Carbonyl Transposition and Regio- and Stereo-specific Syntheses of New Alcohols, Amino-alcohols, and Ketones in the Monoterpenoid 1,3,3-Trimethyl-2-oxabicyclo[2.2.2]octane

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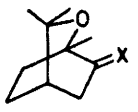
An efficient transposition of carbonyl group R^1–CO–CH_2–R^2 ⟶ R^1–CH_2–CO–R^2 in the 1,3,3-trimethyl-2-oxabicyclo[2.2.2]octane system was carried out *via* hydroboration–oxidation of 6-dialkylamino-1,3,3-trimethyl-2-oxabicyclo[2.2.2]oct-5-enes (3a—c), which gave regio- and stereo-specifically 6-*cis*-dialkylamino-1,3,3-trimethyl-2-oxabicyclo[2.2.2]octan-5-*trans*-ols (4a—c) in high yield. Cope reaction on the *N*-oxide (5b) obtained from the amino-alcohol (4b) with hydrogen peroxide led to 1,3,3-trimethyl-2-oxabicyclo[2.2.2]octan-5-one (6), the other possible isomer of the long-known 1,3,3-trimethyl-2-oxabicyclo[2.2.2]octan-6-one (1b). The ketone (6) was also obtained from 1,3,3-trimethyl-2-oxabicyclo[2.2.2]oct-5-ene (2) *via* its *trans*-epoxide (11), lithium aluminium hydride reduction at 160—165 °C of which gave stereo- and regio-specifically 1,3,3-trimethyl-2-oxabicyclo[2.2.2]octan-5-*trans*-ol (9b). Chromic acid oxidation of (9b) and (4a—c) under various conditions gave the ketone (6) and the amino-ketones (7a—c), respectively. Lithium aluminium hydride reduction of (6) and (7a—c) afforded stereospecifically the *cis*-alcohol (9a) and 6-*cis*-dialkylamino-1,3,3-trimethyl-2-oxabicyclo-[2.2.2]octan-5-*cis*-ols (8a—c), respectively. Hydroboration–oxidation of the alkene (2) was not regiospecific, giving a 3 : 1 mixture of the *trans*-alcohols (9b) and (10b), respectively.

As part of our current interest in the chemistry of the monoterpenoid 1,3,3-trimethyl-2-oxabicyclo[2.2.2]-octane (1a), we report an investigation of 1,3,3-trimethyl-



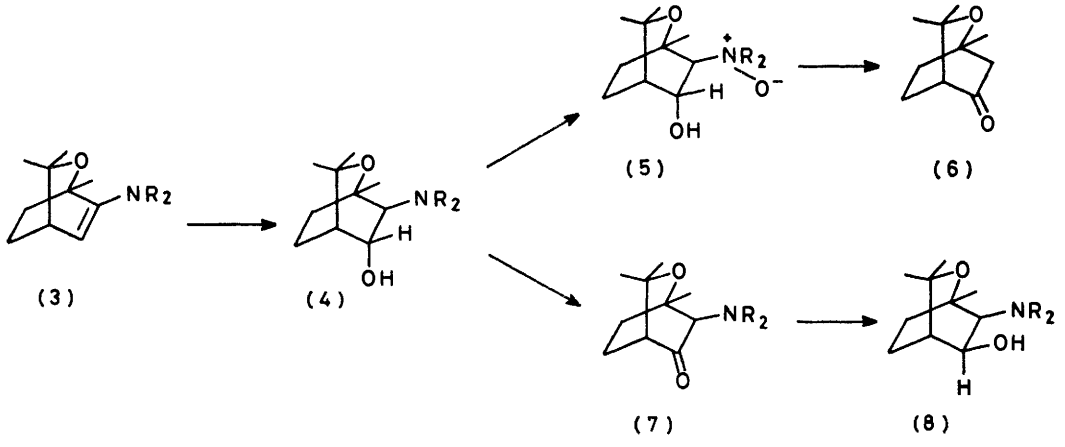
(1a) X = H_2
(1b) X = O

(2)

2-oxabicyclo[2.2.2]oct-5-ene (2) [1] and 6-dialkylamino-1,3,3-trimethyl-2-oxabicyclo[2.2.2]oct-5-enes (3a—c) [2] as synthons for regio- and stereo-specific functionalization of the (1a) skeleton. Primary reactions considered in this context were hydroboration–oxidation, both of (3) and (2), and epoxidation of (2), followed by further steps which ultimately led to the amino-alcohols (4) and (8), the alcohols (9a) and (9b), the amino-ketones (7), and the ketone (6), the last being obtained by two different routes. The amino-alcohols (4) and (8) are of special interest to us as starting compounds for the synthesis of molecules having potential pharmacological action.

