; *m/z* (%) 277 (6.3), 276 (M^+, 23.3), 206 (10.5), 204 (12.3), 149 (12.5), 144 (10.1), 143 (13.2) and 99 (100).

7,7-*Ethylenedioxy*-9a-*methyl*-1,1a,3a,4,6,7,8,9-*octahydro*-3H,-9a*H*-*cyclopropa*[c]*benz*[e]*inden*-2-*one* **15**.—A solution of DMSO (150 mg, 1.92 mmol) in dichloromethane (0.5 cm^3) was added dropwise to a solution of oxalyl chloride (90 mg, 0.71 mmol) in dichloromethane (1.6 cm^3) at −78 °C. The solution was stirred for 2 min after which a solution of the hydroxycyclopropane **14** (178 mg, 0.65 mmol) in dichloromethane (1 cm^3) was added dropwise. The solution was stirred at −78 °C for 1 h and then triethylamine (0.5 cm^3) was added. The reaction mixture was stirred for a further 5 min at −78 °C and was then allowed to warm to room temperature. The mixture was partitioned between saturated aqueous sodium hydrogen carbonate (20 cm^3) and ethyl acetate (3 × 30 cm^3). The combined organic phases were dried ($MgSO_4$) and concentrated under reduced pressure and the crude product was purified by column chromatography on silica gel using ethyl acetate–light petroleum (2:3) as eluent.

α-*Ketocyclopropane* **15** (143 mg, 81%) was obtained as colourless prisms, m.p. 133–134 °C, from ether (Found: C, 74.2; H, 7.95. $C_{17}H_{22}O_3$ requires C, 74.40; H, 8.10%); ν_{max}/cm^{-1} 1720, 1577, 1360, 1098, 1080 and 727; δ_H(300 MHz) 0.95–1.00 (2 H, m), 1.24 (3 H, s), 1.40–1.45 (1 H, m), 1.50 (1 H, dt, *J* 4, 13), 1.68 (1 H, app dq, *J* 13.5, 3.5), 1.78–1.94 (3 H, m), 2.0–2.1 (2 H, m), 2.14 (1 H, m), 2.22 (1 H, dd, *J* 3, 14.2), 2.55 (1 H, app dq, *J* 14.2, 3), 2.62 (1 H, m), 3.95 (4 H, m) and 5.49 (1 H, m); δ_C(75 MHz) 15.09, 21.78, 29.28, 30.46, 30.60, 32.37, 32.92, 36.08, 37.33, 41.95, 44.62, 64.33, 64.47, 108.94, 122.50, 140.56 and 213.84; *m/z* (%) 275 (3.1), 274 (M^+, 8.7), 205 (6.9), 204 (8.3), 100 (12.3), 99 (100) and 91 (11.0).

7,7-*Ethylenedioxy*-9a,9b-*dimethyl*-3a,4,6,7,8,9,9a,9b-*octahydro*-1H,3H-*benz*[e]*inden*-2-*one* **16**.—A solution of the ketocyclopropane derivative **15** (20 mg, 0.073 mmol) in tetrahydrofuran (2 cm^3) was added dropwise to a solution of lithium (10 mg, 1.45 mmol) in liquid ammonia (15 cm^3) at −33 °C. The mixture was stirred for 1 h and then isoprene was added dropwise to destroy excess of lithium and the ammonia was evaporated in a stream of argon. The residue was taken up in dichloromethane, washed with saturated brine, dried ($MgSO_4$), and concentrated under reduced pressure. The product was purified by column chromatography on silica gel using ethyl acetate–light petroleum (b.p. 40–60 °C) (1:4) as eluent. The *title compound* **16** (10.3 mg, 51%) was obtained as colourless prisms, m.p. 173–177 °C, from ether (Found: C, 73.7; H, 9.0. $C_{17}H_{24}O_3$ requires C, 73.90; H, 8.75%); ν_{max}/cm^{-1} 1740; δ_H(300 MHz) 0.92 (3 H, s), 1.18 (3 H, s), 1.65–2.00 (12 H, m), 2.05–2.15 (1 H, m) and 3.95 (4 H, m); δ_C(75 MHz) 16.04, 20.44, 27.65, 30.40, 30.64, 35.85, 40.18, 40.75, 41.94, 44.02, 48.27, 64.20, 64.36, 108.93, 121.98, 139.20 and 218.43; *m/z* (%) 276 (M^+, 3.1), 100 (14.4), 99 (100), 91 (13.9) and 86 (11.6).

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