RESULTS AND DISCUSSION

Hydroboration–oxidation of enamines to give 1,2-amino-alcohols has been reported by Borowitz and Williams.[3] By applying a modified procedure of this reaction on the enamines (3a—c), available in high yield from the nitrimino-derivative of ketone (1b),[2] a regio- and stereo-specific synthesis of g.l.c.-pure 6-*cis*-dialkylamino-1,3,3-trimethyl-2-oxabicyclo[2.2.2]octan-5-*trans*-ols † (4a—c) (Table) was achieved. The relative position of the substituents on C-5 and C-6 was deduced from the free-OH stretching vibrations in the i.r.



(3) (4) (5) (6) (7) (8)

NR_2
(3a), (4a), (7a), (8a) pyrrolidin-1-yl
(3b), (4b), (5b), (7b), (8b) piperidino
(3c), (4c), (7c), (8c) morpholino

† Throughout this paper, *cis* and *trans* refer to the relative positions of the substituents and the ether bridge in the 2-oxabicyclo[2.2.2]octane derivatives.

spectrum ($\nu_{max.}$ 3 590 cm^{-1}) and from the n.m.r. pattern of the C-5 proton. This appeared as an unresolved multiplet with a half-height width of 7—8 Hz, typical of two couplings with the vicinal C-4 and C-6 protons, both of *ca.* 3—4 Hz, in agreement with a dihedral angle of 45—50° with the C-4 proton and a *cis–trans* relationship with the C-6 proton.[4] On the other hand, such a configuration is a consequence of the electron availability on C-5 in the enamines (3a—c) and of a diborane attack possible only from the less hindered *trans* side.

The amino-alcohols (4a—c) reacted with an excess of hydrogen peroxide to give the *N*-oxides (5a—c), but only (5b) gave a high yield of 1,3,3-trimethyl-2-oxabicyclo[2.2.2]octan-5-one (6) in the subsequent step. Owing to the *syn*-periplanar conformation of the C-6–N and C-5–H bonds, these *N*-oxides underwent a mild pyrolysis affording the ketone (6) as the result of a Cope reaction. Hence the described procedure provides a useful method for achieving the conversion of R^1–CO–CH_2–R^2 into R^1–CH_2–CO–R^2 in rigid bicyclic ketones where the carbonyl group is flanked by a unique methylene group, as in the present case and camphor.[5] The advantage in comparison with the original application to substituted cyclohexanones[6] is that the favourable steric features of the starting amino-alcohols do not require the final steps of oxidation and reduction after pyrolysis in order to obtain the transposed ketone. A recently described application of this procedure to hexahydrodibenzofuran derivatives[7] gave the transposed ketone in very low yield.

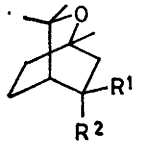
Lithium aluminium hydride reduction of (6) gave, in near quantitative yield, 1,3,3-trimethyl-2-oxabicyclo-[2.2.2]octan-5-*cis*-ol (9a) as the sole product (g.l.c.), whereas we had formerly found in the case of (1b) that a near equilibrated mixture of the two epimeric alcohols (10a) and (10b) was obtained.[8] The *cis* configuration of (9a) was chiefly deduced from its n.m.r. spectrum, where a badly resolved multiplet at δ 4.10, at higher field than the *trans* alcohol (9b) (see later; $\Delta\delta_{cis-trans} = 0.36$), is typical of a *trans* methine proton geminal with an OH group.[9] The stereospecificity of this reduction is attributable to the bulkier crowding on C-5, caused by a C-3 methyl group, in comparison with that on C-6. Oxidation of the amino-alcohols (4a—c) with Jones reagent in various solvents gave in good yield the 6-*cis*-dialkylamino-1,3,3-trimethyl-2-oxabicyclo[2.2.2]octan-5-ones (7a—c).

Amino-alcohols (4a—c) and (8a—c)

	M.p./°C or b.p./°C (mmHg)	Yield (%)	$\nu_{max.}$ ($CHCl_3$)/cm^{-1}	δ ($CDCl_3$)	Found (%) C	H	N	Formula	Required (%) C	H	N
(4a)	132—134 (0.5)	85	3 590, 2 870, 2 810	1.17 (3 H, s, Me), 1.27 (3 H, s, Me), 1.31 (3 H, s, Me), 1.90 (1 H, s, OH), 4.40 (1 H, m, 5-H)	70.5	10.6	5.7	$C_{14}H_{25}NO_2$	70.2	10.5	5.8
(4b)	136—138 (0.5)	82	3 590, 2 850, 2 790	1.15 (3 H, s, Me), 1.25 (3 H, s, Me), 1.26 (3 H, s, Me), 2.03 (1 H, s, OH), 4.52 (1 H, m, 5-H)	71.0	11.0	5.7	$C_{15}H_{27}NO_2$	71.1	10.7	5.5
(4c)	183—184 [a]	95	3 590, 2 850, 2 810	1.16 (3 H, s, Me), 1.25 (3 H, s, Me), 1.28 (3 H, s, Me), 1.92 (1 H, s, OH), 4.55 (1 H, m, 5-H)	65.6	9.8	5.3	$C_{14}H_{25}NO_3$	65.8	9.9	5.5
(8a)	130—132 (0.7)	73	3 400, 2 870, 2 820	1.22 (3 H, s, Me), 1.25 (3 H, s, Me), 1.49 (3 H, s, Me), 3.98 (1 H, dd, $J_{5,6}$ 9.5 Hz, $J_{4,5}$ 2.6 Hz, 5-H), 4.65br (1 H, m, OH)	70.5	10.8	6.1	$C_{14}H_{25}NO_2$	70.2	10.5	5.8
(8b)	135—137 (0.5)	94	3 380, 2 840, 2 810	1.23 (3 H, s, Me), 1.29 (3 H, s, Me), 1.45 (3 H, s, Me), 3.90 (1 H, dd, $J_{5,6}$ 9.5 Hz, $J_{4,5}$ 2.6 Hz, 5-H), 4.90br (1 H, m, OH)	71.0	10.6	5.7	$C_{15}H_{27}NO_2$	71.1	10.7	5.5
(8c)	126—127 [b]	98	3 300, 2 880, 2 850	1.25 (3 H, s, Me), 1.33 (3 H, s, Me), 1.47 (3 H, s, Me), 4.01 (1 H, dd, $J_{5,6}$ 9.5 Hz, $J_{4,5}$ 2.6 Hz, 5-H), 4.70br (1 H, m, OH)	65.7	10.0	5.5	$C_{14}H_{25}NO_3$	65.8	9.9	5.5

[a] From 1 : 1 v/v pentane–ether. [b] From 6 : 1 v/v pentane–ether.

Lithium aluminium hydride reduction of the amino-ketones (7a—c) afforded the 6-*cis*-dialkylamino-1,3,3-trimethyl-2-oxabicyclo[2.2.2]octan-5-*cis*-ols (8a—c)



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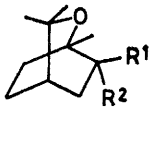
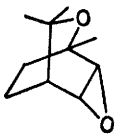


(10)

	R^1	R^2
(9a), (10a)	OH	H
(9b), (10b)	H	OH

(Table) as sole products (g.l.c.). The *cis,cis* configuration was deduced by comparison of the i.r. and n.m.r. spectra with those of the epimeric amino-alcohols (4a—c). The OH stretching appeared at *ca.* 3 400 cm^{-1} as a

broad band, thus showing an internal hydrogen bonding with the neighbouring *syn* nitrogen atom. The C-5 proton exhibited an upward shift of 0.4—0.6 p.p.m. in comparison with the same proton of (4a—c), and a doublet of doublets with two couplings of 2.6 and 9.5 Hz, typical of *endo* protons in other similar bicyclic systems.[4] Moreover, a methyl group showed a downfield shift of *ca.* 0.2 p.p.m. when compared with the same group in (4a—c), as the result of a deshielding effect of the 5-OH group in the *cis* position. Finally, the OH proton is deshielded by 2.7—2.9 p.p.m. in comparison with the same proton in (4a—c), thus showing a strong hydrogen bond with the nitrogen atom. Once more, the strong steric hindrance on the *cis* side of the carbonyl group forces the complex hydride to attack only from the less hindered *trans* side. Another route to the ketone (6), *via* 1,3,3-trimethyl-2-oxabicyclo[2.2.2]octan-5-*trans*-ol (9b), was provided by the alkene (2). Reaction of (2) with *m*-chloroperbenzoic acid in benzene [10] gave in good yield the epoxide (11), practically as the sole product (g.l.c.), showing in its n.m.r. spectrum a pattern for the epoxide ring protons very similar to that of *trans*-2,3-epoxybornane.[11] Because initial attempts to reduce (11) with lithium ethylenediamine [12] were



(11)

disappointing owing to the complex mixture obtained, reduction with lithium aluminium hydride in tetrahydrofuran at 160—165 °C was tried when near pure (95% by g.l.c.) *trans* alcohol (9b) was obtained in high yield. This compound, whose i.r., n.m.r., and mass spectral data and m.p. were quite different from both (10a) and (10b),[8] showed a typical *cis* proton geminal with an OH group at δ 4.46 as a pair of triplets further split by W long-range coupling arising from an ABCX system simplified to AB_2X by the near equivalence of $J_{5.4}$ and $J_{5.6}$.[13] Therefore the *trans* configuration of the 5-OH in (9b) allowed us to assign the *trans* structure also to epoxide (11). *trans* Epoxidation is clearly due both to steric hindrance caused by the *gem*-dimethyl group and to the repulsive effect of the ethereal oxygen towards the approach of peroxidizing agent from the *cis* side. Chromic acid oxidation of (9b) [14] gave the ketone (6) in high yield.

In order to obtain the alcohols (9a) and (9b) by an alternative route, the usual hydroboration–oxidation was tried on the alkene (2). A mixture of four products was obtained, in which (9b) and (10b) were present in the approximate ratio 3 : 1 (g.l.c.), besides small amounts of α-terpineol and *p*-cymene, whose identities were deduced chiefly from g.l.c.–mass spectra. α-Terpineol is likely to be derived from (2) by Lewis co-ordination of diborane to the ethereal oxygen, followed by ring opening and hydride ion transfer to C-4, according to the reaction scheme.

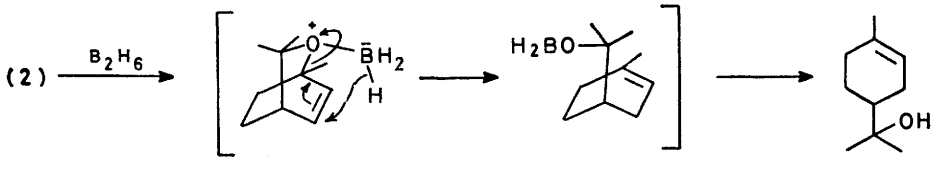
Rather surprisingly, the usual oxymercuriation–demercuriation reaction was not effective and starting (2) was recovered unchanged.

EXPERIMENTAL

I.r. spectra were measured with a Perkin-Elmer 257 spectrometer, n.m.r. spectra with a Perkin-Elmer R12 instrument (60 MHz; tetramethylsilane as internal standard), and mass spectra with a GC/MS Varian Mat 111 spectrometer. G.l.c. was performed on a Fractovap GI instrument (C. Erba; 2 000 × 3 mm dual column differential system, packed with 3% SE 30 on silanized Chromosorb W; injection port temperature 200 °C; linear temperature programming 100—180 °C; heating rate 7 °C min^{-1}; helium flow rate 40 ml min^{-1}). M.p.s were determined with a Fisher-Johns apparatus.

6-cis-*Dialkylamino*-1,3,3-*trimethyl*-2-*oxabicyclo*[2.2.2]-*octan*-5-trans-*ols* (4a—c).—A solution of (3a—c) [2] (50 mmol) in anhydrous tetrahydrofuran (50 ml) was treated with an excess (50%) of diborane at 20—25 °C and stirred for 8 h at room temperature. The excess of hydride was destroyed by careful addition of water, and the organoborane was oxidized with 30% hydrogen peroxide (20 ml) and 6M-sodium hydroxide (20 ml) with refluxing and stirring for 1 h. The mixture was salted out with potassium carbonate, and the organic layer was separated and evaporated. The residue was acidified with 6M-hydrochloric acid and washed with ether. The acidic aqueous solution was made alkaline with 6M-sodium hydroxide, extracted thoroughly with ether, and the extracts were dried (Na_2SO_4). Evaporation of the solvent and bulb-to-bulb distillation *in vacuo* or recrystallization of the residue gave the g.l.c.-pure *amino-alcohols* (4a—c) (Table).

N-*Oxide of* 1,3,3-*Trimethyl*-6-cis-*piperidino*-2-*oxabicyclo*-[2.2.2]*octan*-5-trans-*ol* (5b).—A solution of (4b) (7.60 g, 30 mmol) in methanol (40 ml) was treated with 30% hydrogen peroxide (30 ml) and stirred at room temperature. After 2 and 4 h, more 30% hydrogen peroxide (10 ml each time) was added. The mixture was further stirred for 36 h, evaporated to dryness under reduced pressure, and the residue was washed with ether to give a crude crystalline product (7.80 g), which was used in the next step without



further purification, $\nu_{max.}$ (KBr) 3 500—2 800 (broad), 2 720, and 980 cm^{-1}.

1,3,3-*Trimethyl*-2-*oxabicyclo*[2.2.2]*octan*-5-*one* (6).—(*i*) Crude (5b) (7.80 g) was pyrolysed at 160 °C and 0.5 mmHg, giving a light yellow liquid (6.30 g) which was dissolved in ether (100 ml). The ether solution was washed thoroughly

with 1M-hydrochloric acid, dried (Na_2SO_4), and evaporated to give (6) as a colourless, odorous *liquid* (3.65 g, 72%), $[\alpha]_D^{22}$ −39° (*c*, 3.5 in EtOH), n_D^{20} 1.468 2, b.p. 48—50 °C at 0.2 mmHg (Found: C, 71.3; H, 9.7. $C_{10}H_{16}O_2$ requires C, 71.4; H, 9.6%); $\nu_{max.}$ (neat) 1 730 cm^{-1}; $\delta(CCl_4)$ 1.08 (3 H, s, Me), 1.18 (3 H, s, Me), and 1.25 (3 H, s, Me); *m/e* 168 (12%), 155 (55), 140 (5), 125 (38), 111 (48), 83 (58), 82 (62), 69 (16), 67 (24), 55 (42), and 43 (100). Its *semicarbazone* had m.p. 202—203 °C (from 80% ethanol) (Found: C, 58.8; H, 8.6; N, 18.4. $C_{11}H_{19}N_3O_2$ requires C, 58.6; H, 8.5; N, 18.6%) and its orange 2,4-*dinitrophenylhydrazone*, m.p. 138—140 °C (from 95% ethanol) (Found: C, 55.2; H, 5.8; N, 15.9. $C_{16}H_{20}N_4O_5$ requires C, 55.2; H, 5.8; N, 16.1%).

(*ii*) To an ice-cooled solution of (9b) (5.11 g, 30 mmol) in ether (50 ml) was added dropwise a cooled solution of chromic reagent [14] [30 ml of a solution of $Na_2Cr_2O_7$ (6 g) and concentrated H_2SO_4 (7.8 g) in water]. After vigorous stirring for 30 min at room temperature, the ether layer was separated and the acid phase was extracted with ether. The combined ether extracts were washed with 1M-sodium hydroxide and brine, dried (Na_2SO_4), and evaporated. The pale yellow oily residue was chromatographed on silica gel (3 : 1 v/v pentane–ether) to give a liquid (4.20 g, 83%), identical with the product described under (*i*).

Oxime of (6).—The oxime was prepared by treating a solution of (6) in anhydrous ethanol with a slight excess of hydroxylamine hydrochloride and finely divided anhydrous sodium acetate. After 24 h at room temperature, the mixture was evaporated to dryness under reduced pressure, water was added, the solution was acidified with 1M-hydrochloric acid to pH 3 and extracted with ether to give the *oxime* as a viscous liquid (87%), b.p. 108—110 °C at 0.3 mmHg, which solidified, m.p. 45—46 °C (Found: C, 65.5; H, 9.4; N, 7.7. $C_{10}H_{17}NO_2$ requires C, 65.5; H, 9.4; N, 7.6%).

1,3,3-*Trimethyl*-6-cis-*pyrrolidin*-1-*yl*-2-*oxabicyclo*[2.2.2]-*octan*-5-*one* (7a).—To an ice-salt cooled solution of (4a) (2.39 g, 10 mmol) in ether (75 ml) was added dropwise a cooled solution (6 ml) of chromic anhydride (10 g in 40 ml water and 15 ml concentrated sulphuric acid) with cooling at −5 °C and stirring for 6 h. A saturated solution of sodium potassium tartrate (8 g) was then added and the mixture was made alkaline with 6M-sodium hydroxide. The ether layer was separated and the aqueous phase was extracted with ether; the combined ether extracts were dried (Na_2SO_4) and evaporated. The pale yellow residue was chromatographed on Florisil (pentane) to give (7a) as a yellow *wax* (1.80 g, 76%), b.p. 108—110 °C at 0.08 mmHg (Found: C, 70.9; H, 9.9; N, 5.8. $C_{14}H_{23}NO_2$ requires C, 70.8; H, 9.8; N, 5.9%); $\nu_{max.}$ ($CHCl_3$) 2 870, 2 835, and 1 720 cm^{-1}; $\delta(CDCl_3)$ 1.18 (3 H, s, Me), 1.25 (3 H, s, Me), and 1.33 (3 H, s, Me).

1,3,3-*Trimethyl*-6-cis-*piperidino*-2-*oxabicyclo*[2.2.2]*octan*-5-*one* (7b).—The same procedure reported for (7a) was employed, dissolving (4b) (2.53 g, 10 mmol) in acetone (15 ml) and stirring at room temperature. The crude residue was chromatographed on neutral alumina (pentane) to give (7b) as a white *wax* (1.81 g, 72%), b.p. 100—103 °C at 0.08 mmHg (Found: C, 71.5; H, 10.1; N, 5.5. $C_{15}H_{25}NO_2$ requires C, 71.7; H, 10.0; N, 5.6%); $\nu_{max.}$ ($CHCl_3$) 2 850, 2 810, and 1 715 cm^{-1}; $\delta(CDCl_3)$ 1.17 (3 H, s, Me), 1.29 (3 H, s, Me), and 1.31 (3 H, s, Me).

1,3,3-*Trimethyl*-6-cis-*morpholino*-2-*oxabicyclo*[2.2.2]*octan*-5-*one* (7c).—To an ice–salt cooled solution of (4c) (2.55 g, 10 mmol) in ether–acetone (175 ml; 6 : 1 v/v) was added dropwise a cooled solution (9 ml) of chromic anhydride [see preparation of (7a)] diluted with acetone (9 ml). After the usual work-up, the crude residue was chromatographed on silica gel (4 : 1 v/v benzene–ether) to give (7c) as a white *wax* (1.67 g, 66%), b.p. 140—143 °C at 0.08 mmHg (Found: C, 66.4; H, 9.3; N, 5.6. $C_{14}H_{23}NO_3$ requires C, 66.4; H, 9.2; N, 5.5%); $\nu_{max.}$ ($CHCl_3$) 2 850, 2 750, and 1 720 cm^{-1}; $\delta(CDCl_3)$ 1.09 (3 H, s, Me), 1.23 (3 H, s, Me), and 1.25 (3 H, s, Me).

6-cis-*Dialkylamino*-1,3,3-*trimethyl*-2-*oxabicyclo*[2.2.2]-*octan*-5-cis-*ols* (8a—c). To an ice-cooled solution of lithium aluminium hydride (0.46 g, 12 mmol) in anhydrous ether (20 ml) was slowly added a solution of (7a—c) (10 mmol) in the same solvent (50 ml). The mixture was stirred for 2 h at 0 °C and treated dropwise with water (0.5 ml), 4M-sodium hydroxide (0.5 ml), and finally water (1 ml). The inorganic precipitate was filtered off and the solution was dried (Na_2SO_4) and evaporated. The viscous residues were chromatographed on basic alumina (ether) and distilled *in vacuo* or recrystallized to give the g.l.c.-pure *amino-alcohols* (8a—c) (Table).

1,6,6-*Trimethyl*-3,7-*dioxatricyclo*[3.2.2.$0^{2,4}$]*nonane* (11).—To a solution of (2) [1] (7.61 g, 50 mmol) in anhydrous benzene (50 ml) was added dropwise a solution of *m*-chloroperbenzoic acid (10.35 g, 60 mmol) in the same solvent (150 ml). The mixture was stirred for 30 h at room temperature, filtered, and washed with 1M-sodium hydroxide and brine. Evaporation of the dried (Na_2SO_4) solution gave a g.l.c.-pure product which was vacuum distilled to afford a *liquid* (6.55 g, 78%), $[\alpha]_D^{22}$ −5.8° (*c*, 3.0 in EtOH), n_D^{20} 1.470 5, b.p. 53—55 °C at 0.5 mmHg (Found: C, 71.7; H, 9.3. $C_{10}H_{16}O_2$ requires C, 71.4; H, 9.6%); $\nu_{max.}$ (neat) 3 020, 1 250, 935, and 868 cm^{-1}; $\delta(CCl_4)$ 1.18 (3 H, s, Me), 1.21 (6 H, s, 2 Me), 3.04 (1 H, d, *J* 5 Hz, 2-H), and 3.36 (1 H, t, *J* 5 Hz, 4-H); *m/e* 168 (5%), 153 (4), 150 (14), 138 (16), 135 (7), 110 (34), 109 (15), 107 (16), 97 (17), 95 (58), 82 (26), 81 (24), 79 (15), and 43 (100).

1,3,3-*Trimethyl*-2-*oxabicyclo*[2.2.2]*octan*-5-trans-*ol* (9b).—A mixture of (11) (10 g, 59.4 mmol) and lithium aluminium hydride (10 g) in anhydrous tetrahydrofuran (300 ml) was heated for 20 h in an autoclave at 160—165 °C with occasional shaking. After cooling, the excess of reducing agent was destroyed by addition of water (10 ml), 4M-sodium hydroxide (10 ml), and water (20 ml). The inorganic precipitate was filtered off and the solution was evaporated. G.l.c. of the crude product showed the presence of two components in the ratio 19 : 1. Chromatography on neutral alumina (pentane) gave the major component (9b) as a white *solid* (8.60 g, 85%), $[\alpha]_D^{22}$ −19° (*c*, 2.7 in EtOH), m.p. 68—69 °C (from pentane) (Found: C, 70.7; H, 10.9. $C_{10}H_{18}O_2$ requires C, 70.5; H, 10.7%); $\nu_{max.}$ ($CHCl_3$) 3 590 cm^{-1}; $\delta(CDCl_3)$ 1.06 (3 H, s, Me), 1.22 (3 H, s, Me), 1.30 (3 H, s, Me), 2.68 (1 H, s, OH), and 4.46 (1 H, 2t, $W_{1/2}$ 17 Hz, 5-H); *m/e* 170 (33%), 155 (18), 137 (18), 127 (19), 111 (21), 108 (40), 93 (50), 87 (45), 85 (41), 71 (39), 69 (49), 59 (51), and 43 (100).

1,3,3-*Trimethyl*-2-*oxabicyclo*[2.2.2]*octan*-5-cis-*ol* (9a).—This alcohol was prepared by the same procedure as described for (8a—c), starting from (6) (3.0 g, 17.8 mmol) and lithium aluminium hydride (1.0 g) in anhydrous ether. The solid residue was sublimed (2.95 g, 97%) to give (9a) as white *crystals*, $[\alpha]_D^{22}$ +50.5° (*c*, 2.5 in EtOH), m.p. 90—91 °C (from pentane) (Found: C, 70.5; H, 10.9. $C_{10}H_{18}O_2$ requires C, 70.5; H, 10.7%); $\nu_{max.}$ ($CHCl_3$) 3 605

cm^{-1}; δ($CDCl_3$) 1.11 (3 H, s, Me), 1.25 (3 H, s, Me), 1.45 (3 H, s, Me), 2.12 (1 H, s, OH), and 4.10br (1 H, t, $W_{1/2}$ 18 Hz, 5-H); *m/e* 170 (2%), 155 (28), 137 (10), 127 (10), 108 (16), 93 (34), 87 (16), 85 (24), 71 (16), 69 (18), 59 (31), and 43 (100).

Hydroboration–oxidation of (2).—A solution of (2) [1] (3.04 g, 20 mmol) in anhydrous tetrahydrofuran (50 ml) was treated with an excess of diborane at 10—15 °C and stirred for 1 h at room temperature. The excess of hydride was decomposed with water and the organoborane was oxidized with 30% hydrogen peroxide (10 ml) and 6M-sodium hydroxide (10 ml), stirring for 1 h at 60 °C. The mixture was salted out, extracted with ether, and the ether extracts were washed with brine. Removal of the solvents gave a viscous oil (3.20 g) comprised of four components in the ratio 1 : 4 : 71 : 24 (g.l.c.). The two minor components were identified by their retention times and g.l.c.–mass spectra as *p*-cymene and α-terpineol, respectively. The major product was recognized as (9b) and the remainder as (10b) [8] by g.l.c. superimposition of peaks with authentic samples.

Hydroboration with borane–methyl sulphide complex led to similar results.

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